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Predator-proof Fencing for Invasive Species Control in Hawaii: A Comprehensive Prioritization and Implementation Plan to protect native species

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Predator-proof Fencing for Invasive Species Control in Hawaii: A Comprehensive Prioritization and Implementation Plan to protect native species

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EXECUTIVE SUMMARY

There are over 15 military installations and ranges in Hawaii, and still more on other Pacific islands. Within the over 200,000 acres encompassed by these military lands, there are more than 100 threatened and endangered species representing approximately one third of the total listed species in Hawaii and nearly 10% of all threatened and endangered species in the United States. This creates a challenge for the Department of Defense (DoD) with how to effectively use lands, air, and sea for national security missions while simultaneously conserving species protected by the Endangered Species Act (ESA).

On military installations in Hawaii, a range of introduced vertebrate pest species reside in and around many key natural resource areas that DoD is mandated to protect under the ESA. These introduced pests include predators such as rats (*Rattus* spp.), small Indian mongoose (*Herpestes auropunctatus*), feral cats (*Felis catus*), and feral dogs (*Canis familiaris*), and a variety of ungulates such as feral pigs (*Sus scrofa*), feral sheep (*Ovis aries*), feral goats (*Capra hircus*), and mouflon sheep (*Ovis musimon*). These alien animals consume and trample endangered native plants and their seeds and prey on endangered birds and snails. Despite control programs on some DoD lands, predation and browsing is still a serious problem in many areas. One way to reduce or eliminate the damage would be to exclude and eradicate pests from key natural resource areas using pest proof fences that exclude all of the above mentioned vertebrate pests.

Island Conservation (IC) received funding from the DoD Legacy Resource Management Program, under Cooperative Agreement Number W912DY-07-2-0003, to prioritize sites within Hawaii DoD land holdings that would be candidates for predator proof fencing. The prioritization was done by having each branch of the military nominate their top natural resource sites (13 total) and provide an accompanying site description. A set of ranking criteria that incorporated both biological and feasibility criteria were developed as a group with military personnel, and each site was ranked using these criteria. The top nine sites representing locations managed by all military branches were selected for site visits with IC, consulting biologists, and Xcluder Pest Proof Fencing Company.

In August 2007, IC, consulting biologists, and Xcluder Pest Proof Fencing Company visited the top nine selected sites in order to evaluate the feasibility and cost of building a pest proof fence capable of excluding all pests present at each site. Pest proof fencing appeared to be technically challenging, but feasible, in most locations, and suggested fence alignments, construction plans, and budgets were developed by Xcluder for the top four sites. The top four sites were selected based on the feasibility of constructing a successful demonstration fence within budget and the potential biological benefit in addition to the initial ranking criteria. The sites selected were Pohakuloa Training Area (PTA) *Solanum incompletum* site on the island of Hawaii, and Kahanahaiki and Waieli Bench on Oahu, all of which are owned by the Army, and Niulii Ponds on Oahu which is owned by the Navy. Complete implementation plans for these top priority sites, including pre- and post-fence biological monitoring, eradication, and cost benefit analyses were developed.

This exercise offers a valuable opportunity to determine the potential effectiveness of pest proof fencing for protection of threatened and endangered species in a variety of ecosystems in the Hawaiian Islands and can serve as a model for other predator proof fencing exercises.

BACKGROUND

Islands make up 1.3% of the U.S. land area yet are home to 43% of ESA listed species and 53% of extinctions. Invasive species are the primary threat to island ecosystems and are responsible for approximately two-thirds of all island extinctions in the past 400 years (Reaser et al 2007). Hawaii not only is the state with the greatest number of threatened, endangered, and extinct species, but also the state with the highest proportion of endemic flora and fauna (Ziegler 2002). Non-native mammals – primarily rats, cats, mongoose, goats, sheep, and pigs – have had devastating impacts on listed and at-risk species and are major factors in population declines and extinctions in Hawaii and elsewhere (Ziegler 2002, Reaser et al 2007).

Ungulates have already been excluded from several large tracts of sensitive habitat in Hawaii using fencing. However, these fences do not exclude smaller pest species such as mongooses, cats, and rodents. Impacts of feral cats and mongooses in Hawaii have been well documented, including the predation on many endangered species, primarily birds (Hodges and Nagata 2001, Smith et al. 2002, Laut et al. 2003). Invasive rodents such as rats and mice constitute a potentially even greater threat to native species by contributing to extinctions as well as ecosystem level changes (Fukami et al 2006). In Hawaii, rats have been documented to prey on ground-nesting seabirds, forest birds including the endangered O‘ahu ‘Elepaio and the Laysan finch (VanderWerf and Smith 2002). As omnivorous feeders, rats are also known to eat the seeds, fruits, leaves, and shoots of a variety of plants, including stripping the bark of koa (*Acacia koa*) saplings and eating the seeds of loulu (*Pritchardia* spp.) palms and other endangered plant species (U.S. Army 2006, A. Sheils unpubl. data). These actions may kill plants outright, make them more susceptible to pathogens or insects, or prevent natural reproduction. While rats can be controlled in small areas using bait stations and traps, it is extremely labor intensive and not a permanent solution. Until recently, there was no way to effectively eradicate rats and mice from larger islands, or even to exclude them from specific areas.

On military installations in Hawaii, a range of introduced vertebrate pest species reside in and around many key natural resource areas that DoD is mandated to protect under the ESA. These introduced pests include predators such as rats (*Rattus* spp.), small Indian mongoose (*Herpestes auropunctatus*), feral cats (*Felis catus*), and feral dogs (*Canis familiaris*), and a variety of feral ungulates such as feral pigs (*Sus scrofa*), feral sheep (*Ovis aries*), feral goats (*Capra hircus*), and mouflon sheep (*Ovis musimon*). These alien animals consume endangered native plants and their seeds and prey on endangered birds and snails. Despite control programs on some DoD lands, predation and browsing is still a serious problem. One way to reduce or eliminate the damage would be to exclude and eradicate pests from key natural resource areas using pest proof fences that exclude all of the above mentioned vertebrate pests.

Many areas on DoD-managed lands and lands managed by state and federal resource management agencies within the main Hawaiian islands have been fenced to exclude large herbivores in conjunction with the control of small mammalian predators such as rats and cats. However, efforts to completely exclude both ungulates and small predators have not been used to their potential in Hawaii. In New Zealand and Australia, predator-proof fencing, i.e. fencing designed to keep all terrestrial vertebrates out of an area, has been used widely with extraordinary results (Day & MacGibbon 2002).

Fence designs developed by the Xcluder™ Pest Proof Fencing Company have been previously shown to exclude all rodents and other mammalian pests under New Zealand conditions (Day & MacGibbon 2002) and resource managers in New Zealand have built more than 52 predator proof fences that protect more than 10,000 hectares (T. Day pers comm.). These habitats are now refuges for a majority of the endangered species found in New Zealand. The fencing excludes animals as small as two-day old mice, and prevents animals from digging under or climbing over the fence. Research undertaken in 2002 (MacGibbon and Calvert, 2002) and completed in March 2006 (Burgett et al. 2007) has shown that these fences can be designed to exclude all of the mammalian pests present in Hawaiian conditions.

The use of the predator-proof fencing greatly increases the effectiveness of existing animal control efforts, shifting the focus from reducing predator numbers to eradication (Long and Robley, 2004). Predator proof fencing would make it feasible to remove all animals from within the fenced unit and to focus control efforts on buffer areas around the perimeter of the fence. In Hawaii, the use of predator-proof fencing is especially promising in that it can provide areas within which the entire ecosystem, including native vegetation, can recover and where birds and snails can breed and forage free from the threats of introduced terrestrial vertebrate predators (MacGibbon and Calvert 2002).

The need for this type of approach has been highlighted in several recent high profile publications. Kilpatrick (2006) reasoned that to prevent extinction of endangered bird species, birds must be allowed to evolve resistance to disease and demonstrated using demographic models that this evolution may occur more quickly if the threat of predation by invasive predators likes rats and cats is removed. Duffy and Kraus (2006) argued that conservation in Hawaii is limited by a lack of scientifically justified projects that provide criteria for measuring success. The proposed project will not only provide immediate benefits when fences are built, it will include biological monitoring that will inform adaptive management decisions on how best to implement fencing technology in Hawaii.

Island Conservation (IC), a non-profit organization dedicated to preventing extinctions and protecting natural ecological and evolutionary processes on islands, received a grant from the DoD Legacy Program, Cooperative Agreement Number W912DY-07-2-0003, to prioritize sites within Hawaii DoD land holdings that would be candidates for predator proof fencing. The prioritization was done by having each branch of the military nominate their top natural resource sites (13 total) and provide an accompanying site description. A set of ranking criteria that incorporated both biological and feasibility criteria were developed as a group with military personnel, and each site was ranked using these criteria. The top nine sites representing locations managed by all military branches were selected for site visits with IC, consulting biologists, and Xcluder Pest Proof Fencing Company.

Predator-proof fencing may be applicable globally and can provide a cost-effective solution to managing threatened and endangered species. Fences can provide immediate and long-term conservation benefits for threatened and endangered species. The approach we propose, which includes ecological monitoring of the benefits of the fences, will provide evidence for other installations to utilize this powerful conservation tool.

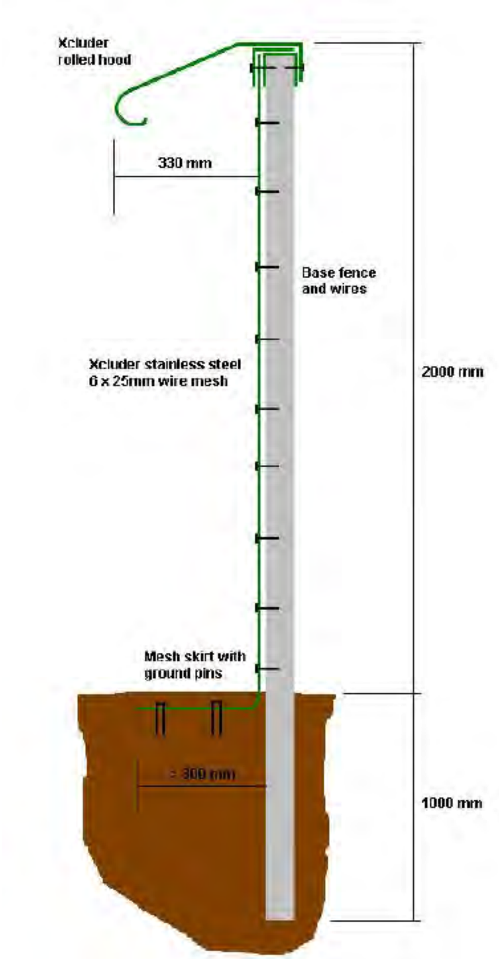


Figure 1: Schematic diagram of an Xcluder predator proof fence.

PRIORITIZATION AND SITE SELECTION

Scoping meeting

A scoping and information meeting was held on May 1, 2007 with IC, consulting biologists Lindsay Young and Eric VanderWerf, and representatives from the Army, Air Force, National Guard, Marines, Navy and the U.S. Fish and Wildlife Service (FWS). This meeting served to introduce all branches of the military to the prioritization project and the concept of pest proof fencing and its history in Hawaii. A copy of the meeting minutes can be found in Appendix 1.

Criteria that could be used to rank and compare candidate sites were developed and these incorporated both biological and technical aspects that would be relevant to the feasibility and suitability of constructing predator proof fencing on military lands. All branches nominated their highest priority natural resource sites that could benefit from predator proof fencing. Nominated sites encompassed a wide range of habitats and elevations and were located on the islands of Kauai, Oahu, and Hawaii. After the meeting, a template site description form (Appendix 2) was provided to all branches in order to gather information on each nominated site for use in the ranking exercise.

Determination and weighting of criteria
Fifteen ranking criteria that highlighted the biological value, the degree of threat, various feasibility factors, and existing monitoring activities at each nominated site were developed as a group at the May 1 meeting for use in ranking and comparing all sites. A complete description of each criterion, their scale, and weighting can be found in Appendix 4, and are outlined in Table 1 below.

Table 1. Ranking criteria, their numerical scale, and the weight of the ranking.

Criteria	Scale	Weight
Number of listed species	0- total # species	1
Urgency of listed species	0- total # species	1
Other at-risk or sensitive species	0- total # species	0.5
Species diversity	1-5	1
Sensitive or important habitats	1-5	1
Restoration potential	1-5	0.5
Severity of impacts from predators	1-5	1
Substrate to be built on	1-5	1
Accessibility of area for materials transport	1-5	1
Technical feasibility	1-5	1
Existing management and monitoring	1-5	1
Compatibility with military training	1-5	1
Environmental compliance documentation needs	1-5	1
Cost/benefit advantage	1-5	1
Potential for vandalism or other damage	1-5	1

By including a variety of criteria it allowed for a numerical comparison of each site that incorporated both biological and technical factors. Scores were listed as rankings from 1-5 with one being the worst and five being the best, or as the total number of at risk species where applicable. Criteria were weighted based on their importance by multiplying the ranking score by the factor indicated. An overall score for each site was calculated by summing the ranks of all criteria.

Prioritization exercise
The initial prioritization exercise, including site description forms, a detailed explanation of the ranking criteria, and a ranking spreadsheet were distributed to all the meeting participants in

Table 3: Example of ranking sheet.

Site	Owner	Approximate size (ha)	# Listed species	Urgency of listed species	Other sensitive species	Species diversity	Important habitats	Restoration potential	Severity of impacts	Substrate	Accessibility	Technical feasibility	Existing monitoring	Compatibility with training	Environmental compliance	Cost/benefit advantage	Vandalism	Total score
	Weighting		1	1	0.5	1	1	0.5	1	1	1	1	1	1	1	1	1	
Mt. Kaala, Oahu	Air Force, Army, State	2.2																0
PTA, Hawaii, Solanum incompletum	Army	9																0
PTA, Hawaii, Zanthoxylum hawaiiense	Army	11																0
PTA, Hawaii, Schiedea hawaiiensis	Army	1																0
Kahanahaiki, Oahu	Army	10																0
Kaluakauila, Oahu	Army	2.9																0
Poamoho Summit, Oahu	State (Army managed)	0.38																0
Waieli Bench, Oahu	(TNC leased, Army managed)	3.35																0
Nuupia Ponds, MCBH, Oahu	Marines	20																0
Lualualei, Oahu, Amastra and Achatinella snail site	Navy	3																0
Makaha Ridge, Kauai	State (Navy leased)	99																0
Niulii Pond, Lualualei, Oahu	Navy	40																0
Puu Hapapa, Oahu	Navy	2.5																0

order to help them rank sites and determine which sites would receive scoping visits. Site description forms for each nominated site were compiled by each branch. Each nominated site was in a separate row and each criterion listed as a separate column. This allowed participants to rank each site separately and then automatically tally the totals using the weights defined in the ranking spreadsheet. Seven completed ranking sheets were received. Table two shows the average score and overall ranking of each site and table three illustrates the ranking sheet. Out of the 13 nominated sites, the top nine sites were selected for scoping visits with Xcluder Pest Proof Fencing Company.

Table 2: Site ranking results from the prioritization exercise

Site	Rank	Average Score	Std. Dev.
Waieli Bench, Oahu	1	63.7	2.4
Kahanahaiki, Oahu	2	58.4	1.8
Nuupia Ponds, MCBH, Oahu	3	56.2	5.9
Kaluakauila, Oahu	4	55.3	1.5
Mt. Kaala, Oahu	5	54.5	4.5
PTA, Hawaii, Solanum incompletum	6	53.8	3.2
Niulii Pond, Lualualei, Oahu	7	52.6	1.0
PTA, Hawaii, Zanthoxylum hawaiiense	8	52.3	0.3
PTA, Hawaii, Schiedea hawaiiensis	9	51.5	2.3
Puu Hapapa, Oahu	10	49.1	3.8
Poamoho Summit, Oahu	11	46.3	5.9
Makaha Ridge, Kauai	12	47.6	6.7
Lualualei, Oahu, snail site	13	42.8	2.0

SITE VISITS

In August 2007, Roger MacGibbon and Dr. Tim Day of Xcluder Pest Proof Fencing visited the top nine selected sites on Oahu and Hawaii with Brad Keitt of Island Conservation and consulting biologists Lindsay Young and Eric VanderWerf. The purpose of the site visits was to appraise each site for its suitability to be enclosed by a pest proof fence and determine the relative ecological benefits that could be gained by pest proof fencing and permanent mammalian pest eradication and to select the top four sites that would receive full implementation plans.

In addition to the initial ranking criteria described above, the following criteria were also considered when selecting the top four sites:

- The utility and probability of success as a demonstration fence.
- Amount of in-kind resources (labor and equipment) available from the military.
- Visual and biological (i.e. clearing native vegetation) impact of fence construction.
- Potential for biological measures of success on both pests and natives.
- Ability of military command and natural resource managers to partner on the project and maintain and monitor the fences in the long term.

Once all sites were examined and evaluated using the initial ranking criteria and the additional factors listed above, the top four sites selected for full implementation plans were:

1. PTA *Solanum incompletum*
2. Kahanahaiki
3. Niulii Ponds
4. Waieli Bench

These four sites represent a wide range of ecosystems and support numerous species that warrant protection and have high probabilities for success as demonstration fences. Success as a demonstration fence was defined as being on buildable terrain, having the support of the resource managers, and feasibility of completion within budget in addition to all other previously mentioned criteria.

Sites that were not selected for full implementation plans but that will still receive costing reports for branch records were:

1. Nuupia Ponds
2. Mt. Kaala
3. PTA *Zanthoxylum hawaiiense*

Nuupia ponds, despite being a biologically significant site, was determined to be too expensive and would likely exceed the budget for a demonstration fence. Furthermore, difficulties with creating a fully enclosed area and unresolved access issues from nearby civilian housing made this a less desirable demonstration site. Mt. Kaala was too small an area being protected to warrant the clearing of such a large area for a fenceline. PTA *Zanthoxylum hawaiiense* was extremely similar to the PTA *Solanum incompletum*, but had fewer species needing protection and more difficult terrain to construct a fence on. Two sites, Kaluakauila and PTA *Schidea hawaiiensis,* were too technically challenging to construct fences that would be rodent proof and were not provided with costing reports. A brief summary of each of the nine sites is presented in Table 4. Details of each site visit and more explanation for selection rationale can be found in Appendix 5.

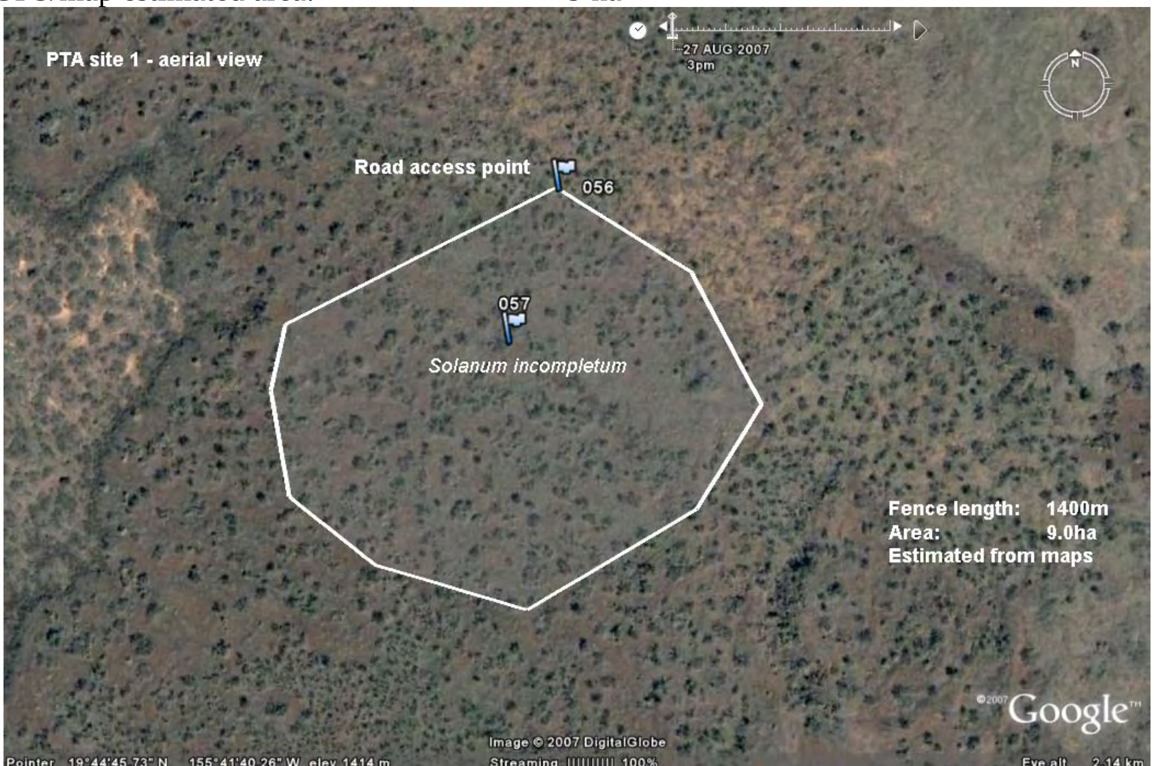
Table 4: Comparison of sites visited in order of ranking.

Site	Fence length (m)	Area (ha)	Access	Construction impact	In kind resources	Approx. cost
PTA *Solanum incompletum*	1400	9	Good	Low	High	$384,000
Kahanahaiki	1450	9.95	Fair	Intermediate	High	$399,000
Niulii Ponds	940	3.2	Excellent	Low	Intermediate	$234,000
Wailei Bench	295	0.6	Fair	High	High	$115,000
Nuupia Ponds	3005	50	Excellent	Low	Low	>$1,000,000
Mt. Kaala	840	4	Excellent	High	Intermediate	~$210,000
PTA *Zanthoxylum hawaiiense*	1800	11	Good	Low	High	~$450,000
Kaluakauila	N/A	N/A	Poor	N/A	N/A	N/A
PTA *Schidea hawaiiensis*	N/A	N/A	Good	N/A	N/A	N/A

POHAKULOA TRAINING AREA *SOLANUM INCOMPLETUM* IMPLEMENTATION PLAN

Proposed fence length: 1400 m – marked on map

GPS/map estimated area: 9 ha



A. Site analysis

Primary fence purpose:
Protection of three endangered plant species, *Solanum incompletum* (four individuals), *Silene lanceolata* (approximately 21 individuals), and *Zanthoxylum hawaiiense* (five individuals), from predation by rats and sheep. The site is also large enough in size to begin to examine eradication of the full suite of pests present and measure ecosystem effects of predator proof fencing.

Fencing feasibility:
The site was visited and several areas were walked over and marked with GPS. Exclusion fencing is possible in this site, although the exact fenceline proposed was not walked during the site visit. The terrain at the site is similar throughout the area and the fencing route and area could easily be shifted to include additional rare plants, avoid difficult fencing situations and maximize cost-effectiveness.

Site access is possible by vehicle, although improvement to some roads close to the site would aid travel. All materials, equipment and staff would be able to access the site daily by vehicle and army assistance at this site would be possible. Heavy earthmoving machinery will be required to form the platform on which the fence will be built. The 'a'a lava substrate requires crushing into fine material creating a smooth road surface. This is achievable with several passes of a large bulldozer or similar machine.

Fence posts in this site would be drilled and concreted into the substrate where necessary. One pedestrian access gate would be required.

Site issues:
Travel to and from the site each day would be time consuming unless crew were allowed to camp nearby. The ground disturbance required for fenceline formation will need to be cleared with the Army as there is the (small) possibility of unexploded devices within the construction area. Military assurance of the site safety would be necessary. Army assistance with site preparation and logistics could help defray the costs associated with access at this site.

Value of pest proof fencing:
The value of fencing this site appears to be significant and would make an excellent demonstration site. Complete mammalian pest eradication would seem to be a realistic target because the site is accessible; the terrain is reasonably level and negotiable by foot; and the vegetation cover is sparse allowing the ground surface to be covered without encumbrance.

Fencing and eradication is likely to remove mammalian pest damage to the threatened plant species and allow an opportunity for regeneration. There is also a good time window in which to make a variety of comparisons about the impacts of predators and ungulates by collecting data inside and outside the predator fence, and before and after the ungulate fence (currently being constructed) is completed. The site could provide a good opportunity for testing the efficacy of predator fencing at reducing nest predation for these and other bird species by conducting artificial nest experiments with nests placed on the ground and in trees inside and outside the fence.

The predator fence would provide a suitable location in which to outplant all of the endangered plants from PTA, including several not currently found in the immediate fenced area, thereby advancing conservation of numerous plant species. The army crew at this site is very enthusiastic and supportive of this project and appears to have the capacity required to monitor and maintain this site.

B. Fence construction and costing detail

Fence design:

The proposed pest proof fence for this site is the Xcluder "Kiwi" design standing 1.95 meters above the ground (figure 1). This fence will completely exclude all pest mammals found at the site, including juvenile mice. A 5 meter wide level platform will be formed by bulldozer for the fence to be built on. The fence will be supported by galvanized steel posts of a similar dimension and material to those used in the area on ungulate fences. The posts will be spaced at 3 meter intervals. The face of the fence will be covered with stainless steel mesh (marine grade 316) with an aperture of 5.5mm by 25mm. This is sufficient to prevent the passage of very young mice. The mesh extends horizontally out from the base of the fence by no less than 350mm and its leading edge will be sealed to the lava substrate with a cement – aggregate mix. This mesh "skirt" is effective at preventing the passage of digging and burrowing animals, including mice. A supply of crushed a'a lava will be necessary to mix with the cement so that a mouse proof seal is produced. An "army green" coloured, zinc-aluminium coated steel hood will be attached to the top of the fence (see figure 1 in appendix one); this serves to prevent the passage of jumping and climbing animals.

Construction requirements and duration:

Work will commence on the site with the preparation of the fence platform. A 5 meter wide level platform of crushed a'a lava will be formed along the line using a 300 to 500 horsepower tracked bulldozer. Multiple passes will enable the lava to be crushed down to moderately small sizes sufficient to minimize the likelihood of mouse passage.

All vegetation must be removed from this platform and all trees and shrubs must be kept permanently no less than 4 meters away from the fence indefinitely so as to prevent the reinvasion of cats and rats by jumping over the fence from elevated vegetation.

8.4 metric tonnes of crushed lava will need to be procured to seal the mesh skirt edge against the lava surface to make it mouse proof. The crushed lava is mixed with cement at a ratio of 6 kg lava to 2 kg cement for every lineal meter of fence and applied in a thin strip along the mesh skirt. If access to the site allows it, this mix can be applied directly from a concrete truck. Ideally the lava should be crushed so that the majority of lava fragments are no wider than 6mm. A commercial rock quarry exists quite close to the site but it has not been determined whether they can supply crushed lava to the size specifications required. If the lava must come from further afield approvals and fumigation for weeds may be required to enable the importation of crushed lava from other than local sources.

The very porous nature of the substrate means that no drainage will be crossed and no drainage piping is likely to be required. An Xcluder remote electronic surveillance system (see appendix one) is unlikely to be required on this fence because of the absence of tall trees to threaten the fence and the lack of public access to the site. The duration of fence construction from the commencement of earthworks to the completion of construction is likely to be approximately 35 working days or 7 weeks. The fencing team would probably stay in Hilo and drive to site each day.

Fence construction costing:
The costing is an estimate to build an Xcluder pest proof fence to the specifications stated above. The cost will remain current for 2 months from the date of this report after which regular price review will be necessary. Changing $US : $NZ currency exchange rates, fuel price changes and steel price changes could all alter the cost significantly over relatively short periods.

The costing assumes that three Xcluder personnel will be present throughout the construction period to manage the project, train the local fencers, supervise construction, install specialty components such as gates, and ensure that the fence is completed to Xcluder specifications. Apart from the Xcluder supervisors all fencing labour and contractors are to be sourced in Hawaii.

Costings have been determined on the basis that all fence materials and components, with the exception of the steel pipe posts, are purchased in New Zealand and freighted to Hawaii. In reality sourcing additional materials in Hawaii where there is a cost advantage to do so would be beneficial. All costs in $US.

Earthworks	$16,800.00
Fencing materials and components (incl. freight to site)	$187,506.00
Mesh skirt sealing materials and transport	$10,556.00
Fence construction labour and equipment hire	$95,033.00
Xcluder project management, supervision, training and QC	$73,900.00
Total cost to build a 1400 meter pest proof fence	**$383,795.00**

Cost saving opportunities:
The costing above has been calculated on the basis that all materials, labour and contractors are paid for and at commercial rates. There are some opportunities for the fence cost to be reduced:

- If the army were able to supply experienced fencers for no charge, or reduced rates, up to $63,200 could be saved.

- The route provided attempts to maximize the number of threatened plants enclosed. It may be possible to reduce fence length, and hence cost, by finding a more efficient line to optimise the number of threatened plants enclosed.
- The earthworks, or fence platform formation needs to be undertaken by professionals using the appropriate equipment, however, the army may be persuaded to sponsor the earthworks providing they can supply the contractors and equipment. This could save up to $16,800.00.

C. Summary conclusions

This site is rated as equal top with the Kahanahaiki site for its potential to generate significant ecological gains in response to the construction of a pest proof fence. This is because:

1. The site is suitable for the construction of an effective fence that will permanently exclude all mammalian pests found in the area.
2. There are no major threats to the integrity of the fence so the maintenance of the fence in fully functional condition should not be a significant demand on resources.
3. Complete mammalian pest eradication is a realistic target.
4. There are threatened plant species within the area that will immediately benefit from the absence of mammalian pests.
5. The area is large enough to generate measurable signs of natural recovery at an ecosystem level.
6. The army conservation personnel are motivated to improve the ecological health of the land they manage, and they appear to have the resources to manage and maintain a pest fenced area.
7. The site would be a good demonstration area for the application of pest proof fence technology on a’a lava.

KAHANAHAIKI MAKUA MILITARY RESERVATION IMPLEMENTATION PLAN

GPS measured proposed fence length: 1450 m – marked on map
GPS/map estimated area: 9.95 ha

A. Site analysis

Primary fence purpose:

Protection of the entire site from mammalian pests (*Rattus rattus, Rattus exulans, Mus musculus, Felis catus,* the small Indian mongoose (*Herpestes javanicus*)) and predatory snails. This site supports diverse native mesic forest and supports several endangered plant species, including *Schidea obovata, Cenchrus agrimonioides, Schiedea nuttallii,* and *Cyanea superba,* a large an important population of the endangered tree snail *Achatinella mustelina,* and a single female of the endangered Oahu Elepaio (*Chasiempis sandwichensis* ssp. *ibidis*). There has been extensive monitoring on plants, snails, birds and pest species at this site. The site is large enough in size to begin to examine ecosystem effects of predator proof fencing.

Fencing feasibility:

An appropriate fenceline was identified, walked and marked with GPS. Exclusion fencing is possible in this site. This proposed fenceline encompasses just the Maile Flats portion of the larger Kahanahaiki management unit. The route follows the existing ungulate fenceline on the east, south, and west sides. The east, south, and west sides of the fence require significant, but relatively simple earthworks prior to fence construction, because much of the ground is relatively level and has already been prepared to some degree when the ungulate fences were established. Use of earth moving machinery (e.g. a small excavator) would greatly aid preparation of this area.

Three options were considered for the northern boundary: 1) the Maile Flats area as proposed by the Army; 2) a larger area that would include the upper portion of Kahanahaiki Gulch; and 3) a still larger area that would encompass even more of Kahanahaiki Gulch. Examination of the terrain on foot confirmed the Maile Flats option to be the only cost-effective route for the fence. This route crossed the western fork of the upper gulch approximately 30 meters above the “Schweppes Trail”, climbed over the middle ridge, roughly followed the orange trail down into the eastern fork of the upper gulch, then climbed the slope and emerged at the fenceline near the top of the switchbacks on the access trail.

Preparation of the northern boundary fenceline would be most efficiently achieved with sufficiently large earthworks machinery to create a level platform cleared of vegetation and tree roots. Pest-proofed culverts will need to be placed under the fence track in both gulches to allow water to pass under the fence without compromising its integrity. These heavy concrete pipes can only be effectively placed under the fence track with machinery that has significant lifting capability.

A fence at Kahanahaiki would require initial vegetation clearing limited to the fenceline and access track, after which only ongoing routine fenceline maintenance would be required. The fenceline is ideally suited to being monitored by electronic surveillance technology. Two pedestrian access gates would be required (one at the main access track

(North end) and one at the top of the site (South end)). Army assistance to aid site access, fenceline preparation and fence construction at this site is possible.

Site issues:
Access to the site for fencing staff requires at least an hour of driving then walking into the site. Upgrading the site access to allow passage of a 4WD motorbike would significantly improve construction efficiency and the ability to move equipment in and out of the site. This track would prove highly valuable in future years for the follow-up maintenance and monitoring associated with the site as its biological value continues to increase. All materials and construction tools and equipment would currently have to be flown to the site by helicopter because of the lack of road access. Army assistance with site preparation and logistics could help defray the costs associated with access at this site.

Another significant site issue is that the proposed fence line passes through high quality native forest. In order to meet the specifications for a predator proof fence there must be a 4 to 5 m opening in the forest to keep animals, primarily rodents and cats, from using the vegetation to climb or jump over the fence line. Clearing of native forest can be considered drastic and will cause land managers to question the value of this in order to build a fence. Ideally a fence line would follow edges of forest and be built in marginal habitat. For the small scale of the demonstration fences proposed in this project it is not possible to restrict the fence line to these types of areas and at the same time encompass high quality forest. However, for any proposed predator proof fence, land managers must weigh the disturbance and impact of the fence building against the value of the protected area. Given that introduced rodents are one of the most significant drivers of ecosystem degradation in Hawaii (K. Swift pers. comm.) installing predator proof fences can be expected to create dramatic benefit for the protected area. It is expected this benefit will far outweigh any negative impact of putting in the fence. The proposed demonstration fences are designed to measure that benefit.

Value of pest proof fencing:
The value of fencing this site appears to be significant and would make an excellent demonstration site. Eradication of all mammalian pests is a realistic target, although the creation and maintenance of vehicular access to the site will greatly increase the likelihood of success (by way of more cost effective use of resources and the ability to undertake a more intensive campaign).

Because the Kahanahaiki area has been managed and monitored intensively since 1996, it provides an excellent opportunity to compare the costs of predator fencing with methods currently in use, and also to evaluate any improvements in resource protection provided by predator fencing. It is also large enough in size to begin to examine ecosystem effects of predator proof fencing. There has been some work completed already and there is further opportunity to experimentally evaluate the efficacy of *Euglandina rosea* exclusion fencing. If successful this fencing could be used at the site to enable research into eradication of *Euglandina rosea* from a protected area. The army crew at this site is very enthusiastic and supportive of this project and appears to have the capacity required to monitor and maintain this site.

B. Fence construction and costing detail

Fence design:

The proposed pest proof fence for this site is the Xcluder "Kiwi" design standing 1.95 meters above the ground (see figure 1 in Appendix 1). This fence will completely exclude all pest mammals found at the site, including juvenile mice. A fence platform of 3 to 5 meters wide will be formed for the fence to build on. The logistical challenges of achieving this at this site are discussed in a section below.

The fence platform will have a mounded cross-sectional profile with water-tables alongside to catch and prevent surface water runoff from flowing through the line of the fence (see appendix one). Concrete or plastic culvert pipes, each fitted with pest proof screens, will be used to carry accumulated drainage water under the fence. 75% of the length of the fence will be supported by wooden posts at 4 meter intervals which will be mechanically driven, vibrated or hand dug into the ground. The soil depth along three-quarters of the proposed fence line is sufficient to use wooden posts. Wooden posts are generally cheaper to install and can produce a more sturdy fence than steel pipe posts. 25% of the fence, where the rock substrate is close to the surface, will be built using galvanized steel posts at 3 meter intervals. The face of the fence will be covered with stainless steel mesh (marine grade 316) with an aperture of 5.5mm by 25mm. This is sufficient to prevent the passage of very young mice. The mesh extends horizontally out from the base of the fence by no less than 350mm and this "skirt" will be pegged to the soil surface using 9 inch ground pins and a layer of soil will be bladed back over the top. This "skirt" is effective at preventing the passage of digging and burrowing animals, including mice. An "army green" coloured, zinc-aluminium coated steel hood will be attached to the top of the fence (see figure 1, appendix one); this serves to prevent the passage of jumping and climbing animals.

Construction requirements and duration:

1. Earthworks and getting machinery to site:

To create a functional and durable pest proof fence a suitable fence platform that meets Xcluder specifications must be formed. While Army labour has been offered to manually clear the fenceline of vegetation and form a platform the work required to manually create the type of platform desired is unrealistic. Consequently, it is essential that an excavator no smaller than 6 tonnes in size is able to be transported to the site. This could be achieved by having the excavator form a narrow three meter wide access track to the site along the current 750 meter foot access route. If the formation of such an access track is not permissible then the excavator would need to be flown in by helicopter. The only helicopter with the capacity to lift a 6 tonne machine is an Army Chinook (12 tonne lifting capacity). The excavator would also be used to drive the posts.

All fencing materials and additional equipment such a generators, compressors and fencing tools would need to be carried to site by helicopter.

The creation of small vehicle access track to the construction site would enable the fencing team to travel to and from the site daily and would facilitate more efficient and less costly fence construction. If daily access to the site is not possible the fencing team will need to camp on site.

2. Vegetation clearance:
All vegetation will need to be cleared from the fence platform and from a 4 meter wide swath on the outside (pest side) of the fence. This is to ensure no pests reinvade the fenced area by leaping off an elevated branch of a tree. There will be a significant quantity of vegetation to be moved at this site and some thought will need to be given as to how this is best disposed of.

3. Remote electronic surveillance:
The Xcluder remote electronic surveillance system is recommended for this fence. The proximity of trees to the fence poses a significant threat of breach due to tree fall and so a high risk of pest reinvasion. The remote site location means that regular fence inspections will not be practical; the surveillance system will provide a cost-effective 24 hour, 365 day fence monitoring service and will greatly improve the capacity to sustain the pest-free status of the fenced area.

4. Construction duration
The duration of fence construction from the commencement of earthworks to the completion of construction is likely to be approximately 32 working days or 6 and a half weeks.

Fence construction costing:
The costing is an estimate to build an Xcluder pest proof fence to the specifications stated above. The cost will remain current for 2 months from the date of this report after which regular price review will be necessary. Changing $US : $NZ currency exchange rates, fuel price changes and steel price changes could all alter the cost significantly over relatively short periods.

The costing assumes that three Xcluder personnel will be present throughout the construction period to manage the project, train the local fencers, supervise construction, install specialty components such as gates, and ensure that the fence is completed to Xcluder specifications. Apart from the Xcluder supervisors all fencing labour and contractors are to be sourced in Hawaii. Provision has been made to transport all materials and equipment to the site by helicopter with the exception of the 6 tonne excavator.

This costing assumes that a vehicular access track to the fence site will be formed and the fencers will have daily access to the site. Provision has been made for 4 extra days of excavator work to form this access track. Two pedestrian access gates and one vehicle gate have been included in the costings. The costing has been determined on the basis that all fence materials and components, with the exception of the steel pipe posts, are purchased in New Zealand and freighted to Hawaii. In reality, some additional materials should be sourced in Hawaii where there is a cost advantage to do so. All costs in $US.

Earthworks	$29,250.00
Fencing materials and components (incl. freight to site)	$199,057.00
Access track formation and helicopter freight of materials	$10,400.00
Fence construction labour and equipment hire	$85,671.00
Xcluder project management, supervision, training and QC	$73,967.00
Total cost to build a 1450 meter pest proof fence	**$398,345.00**
Optional but recommended Xcluder surveillance system	$21,050.00

Cost saving opportunities:
The costing above has been calculated on the basis that all materials, labour and contractors are paid for and at commercial rates. There are some opportunities for the fence cost to be reduced:

- If the army were able to supply experienced fencers for no charge, or reduced rates, up to $52,480.00 could be saved.
- If the Army offered to helicopter freight all materials and equipment to the site at no cost this would generate a further saving of $6240.00.
- The length of the fence could be reduced by 50 to 100 meters but the alternate line for the fence at the northern end is less satisfactory than the existing line.
- Included is the cost of freighting the wooden posts and battens from New Zealand because of the difficulty finding reliably high quality wooden posts in Hawaii. If good quality wooden posts can be sourced in Hawaii at a competitive rate container freight costs from New Zealand may be reduced by $5000.

Possible cost increases:
If permission is not granted to have the excavator gain access to the site along the 750 meter walking track and the Army do not wish to donate Chinook helicopter time then the added cost of hiring the Chinook would need to be added. This may amount to $5000.

C. Summary conclusions
When all factors are considered this site is rated equal first with the PTA #1 site. The reasons for this are:

1. The site is suitable for the construction of an effective fence that will permanently exclude all mammalian pests found in the area.
2. Complete mammalian pest eradication is a realistic target provided access to the site can be improved.

3. The site has the greatest ecological potential, if fenced, of all the sites visited. This is because of the maturity of the vegetative cover and the size of the area which should enable ecosystem level recovery to be recorded.
4. Monitoring and maintenance of the fence can be assisted by the installation of an Xcluder Remote Surveillance System but small vehicle access to the fence would greatly improve the capacity of Army personnel to maintain the fence and preserve the area's pest-free status.
5. The army conservation personnel are motivated to improve the ecological health of the land they manage, and they are well resourced to manage and maintain a pest fenced area.
6. The site would be a good demonstration area for the application of pest proof fence technology in more mature Hawaiian forest conditions, especially if small vehicle access could be installed.

NIULII PONDS IMPLEMENTATION PLAN

GPS measured proposed fence length: 940 m – marked on map
GPS/map estimated area: 3.2 ha

A. Site analysis

Primary fence purpose:
Protection from predators (rats, mongoose, cats, dogs) of several species of waterbirds and the Hawaiian Short-eared Owl in the Niulii ponds. This is expected to enable improved breeding and survival of Night heron, koloa hybrids, coots, stilts, moorhen and pueo. Secondary aim to protect two local (but separate) populations of *Abutilon menziesii* from rodent seed predation.

Fencing feasibility:
An appropriate fenceline was identified, walked and marked with GPS. Exclusion fencing is easy in this site. An existing track around the perimeter of the ponds requires only some further compaction and widening in one area to provider an ideal fence building platform. The suggested fenceline follows the existing track on the North, West and South sides, but has been straightened on the East side by going through the Kiawe forest. This shortens the fence length by approximately 40m and increases the protected area by almost 1ha.

Fence maintenance would be minimal, and the maintenance staff met were highly supportive and enthusiastic about the concept. The site can be accessed entirely by vehicle for all materials, equipment and staff. It would be both a time and cost effective site. One vehicle/pedestrian access gate into the pond area would be required, plus one additional pedestrian gate at the northern end.

As the *Abutilon* populations were located a significant distance from the wetland, 2 separate rodent exclosures are proposed directly around the plants were suggested.
Navy assistance is possible.

Site issues:
The site is relatively small, so careful consideration of the true biological potential of the site is needed (e.g. what capacity does the wetland have for increases in bird numbers after predation removal). The ponds are dependent on sewage outflow from the military base. It is important to determine the long term future of the site and whether the water levels will remain if sewage output drops. As the site is on a closed-access military base, it may have limited use for public outreach purposes.

Value of pest proof fencing:
The value of fencing this site appears to be reasonable provided a reliable water supply can be sustained. Complete mammalian pest eradication is certainly achievable. Removal of predation of the water birds and their nests is likely to allow improved reproductive success. It is unknown however what the carrying capacity of this relatively small area may be, so an assessment of this potential may be required in order to justify the cost of fencing such a small site. The Navy crew at this site was very enthusiastic and supportive of this project and appeared to have the resources and commitment required to monitor and maintain this site.

B. Fence construction and costing detail

Fence design:
The proposed pest proof fence for this site is the Xcluder "Kiwi" design standing 1.95 meters above the ground (see figure 1 in Appendix 1). This fence will completely exclude all pest mammals found at the site, including juvenile mice.The elevated pond retention wall on the western side of the ponds will be widened to enable small vehicle access down both sides of the pest fence. A 4 to 5 mere wide swath of vegetation will be cleared down the eastern side of the ponds to remove any elevated pest jumping spots. The organic layer will be stripped away from the ground surface to allow the fence to be installed and then this material will be bladed back over the fence platform and mesh skirt.

The fence will be supported by wooden posts at 4 meter intervals which will be mechanically driven into the ground. The soil depth along the proposed fence line is sufficient to use wooden posts. Wooden posts are generally cheaper to install and can produce a more sturdy fence than steel pipe posts. The face of the fence will be covered with stainless steel mesh (marine grade 316) with an aperture of 5.5mm by 25mm. This is sufficient to prevent the passage of very young mice. The mesh extends horizontally out from the base of the fence by no less than 350mm and this "skirt" will be pegged to the soil surface using 9 inch ground pins and a layer of soil will be bladed back over the top. This "skirt" is effective at preventing the passage of digging and burrowing animals, including mice. An "army green" coloured, zinc-aluminium coated steel hood will be attached to the top of the fence (see figure 1, appendix one); this serves to prevent the passage of jumping and climbing animals.

Construction requirements and duration:
Fence construction on this largely level, easy to access site will be straight-forward. Daily access for the fencing crew and supervisors will need to be negotiated with the navy. The duration of fence construction from the commencement of earthworks to the completion of construction is likely to be approximately 35 working days or 7 weeks. A small number of culverts and Xcluder culvert screens will be used to manage drainage flow into and out of the fenced area.

Fence construction costing:
The costing is an estimate to build an Xcluder pest proof fence to the specifications stated above. The cost will remain current for 2 months from the date of this report after which regular price review will be necessary. Changing $US : $NZ currency exchange rates, fuel price changes and steel price changes could all alter the cost significantly over relatively short periods.

The costing assumes that three Xcluder personnel will be present throughout the construction period to manage the project, train the local fencers, supervise construction, install specialty components such as gates, and ensure that the fence is completed to Xcluder specifications. Apart from the Xcluder supervisors all fencing labour and contractors are to be sourced in Hawaii. Costing has been determined on the basis that all fence materials and components are purchased in New Zealand and freighted to Hawaii. In reality, sourcing additional materials may occur in Hawaii where there is a cost advantage to do so. All costs in $US.

Earthworks	$8,580.00
Fencing materials and components (incl. freight to site)	$135,113.00
Fence construction labour and equipment hire	$50,667.00
Xcluder project management, supervision, training and QC	$39,668.00
Total cost to build a 940 meter pest proof fence	**$234,028.00**

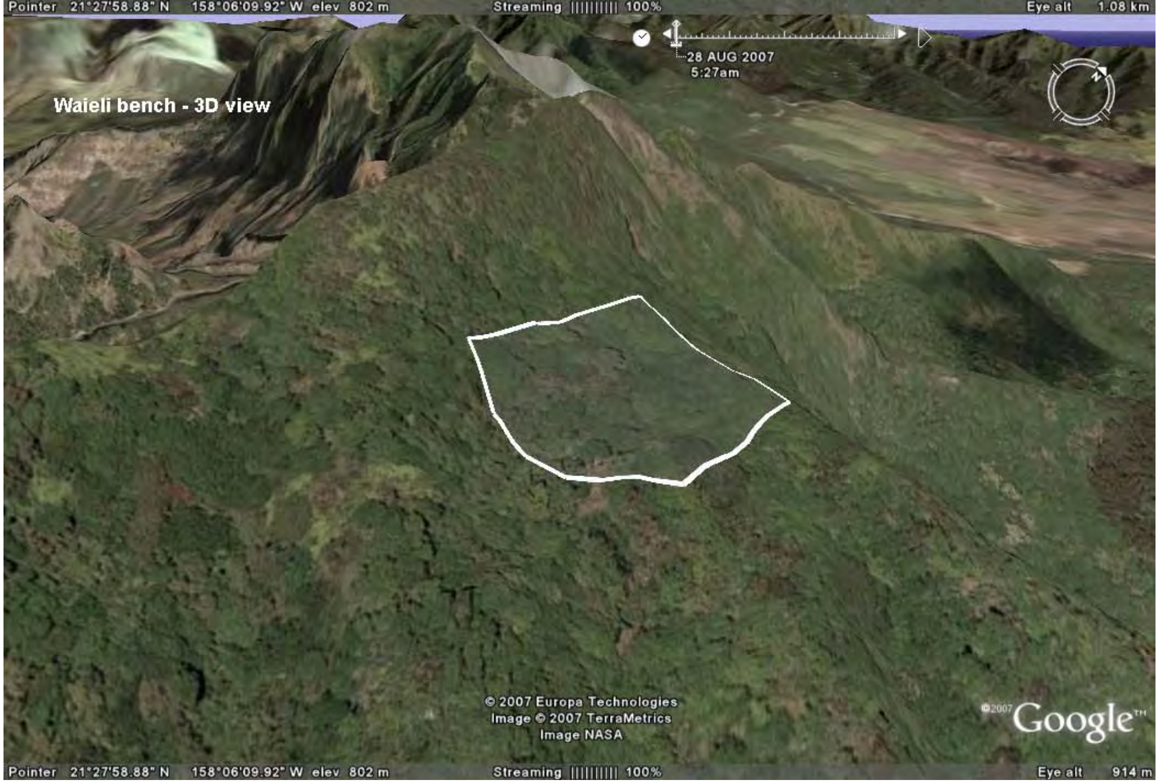
Cost saving opportunities:
There are probably few significant ways that the cost of the fence could be reduced unless the navy offered fencers at a subsidized rate.

C. Summary conclusions
This site is rated in third place behind PTA#1 and Kahanahaiki on the following basis:

1. The site is suitable for the construction of an effective fence that will permanently exclude all mammalian pests found in the area.
2. There are no major threats to the integrity of the fence so the maintenance of the fence in fully functional condition should not be a significant demand on resources.
3. Complete mammalian pest eradication is an achievable target.
4. The ponds provide water habitat for birds that is absent from the nearby landscape.
5. While the permanent removal of pests will increase bird survival and breeding success the bird carrying capacity is low and there are no “spill-over” areas for excess birds in the immediate vicinity. If excess birds can and do readily find the habitat at Pearl Harbour then the ecological value of this site may be moderately high.
6. The on-going reliability of the water supply to the ponds from the naval barracks is not assured and so the future value of the site cannot be guaranteed.
7. The site is not readily accessible to the public and so its value as a demonstration site is more limited than the PTA site and Kahanahaiki.

WAIELI BENCH IMPLEMENTATION PLAN

GPS measured proposed fence length: 295 m – marked on map
GPS/map estimated area: 0.6 ha



A. Site analysis

Primary fence purpose:
Protection of the endangered tree snail *Achatinella mustelina* from predation by *Rattus rattus, Rattus exulans, Mus musculus* and the predatory snail *Euglandina rosea.* In addition the site contains other extremely rare mollusks that that are not listed, including *Cookeconcha* sp., *Helicinid* sp., *Amastra micans*, and *Laminella sanguinea.* Several species of critically endangered plants have been outplanted at the site, including *Cyanea grimesiana subsp. obatae, Cyanea pinnatifida, Delissea subcordata, Phyllostegia hirsuta, Phyllostegia mollis*, CR *Plantago princeps var. princeps, Schiedea hookeri, Solanum sandwicense*, and *Urera kaalae.*

Fencing feasibility:
An appropriate fenceline was identified and walked. Exclusion fencing is possible in this site. The suggested fenceline followed along the top of the bench just below the steep slopes of Puu Hapapa, and just above the steep slope on the bottom of the bench. It is recommended to avoid the steeper slopes because of the higher potential for damage to the fence from rockfalls, surface water flow, and erosion. As such, there is limited opportunity to expand the fenced area beyond that walked and marked with GPS.

Forest would need to cleared on the outside of the fence to create a barrier over which pests could not jump (usually four meters wide), and this barrier must be wider on a steeper slope because pests can use the slope to increase their leaping distance. As feral cats are not a target for this site, a lower 1.3 meter tall fence (the minimum height needed to exclude rats and mongoose), could be used.

No fence design has yet been proven to exclude *Euglandina rosea*, although several known fence modifications that are effective for other snail species could be effective. This site would provide the opportunity to test these modifications for snail exclusion on an experimental basis. One pedestrian access gate would be required. Army assistance to aid construction at this site is possible.

Site issues:
Access to the site for materials and fencing staff is limited. All material would have to be flown to the site by helicopter because of the remote location. The army indicated that they could cover costs of material transport, using a large military helicopter to move all materials to a staging area and directly contracting with a local helicopter company to shuttle material to the project site.

The need to provide daily site access for staff (or to camp on site during construction) would limit the efficiency of fencing crews. Due to the remote location, no heavy machinery would be able to be used on site. Formation of the fence platform and vegetation removal required to construct a fully effective fence at this site would need to be achieved by hand.
Clearing forest along the fenceline may positively or negatively affect the microclimate preferred by snails and host plants. Because the site is small, the effect of creating an open

edge around the entire perimeter could significantly modify habitat quality over a significant portion of the area. While an effective rodent fence could easily be built on the site, the efficacy of *Euglandina rosea* exclusion could not be guaranteed until further research is undertaken.

Value of pest proof fencing:
The value of fencing this site is uncertain. The threatened snail population at the site is abundant, but it is unknown what factors are affecting the success or decline of the population. If predation by rodents is a key limitation for the threatened snail population a fence is likely to provide benefit. If predation by *Euglandina rosea* is a key limitation for the threatened snail population the fence will provide an opportunity to experimentally test predatory snail exclusion, but will only provide benefit to the threatened snails if the experimental exclusion is successful.

Threatened snails may be abundant at this site simply because of the specific habitat present being highly suitable for their needs. Modifying this habitat by establishing a perimeter fenceline may have positive or negative consequences for the habitat and it is unknown whether snails will be affected by this modification. In order to make more informed decisions on the value of fencing it would be desirable to have more information about the status of snail populations, the severity of impacts by rodents and *Euglandina*, and the efficacy of current pest management.

Fencing this site should only be done on the basis that it provides an experimental opportunity to learn more about protection and management of the endangered tree snail *Achatinella mustelina*. It should be considered that there may be some unintended risk of negative consequences from the experiment.

B. Fence construction and costing detail

Fence design:
Two possible fence designs are suggested for this site:

1. The Xcluder “Kiwi” design standing 1.95 meters above the ground (see figure 1 in Appendix 1). This fence will completely exclude all pest mammals found at the site, including juvenile mice and cats.
2. The Xcluder “small mammal” fence. This fence stands 1.3 meter tall and will exclude mice, rats, mongoose and feral pigs but will not exclude cats. See appendix one for the design specifications.

The decision as to which fence design is chosen depends on the evidence available on the influence of feral cats on the rare indigenous snails at this site. If cats are determined to have no impact on the snails then the small mammal fence option is recommended. Both designs have equal potential to be made *Euglandina* proof.

At this site, both fence designs will be supported by galvanized steel posts spaced at 3 meter intervals. The rocky substrate prohibits the use of wooden posts.

The face of the fence will be covered with stainless steel mesh (marine grade 316) with an aperture of 5.5mm by 25mm. This is sufficient to prevent the passage of very young mice.

The mesh extends horizontally out from the base of the fence by no less than 350mm and its leading edge will be sealed to the rocky substrate with a dry cement – aggregate mix that will harden over time with moisture derived from the atmosphere.

An “army green” coloured, zinc-aluminium coated steel hood will be attached to the top of the fence. The hood extends 350 mm out from the fence on the 1.95m high kiwi design but is narrower on the small mammal fence.

Construction requirements and duration:
Because of the lack of vehicular access, all vegetation clearance and ground formation will need to be done by hand. Manual clearance on a rocky substrate invariably means that the job will not be of the same standard as one on a mechanically formed platform, but the fence should be able to be made pest proof. If cats are not the target of exclusion the vegetation free zone on the outside of the fence could be reduced to 3 meters.

The extent and difficulty of the manual work required and the need for the workers to camp on site will make this fence a slow and expensive project. Worker fatigue will be a factor that will need to be carefully managed. Use of a larger fencing team for a shorter duration should optimize productivity and cost. The duration of fence construction from the commencement of vegetation clearance to the completion of construction is likely to be approximately 8 working days with a team of 8. All materials and supplies will need to delivered to the site by helicopter. A gap will need to be cleared in the canopy before the fence materials can be unloaded on site.

Fence maintenance issues:
The risk of damage to the fence from tree fall will be high at this site. This, accompanied with the remoteness of the site, means that the likelihood of periodic fence breach and pest reinvasion is reasonably high. An Xcluder remote surveillance system would provide valuable monitoring information but the ability of army conservation employees to respond at short notice and repair the fence is questionable.

Fence construction costing:
Two cost estimates have been calculated, one for the standard “Kiwi” design and the other for the small mammal fence that will not exclude cats. These costs will remain current for 2 months from the date of this report after which regular price review will be necessary. Changing $US : $NZ currency exchange rates, fuel price changes and steel price changes could all alter the cost significantly over relatively short periods.

Both costings assume that three Xcluder personnel will be present throughout the construction period to manage the project, train the local fencers, supervise construction, and ensure that the fence is completed to Xcluder specifications. Apart from the Xcluder supervisors all fencing labour and contractors are to be sourced in Hawaii. Costings have been determined on the basis that all fence materials and components, with the exception of the steel pipe posts, are purchased in New Zealand and freighted to Hawaii. In reality sourcing additional materials in Hawaii where there is a cost advantage to do so would be beneficial. All costs in $US.

Option 1: Full, cat proof Kiwi design

Fencing materials and components (incl. freight to site)	$54,213.00
Helicopter freight to site	$6,240.00
Fence construction labour and equipment hire	$28,307.00
Xcluder project management, supervision, training and QC	$25,907.00
Total cost to build a 295 meter pest proof fence	**$114,667.00**

Option 2: Small mammal fence (1.3 meters high)

Fencing materials and components (incl. freight to site)	$29,447.00
Helicopter freight to site	$6240.00
Fence construction labour and equipment hire	$25,697.00
Xcluder project management, supervision, training and QC	$24,388.00
Total cost to build a 295 meter small mammal proof fence	**$85,772.00**

Cost saving opportunities:
There are some opportunities for the fence cost for either option to be reduced:

- If the army were able to supply experienced fencers for no charge, or reduced rates, up to $18,800 could be saved with option 1 and $17,300.00 with option 2.
- The provision of an army helicopter for freighting materials to site at no cost would save $6240.00.
- The earthworks, or fence platform formation needs to be undertaken by professionals using the appropriate equipment, however, the army may be persuaded to sponsor the earthworks by providing their own the contractors and equipment.

C. Summary conclusions

This site is rated in fourth position of the four top sites under consideration. This is because:

1. Complete pest eradication should be relatively easy to achieve.
2. Fence construction will be a challenge with all work having to be done manually.

3. The maintenance of pest integrity and the prevention of pest reinvasion will also be a challenge because of the close proximity of trees to the fenceline and the remoteness of the fence from maintenance staff.
4. The lower small mammal fence would be the easiest to build and maintain at this site. Its suitability depends on the likely impact of feral cats on the fauna within the fence.
5. There is a distinct risk that the process of clearing vegetation and building the fence may alter the habitat in a way that results in the site being less desirable for the threatened snail species than it is currently.
6. This site would have ecological merit if it was constructed with the prime purpose of providing an experimental opportunity to learn more about protection and management of the endangered tree snail *Achatinella mustelina*.

MAINTENANCE OF PEST PROOF FENCES

A well built pest proof fence that has been built with precision using proven materials is only as good as the monitoring and maintenance program that supports it.

Accidents, vandalism and acts of nature are likely at some stage to lead to the fence being damaged or breached. A good maintenance and monitoring program will detect the breach immediately upon its occurrence; will have people and resources in place to make emergency repairs; and will have reduced the likelihood of pests entering when a breach occurs.

Many of the projects building pest proof fences aim at achieving complete eradication of all mammalian pests followed by the reintroduction of threatened indigenous plant and animal species. When these gains have been achieved, the 'biological stakes' will be raised and what can be lost as a result of one hole in the fence will increase substantially. The importance of a well planned and enforced monitoring and maintenance program in these situations is considerable. In summary the following should be considered:

• The pest fence will need to be physically inspected on a regular basis. How regularly this is done depends on the risks prevalent on the site. Proximity to the public (vandalism and accidental damage); the nature and size of animals adjacent to the fence (damage from large livestock such as cattle and horses); the volatility of seaend coastlines (which could be damaged or modified in storms); the proximity, extent and size of trees; the regularity and severity of flooding; and the regularity of people entering and leaving the fenced area, plus the value of what exists on the inside of the fence all contribute to the risks faced and should determine the regularity of inspection. Inspection may need to be once weekly for some reserves and once monthly in others.
• A physical fence inspection should be undertaken on foot where possible. Walking along the fenceline allows the observer to view and inspect the fence closely and directly. Inspections should be periodically undertaken from both sides of the fence.
• The duration between physical inspections can be increased by the installation of electronic surveillance systems. Already available is a solar-powered system that can detect open gates and fence damage, the location along the fence and the extent of the damage and report it back to a control board or phone electronically.
• Fence owners are encouraged to complete a risk analysis of their fenceline. This analysis should identify possible breach sites (such as at the watergates of flood prone streams; adjacent to trees on steep or wind-prone land; or next to areas of public access); nominate personnel who will be responsible for attending to any breach; and make provision for fence repair supplies to be stored in the vicinity of high risk areas.
• To reduce the likelihood of pests entering the pest free zone through a fence breach it is recommended that a low-pest buffer zone (using traps and poisons) is established around the outside of the fence perimeter. The width of this buffer zone will depend on the nature of the pests; their abundance; and the plants and animals at risk on the inside of the fence. Several species, including rats and perhaps feral cats, seem to

establish the fence as a territory boundary and so regularly patrol it, increasing their chances of finding a breach before it is repaired. Consequently, pests that are strongly territorial and those that travel substantial distances often need to be the most extensively controlled.

• When a fence breach occurs it is important that any pests that do enter the pest-free area are detected early. If a breach goes unnoticed for some time and there is no pest detection program in place it may very quickly become necessary for the entire fenced area to be re-poisoned or trapped to attain pest free status again.

The best way to detect pest intrusions is to establish a network of bait stations, traps or tracking tunnels around the inside of the fence line and also either a grid of stations throughout the protected area or at least scattered stations in strategic locations. Such a grid of bait stations or traps will probably have been established previously to achieve complete pest eradication; retention of the station grid will certainly assist with the early detection of any re-invaders. In one New Zealand example, a small hole occurred in a pest proof fence as a result of careless use of some farm machinery. The hole went unnoticed for a week and in that time it appears that up to 10 mice may have entered the pest-free valley. Only the established bait station and tracking tunnel network enabled the mice to be located and dealt with.

PERMITS AND COMPLIANCE

Constructing a pest proof fence in any natural area, particularly one with endangered species, will require a suite of permits and consultations with multiple state and federal agencies. In cases where the proposed fence follows an existing fenceline with an existing environmental assessment (EA), the EA and compliance documentation may cover the installation of the new fence. In areas without a fence and/or has a fence but construction of a new fence significantly alters the surrounding area, new permits will likely be required. While the permits required will vary depending on the location and its zoning, the species present and existing permits, the list below covers most permits that may be required in this situation. Many of these permits can be applied for simultaneously greatly shortening the time required. The exception to this are special management area (SMA) and shoreline permits which can only be applied for once an EA has been completed. For projects in an SMA this should be taken into consideration when estimating project timelines.

For this exercise, the top four selected sites all have existing EA’s for ungulate fences and are not within SMA’s, shorelines, or have any known historical sites present. The permit burden for construction of a pest proof fence at these sites would be minimal, and each branch has indicated a willingness to participate in obtaining new permits if required. For the remaining three sites, PTA *Zanthoxylum hawaiiense* would not require a new EA, and Mt. Kaala would require an EA, ESA Section 7 and NEPA consultations. Nuupia ponds would require all permits listed above and would require additional consultation with cultural groups and civilian neighbors per base legal requirements for construction. All fences greater in length than 1000 m would require a grading permit from DPP. The use of environmental toxicants for pest removal may require additional permits if not currently being used (such as at Niulii) and consultation with appropriate agencies is recommended.

Table 5: List of permits, issuing agencies, and when permits are required.

Permit	**Issuing/Approving Agency**	**Requirements**
EA	State Board of Land and Natural Resources	Development that impacts natural areas
ESA Section 7 Consultation	USFWS	Actions that effect critical habitat and/or ESA species
NEPA	EPA	See above
Conservation District Use Application (CDUA)	Department of Land and Natural Resources (DLNR)	If development is in a conservation zoned parcel
SMA use permit	Department of Permits and Planning (DPP)	If fence is in an SMA
Shoreline setback variance	DPP	If fence comes to a shoreline
Shoreline certification Application	DLNR Land Division	If fence comes to a shoreline
Archaeological survey	OHA, burial council	Hawaiian burials
Section 106 consultation	SHPO, National Historical Register	If historical sites are present (anything older than 1950)
Grading permit	DPP	Grading > 1 acre (1,000 m of linear 4m wide fence)

PEST ERADICATION WITHIN FENCES

Once the proposed demonstration fences are completed and inspected for quality control it will be necessary to remove all non-native mammals from within the fenced areas. The techniques to accomplish this goal will vary according to target species. In general, the techniques used will be those that have proven successful at eradicating vertebrates from islands. These techniques are scalable and could be used on even very large fenced areas so that eradication of non-native mammals within a fenced area is not a limiting factor in fence size.

For the proposed demonstration fences it is assumed that all ungulates will leave the area before fences are completed. A survey for their presence will be made and any found inside a fence would be shot and the body disposed using standard military protocols. It is also likely that cats and mongooses will escape the fences on their own because the fences are 1 way barriers and the animals can climb out of the fence. Surveys using standard procedures (spotlighting, tracking, and searching for sign) would be used to determine presence and any remaining animals would be trapped and humanely euthanized using existing military protocols for these activities.

Because of their small home ranges rodents are likely to remain within the fenced areas and will need to be eradicated. The preferred rodenticide to target both rats and house mice is brodifacoum, a second generation anti-coagulant. This can be delivered either through bait stations laid in a grid across the fenced area or via a broadcast of bait pellets on the ground. The bait station approach would require 25 m spacing of the stations or a total of about 160 stations for the largest (~10 ha) of the proposed demonstration fences. Broadcast baiting is a more scalable method and becomes increasingly cost efficient at larger scale and is therefore the recommended method. Confirmation of eradication success will involve several measures of efficacy, including trapping and chew sticks to look for rodent sign.

The costs for non-native mammal eradication within the proposed fence areas are as follows:

POHAKULOA TRAINING AREA *SOLANUM INCOMPLETUM*

Ungulate, cat and mongoose, confirmation of absence	
Supplies: traps, track pads	$ 550
Travel	$1,200
Personnel	$3,300
TOTAL	**$5,050**

Rodent eradication and confirmation of absence	
Supplies: traps, bait	$ 2,650
Travel	$ 3,400
Personnel	$12,400
TOTAL	**$18,450**

KAHANAHAIKI MAKUA MILITARY RESERVATION

Ungulate, cat and mongoose, confirmation of absence	
Supplies: traps, track pads	$ 550
Travel	$1,200
Personnel	$3,300
TOTAL	**$5,050**

Rodent eradication and confirmation of absence	
Supplies: traps, bait	$ 2,650
Travel	$ 3,400
Personnel	$16,400
TOTAL	**$22,450**

NIULII PONDS

Ungulate, cat and mongoose, confirmation of absence	
Supplies: traps, track pads	$ 250
Travel	$1,200
Personnel	$2,300
TOTAL	**$3,750**

Rodent eradication and confirmation of absence	
Supplies: traps, bait	$ 1,450
Travel	$ 2,800
Personnel	$ 8,400
TOTAL	**$12,650**

WAELI BENCH

Ungulate, cat and mongoose, confirmation of absence	
Supplies: traps, track pads	$ 250
Travel	$3,200
Personnel	$3,300
TOTAL	**$4,850**

Rodent eradication and confirmation of absence	
Supplies: traps, bait	$ 1,450
Travel	$ 4,800
Personnel	$ 8,400
TOTAL	**$14,650**

BIOLOGICAL MONITORING

Monitoring of biological resources on Department of Defense lands is crucial for demonstrating and measuring the benefits and effectiveness of predator fencing as a management technique. Information collected by Natural Resources Management staff at each site prior to fence construction will provide valuable baseline data for comparison. However, the types and amount of information gathered varies among installations, and in some cases there may be insufficient data available to make the desired comparisons. In such cases it will be necessary to measure the effects of predator fences through the use of simultaneous treatment and control sites located inside and outside areas that have been fenced and from which predators have been excluded. Monitoring methods currently used at each installation are summarized in the site descriptions, which can be found in Appendix 3. Results of all monitoring associated with gauging effectiveness and cost-benefit of predator fences should be made available to the public, in either technical reports or scientific journals.

BIRD POPULATION MONITORING

Introduced mammalian predators are one of the most serious threats to all native bird species in Hawaii and also on many other islands (Côté and Sutherland 1997, Scott et al. 2001, USFWS 2006). Rats, particularly black rats (*Rattus rattus*), are the primary nest predator on many island birds (Atkinson 1977, Atkinson 1985, Robertson et al. 1994, VanderWerf and Smith 2002). Feral cats are also a serious problem for many bird species, and predation on nests by feral cats has been documented in the endangered Palila (Laut et al. 2003). Ground-nesting bird species such as Nene (*Branta sandvicensis*), Hawaiian Stilt, Hawaiian Coot, and Hawaiian Moorhen, and seabirds such as the endangered Hawaiian Petrel (*Pterodroma sandwichensis*) are particularly vulnerable to predation by feral cats, mongoose, feral dogs, and rats (Simons and Hodges 1998, Hodges and Nagata 2001, USFWS 2004, USFWS 2005).

Ideally, the best way to measure the effectiveness of predator exclusion on bird populations is to directly measure population size, survival rates, and reproductive rates of wild birds. This can be accomplished using temporal comparisons before and after fence construction, and/or simultaneous spatial comparison from inside and outside the fenced area. However, if the species of interest has been extirpated from the area or occurs at low density it can be difficult or impossible to collect sufficient information in order to make these comparisons. In some cases there may be no baseline data with which to make temporal comparisons, requiring comparison of rates inside and outside an exclosure.

There is an extensive literature on bird population monitoring and numerous techniques are available that are suitable for a variety of purposes and situations (Ralph and Scott 1980, Bibby et al. 1992, Buckland 2006). For the purposes of this project, the methods likely to be most suitable are territory mapping (or spot mapping) and the Variable Circular Plot.

Spot Mapping

Territory or spot mapping is appropriate for species that are territorial or occur in well-defined home ranges. It has been used to effectively monitor abundance and demography of the Elepaio on Oahu and Hawaii (VanderWerf et al. 2001, VanderWerf and Smith 2002, VanderWerf 2004, U.S. Army 2006), and could also be used to monitor nesting Hawaiian Petrels, the number of waterbirds at wetland sites, and possibly the number of Nene in a particular area (USFWS 2004).

Variable Circular Plot

The Variable Circular Plot method (Reynolds et al. 1980, Scott et al. 1986) is suitable for a variety of species and involves estimating the horizontal distance to each individual detected at a series of points at set intervals along a transect. Using distance-based analytic techniques, such as those provided in program Distance (Thomas et al. 2006), it is possible to calculate an effective detection radius from the distribution of detections around sampling points and to use this information to estimate the density of each species and its population size in the area of interest. Density and population estimates derived from this method are likely to be fairly accurate for more numerous bird species that do not occur primarily in flocks, but estimates will be less precise for less common species with smaller sample sizes and for species with clumped distributions. It is difficult to determine the appropriate number of sampling points and frequency of sampling without information on the detection rate of birds at a particular site. At least 15-20 points would be advisable as a minimum number, and this is the number that can usually be done in one morning, more would be desirable in most circumstances.

The Variable Circular Plot method has been used extensively in Hawaii (Scott et al. 1986, Hawaii Division of Forestry and Wildlife unpubl. data), and these surveys have usually used the following methods. Sampling points are located at 150-200 meter intervals along a transect. Points should be farther apart in more open habitats where birds may be detected at longer distances. At each point an observer records the horizontal distance to each bird detected during an eight-minute count period, its species, and whether it was first detected by sight or sound. At each point the following information also should be recorded: date, transect number (or name), observer’s name, start and stop times, weather conditions (wind on the Beaufort scale from 0-4, rain on a scale from 0-4, and cloud cover), and any other noteworthy information. Surveys for most forest birds are usually conducted in March or April to coincide with the onset of breeding, but for Palila surveys are conducted in January. Repeated each transect more than once during the season would increase sample size and improve the precision of density and population size estimates. Surveys should begin shortly after sunrise but should not include the dawn chorus, and should end each day by 11:30am, or earlier if weather conditions inhibit detection of birds.

Time Frame Restrictions and Detecting Population Responses

Detecting changes in bird abundance associated with construction of predator fences will be difficult over the relatively short time period of this project, and it may be more feasible to detect changes in other population parameters, such as nesting success. Bird populations may respond slowly to management, and it may require several years for birds to begin using an area or for increased rates of recruitment to result in detectable population increases. For birds that have been extirpated from an area, simply their presence in the area following predator fencing would demonstrate success.

For territorial species like Elepaio, spot mapping would provide an easily quantifiable measure of response to management, but the response might not occur right away because Elepaio have strong site fidelity and population increases probably would occur only through dispersal of young birds in nearby areas. In sites where Elepaio already occur but suffer high rates of nest predation, monitoring of nest success would reveal whether reproduction increases as a result of predator fencing, which hopefully would lead to larger population size eventually.

Waterbirds like Hawaiian Coots, Stilts, and Moorhen tend to move among sites more often and over longer distances, so spot mapping of the number of birds present might detect increases in the number of birds using an area more rapidly. As with Elepaio, monitoring of nest success would reveal whether reproduction increases as a result of predator fencing.

Population estimates from the Variable Circular Plot method often have relatively large confidence intervals that can obscure population trends. It therefore may require several years of data or a large number of sampling points in order to detect population changes. In addition, non-territorial birds may move in and out of a fenced area, possibly masking any local changes in density due to predator exclusion. It is possible to measure the effect of predator fences on bird populations, but it must be realized that detecting such patterns is not easy and may require several years of data. Nevertheless, collection of such data is valuable in the long-term and the sooner it begins, the sooner it will be possible to measure the long-term effects of predator fencing on bird abundance.

Artificial Nests

One method of obtaining information on predation rates more rapidly is through artificial nest experiments. Artificial nests have the advantages of sample sizes as large as desired, ability to adjust for confounding factors such as nest height, location, and density, and less time required to place artificial nests than to find real nests. However, the use of artificial nests has been criticized on several grounds, most importantly because the rates of predation on artificial and real nests may not be the same (King et al. 1999). Artificial nests lack incubating adults, begging nestlings, and fecal material, and therefore may provide fewer visual and olfactory cues to predators, making predation less likely (Petit et al. 1989, Haskell 1994). In contrast, predation on artificial nests may be higher if they are more conspicuous than real nests or if incubating adults are able to drive off predators (Wilson et al. 1998, King et al. 1999). Predation on real and artificial nests was similar in some previous studies (Yahner and DeLong 1992, VanderWerf 2001), but in others predation was higher on artificial nests (Storass 1988, Reitsma et al. 1990, Wilson et al. 1998, King et al. 1999). The use of Japanese Quail (*Coturnix japonica*) eggs in artificial nests has been criticized because they may be too large for some predators to break, possibly resulting in erroneously low estimates of predation (e.g., Roper 1992, Haskell 1995, DeGraaf and Maier 1996, but see Craig 1998). Despite these criticisms, if artificial nests are made as similar as possible to real nests, artificial nests are still a useful tool for examining relative predation rates in different areas or at different seasons, or for measuring a treatment effect (Major and Kendal 1996). For the purposes of this project, artificial nests are a useful and appropriate tool because the difference in predation rates inside and outside a fence or before and after predator exclusion is of primary interest. Another important advantage particularly relevant to this project is that artificial nests can be used to simulate predation on species that no longer occur in the area but for which restoration efforts are planned.

A previous study by VanderWerf (2001) used artificial nests placed in trees and on the ground to simulate predation rates on Oahu Elepaio nests and recently fledged juveniles before and after control of rodents using snap traps and bait stations. The same methods used can be used to measure reduction in nest predation rates on `Elepaio at Kahanahaiki on Oahu, on Hawaiian Stilts, Hawaiian Coots, and Hawaiian Moorhens at Niulii Ponds on Oahu, and on `Elepaio, `Amakihi, Palila, Nene, and Hawaiian Petrels at Pohakuloa Training Area on Hawai`i. The artificial nest methods below were adapted from VanderWerf (2001).

Each artificial nest experiment should consist of at least one treatment site located inside the fence and one control site located outside the fence. If sufficient resources are available, the experiment could be replicated by using multiple treatment and control sites. At each site, 20 artificial nests containing two eggs should be placed either in trees, in order to simulate predation on forest bird nests, or on the ground in order to simulate predation on ground-nesting species. VanderWerf (2001) used small wicker baskets lined with Spanish moss as artificial nests. Other types of baskets or other nest-shaped objects could be used as nests, but objects with strong or unnatural odors should not be used. VanderWerf (2001) placed artificial nests in cages with captive birds for several days prior to placement in the field to give them natural olfactory cues, and this should be done if possible. Each nest should contain two eggs. Japanese Quail eggs should be used for tree nests to simulate predation on forest birds, quail eggs or domestic chicken eggs can be used to simulate predation on larger ground-nesting birds. Height of nests and position of nests placed in trees should be similar to those of natural bird nests if possible. Placement of ground nests should also be as realistic as possible, such as in tall grass, within or under a clump of grass, or in a small cave or rocky overhang, and not out in the open. Nests should be separated by at least 30 meters, and more if possible, to maintain their independence and decrease the chance that a predator will learn to “trap line” multiple nests. Nest locations should not be flagged or directly marked in any way because the marks could serve as cues to predators. If necessary markers can be placed at a specified distance and bearing from the nest to help observers refind nests. The incubation period of many small Passerines is 14-16 days, so tree nests should be left in the field for approximately 15 days. Nests should be checked after 5, 10, and 15 days, or more often if possible, to obtain information on rates of predation, using a mirror-pole if necessary to look inside nests. Ground nests should also be left in the field for a period similar to the incubation period in the species of interest. Nests should be counted as depredated if the eggs are gone, broken, moved from the nest, or have scratches or tooth marks. Nest predation inside and outside the fence can be compared at 5, 10, and 15 day intervals using chi-squared tests. Below is an example of one way to report results graphically.

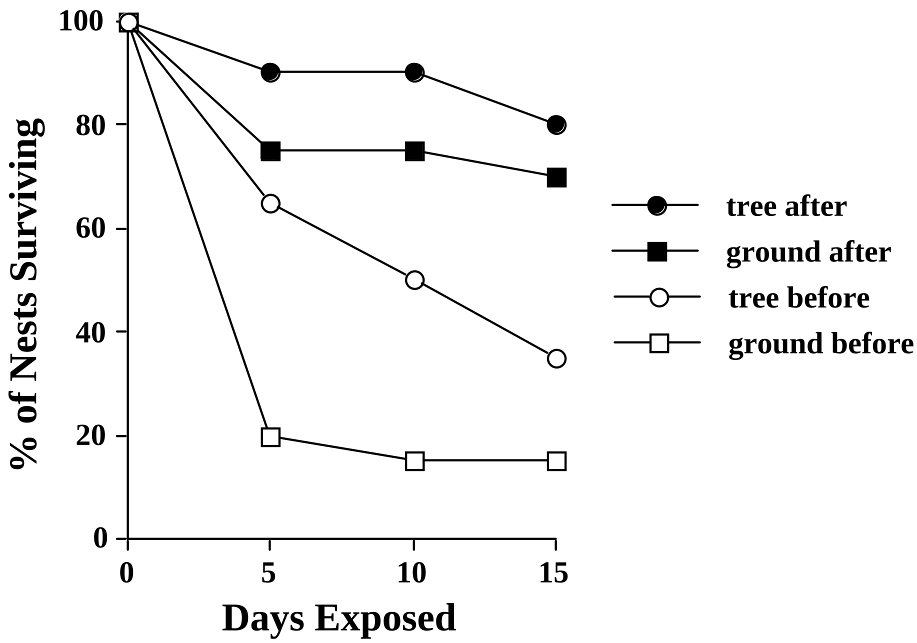


Figure 2. Example of one way to graphically present results of artificial nest experiments. From VanderWerf (2001).

INVERTEBRATE MONITORING

Invertebrates are a relatively inconspicuous but extremely important component of ecosystems. Changes in abundance, diversity, and species composition of the invertebrate fauna at a site may help to indicate improved ecosystem functioning. Because they are generally more numerous and have shorter generation times, invertebrates may show population responses to management more quickly than vertebrates. In New Zealand, abundance of beetles inside the Maungatautari predator exclosure increased 8% per month immediately after alien mammals were removed, and 50 species of beetles were collected that were unknown at the site previously (Watts 2007). A variety of methods are available for sampling different types of insects and other invertebrates.

Pit-fall Traps

For ground-dwelling species, pit fall traps are an effective method of sampling. Pit fall traps typically consist of a shallow (10cm) hole dug into the ground with a small container (typically a 10 cm diameter plastic cup) containing propylene glycol (anti-freeze) or some other preservative/killing agent into which insects fall. Pit fall traps are often placed at regular intervals along a transect, but can also be placed in patterns at specific distances from locations of particular interest, such as pest traps or protected plants. Low walls of garden edging or similar material can be placed along transects to increase catch rate by guiding invertebrates into pitfall traps. Effect of predator exclusion could be evaluated by comparing numbers of invertebrates captured inside versus outside fences, or before and after fence construction, or both. In either case, each treatment and control should consist of a minimum of 10 pit fall traps, and more if possible. Invertebrate abundance could be measured as total number of individuals and/or biomass captured per trap-night or per trap-hour. Invertebrates captured should be identified to species if possible to determine whether diversity is affected by predator exclusion and if native species in particular are increasing in abundance. Abundance of invertebrates in different feeding guilds (herbivores, detritivores, nectarivores, parasites, predators, etc.) can be examined to look for shifts in ecosystem functioning.

Malaise Traps

Malaise traps are suitable for flying invertebrates, and consist of a sheet suspended in the air from which insects are collected either by hand with an aspirator or in a jar suspended under a second sheet arranged in a funnel fashion. Placement of lights, especially black lights, next to the sheet can be used to attract many nocturnal species and increase capture rates. As with pit fall traps, invertebrate abundance could be measured as total number of individuals and/or biomass captured per trap-night or per trap-hour, and invertebrates should be identified to species if possible to determine overall diversity, abundance of native species, and representation of different feeding guilds. Malaise traps should be deployed on at least three nights per site, and trapping should be conducted at different seasons to improve representation. Activity of flying insects can vary greatly depending on temperature, rainfall, wind, and other weather conditions, so trapping should be conducted simultaneously on the same nights at treatment and control sites.

Burlese Funnels

Burlese funnels are most effective for species that inhabit leaf litter and soil, and consist of a funnel with a light bulb suspended above it and a collecting jar underneath. Many soil and litter invertebrates will attempt to escape from the heat and light generated by the light bulb by burrowing deeper into the soil, eventually reaching the bottom of the funnel and falling into the collecting jar. At least three treatment and three control sites should be sampled, and at least three samples collected from each treatment and control site to account for local variation (a total of at least nine treatment and control samples). Treatment and control sites should be matched as closely as possible for soil or litter type, moisture content, aspect (north vs. south-facing, etc), shading, and other potentially confounding factors. Invertebrate abundance could be measured as total number of individuals and/or biomass per dry gram of leaf litter or per liter of soil, and invertebrates should be identified to species if possible to determine overall diversity, abundance of native species, and representation of different feeding guilds.

Hawaiian Picture-winged Flies

Some invertebrate species may require more specialized monitoring techniques. Hawaiian picture-winged flies can be attracted with baits made from fermenting mushrooms and other substances and collected for observation and identification. It should be noted that several species of picture-winged flies were recently listed as endangered (USFWS 2006). These and other rare species of Hawaiian *Drosophila* should not be collected using lethal methods because their populations may be very small and it may be difficult to determine their identity prior to collection.

SNAILS MONITORING

Many species of native Hawaiian snails are very rare and must not be collected or monitored using lethal means (Hadfield 1986, Hadfield et al. 1993). All species in the genus *Achatinella* are listed as endangered (USFWS 1992) and several other species are very rare but are not listed under the ESA. A detailed study of the movements and demography of *A. mustelina* and *A. sowerbyana* is currently being conducted at two sites on Oahu by University of Hawaii graduate student Kevin Hall. This study involves visually searching for snails on vegetation in a grid of 5m by 5m quadrats, marking each snail with a unique alphanumeric label glued on its shell, measuring it, and releasing it unharmed at the site of capture. Repeated visits are made to search for and recapture marked snails in order to measure survival over time, recapture probability, movements, and local population size. Estimates of survival, recapture probability, and local population size can be calculated with program MARK (White and Burnham 1999). Information on size distribution of snails captured can be used to measure reproduction and recruitment. Though labor intensive, this type of detailed study will provide extremely valuable information on abundance and demography of these snail populations, and would provide a powerful method of measuring the effect of predator exclusion on survival and population size.

Predator fences should exclude rats, which are one of the primary predators on *Achatinella* and other native snails, but whether they will also exclude the predatory snail *Euglandina rosea*, the other major predator on *Achatinella*, will depend on whether an effective snail exclusion device can be perfected and whether *Euglandina* can be eradicated within the exclosure. The Army Natural Resources staff is currently conducting *Euglandina* exclusion trials in the laboratory, and one design that employs strips of copper sheeting cut into spikes and mounted vertically seems promising. Methods for eradicating *Euglandina* from exclosures need to be developed. Hand-picking may help reduce the abundance of *Euglandina*, but additional methods will likely be necessary to get the last few individuals, possibly including poison bait or attractants and traps.

Less intensive forms of monitoring for *Achatinella* have been conducted in the past, including timed searches for snails to determine relative abundance, and marking the shell with a colored dot to calculate simple estimates of local population size, but without information on movements provided by uniquely marked individuals less confidence can be placed on the resulting estimates. Data on size distribution can provide information on reproduction and recruitment.

NATIVE PLANT MONITORING

Endangered plants occur at all of the sites discussed in this report and comprise the bulk of listed species on DoD lands and at most other locations in Hawaii. The effects on native plants from browsing and trampling by ungulates and gnawing and seed destruction by predators is ubiquitous and very serious in many areas. Monitoring of plant populations will thus comprise the most important means of gauging effectiveness of predator fencing and eradication at many sites.

Plant monitoring need not, and should not, be limited to endangered species; benefits to more common plant species that form the bulk of native habitats should also be monitored, using each of the techniques described below. Improved status of dominant plant species can help to demonstrate restored ecosystem integrity.

Non-native slugs can also cause serious damage to many native plants, but methods of excluding and eradicating slugs have not been perfected. Methods developed for exclusion of the predatory snail *Euglandina rosea* might also be effective at excluding slugs, but this will require testing.

Wild Plants

Monitoring of wild plants for survival, amount of gnawing, browsing, seed predation, and other damage will be one important method of monitoring the efficacy of predator fencing and eradication, particularly at sites where baseline data on status of endangered plants is available for comparison. Natural recruitment of wild plants should also be watched for and measured.

Outplanting

In addition, outplanting can be used to increase sample sizes in comparisons of the effectiveness of fencing and for species that no longer occur at a site. Endangered plants have been outplanted at several DoD sites, and comparison of outplanting results before and after fencing or inside and outside the fence would be an important method of demonstrating the effect of predator and ungulate exclusion.

Seed and Fruit Predation Experiments

A variety of experimental approaches have been used to measure predation and dispersal of seeds and fruit by native and alien predators. Most approaches involve placing a known number of seeds or fruits in a location where they are accessible to predators of interest, and then recording how many seeds or fruits are removed at various time intervals. This technique can be used to compare seed predation under a variety of environmental conditions and management regimes, such as before and after construction of a predator fence or inside and outside the fence. Multiple species can be tested with separate experiments, or species can be tested simultaneously if preference for different seed or fruit species is also of interest. If possible, the experiment should be replicated in at least two locations within the study area and/or at different seasons.

Another technique that can be added to seed predation experiments to provide additional information is tracking of the locations to where seeds are removed by presumed predators. Knowledge of seed dispersal distance, location, and condition can provide information about the identity of seed predators, the area over which predators search, and the degree of damage caused. The two most common methods of seed tracking are attachment of a spool of fine line, such as sewing thread or hip chain, and insertion of a small magnet that can be located with a magnetic detector. Takahashi et al. (2007) provide a recent example that used both methods of seed tracking, and from which the following methods were adapted.

A known number of fruits or seeds, 100 if possible or else as many as practicable, should be collected from each plant species to be included in the experiment. Seeds should be obtained from the study area if possible, or else from another source of the desired species. A small ferrite (iron) magnet (approximately 3.0 mm in diameter × 6 mm in length, 0.3 g) should be inserted into each fruit or seed. For species with hard seeds or fruits it may be necessary to glue the magnet to the surface or drill a hole slightly smaller than the magnet in order to insert it. Alternatively, the free end of a spool of fine line can be glued to each seed or fruit. The length of the line required may depend on the size and behavior of the predators likely to remove the study subjects, but in the case of rodents should be at least 50 meters, and longer if possible. The fruits or seeds with a magnet or line should then be placed in a location where they are accessible to the predators of interest. If desired, larger predators can be excluded with wire mesh of the appropriate size. If multiple species are being tested simultaneously it may be desirable to use different colored line for each species or to label each spool so the fate of seeds of different species can be determined. Seeds should be checked daily if possible, and the number of seeds remaining should be recorded. The lines to any removed seeds should be followed to their end, and magnet-inserted seeds should be searched for. Takahashi et al. (2007) searched their study area with a magnetic locator (GA-52Cx, Schonstedt Instrument Company, Kearneysville, WV, USA) to find seeds with magnets. The location, length of spooled line, and straight-line distance of each seed removed should be recorded and the microhabitat at the location should be described. The condition of the seed or fruit (damage, viability) should also be recorded. More detail and additional relevant references can be found in Takahashi et al. (2007).

SITE-SPECIFIC MONITORING RECOMMENDATIONS

Pohakuloa Training Area *Solanum incompletum* site, Hawaii (Army)

This site is not currently enclosed in an ungulate fence, but ungulate fencing is underway and may be finished by 2010. Rats are being controlled in the immediate vicinity of *Solanum* plants using diphacinone in bait stations, but the efficacy is not well known. The proposed fence includes three endangered plant species: *Solanum incompletum* (four individuals), *Silene lanceolata* (approximately 21 individuals), and *Zanthoxylum hawaiiense* (five individuals). Three of four *Solanum* plants in the small existing exclosure were recently killed. The last live plant has gnaw marks indicative of rodents, probably rats. Sheep droppings were abundant in the area, and a few droppings were visible on top of rocks inside the exclosure. Several rocks inside and outside the exclosure had been worn by ungulates hooves, presumably as they jumped over the fence. In addition to monitoring wild individuals of endangered plant species, the predator fence would provide a suitable location in which to outplant all of the endangered plants from PTA, including several species not currently found in the immediate area, thereby advancing conservation of numerous plant species. The only native bird that is regularly present in the area is the Hawaii Amakihi (*Hemignathus virens*), and it is common. Other native bird species that have been observed nearby include Apapane (*Himatione sanguinea*), Nene (*Branta sandvicensis*), and Pueo (*Asio flammeus*). Hawaii Elepaio (*Chasiempis sandwichensis*) were present in the area until the early 1990s.

Since the bird species of greatest interest do not currently occur at the site, artificial nest experiments will be needed to investigate the effect of predator fencing on nest success. Sufficient numbers of Hawaii Amakihi may occur at the site to collect information on predation of natural nests, but the time required to locate natural nests would be substantial, and the use of artificial nests would probably be more cost-effective. Predation on nests of forest birds like Amakihi, Elepaio, and Palila could be simulated with nests placed in trees, and predation on ground-nesting birds including Nene and Hawaiian Petrel could be simulated with artificial nests place on the ground. For details on artificial nest methods, see the section above on artificial nest experiments.

For plants, survival and amount of gnawing and browsing of individuals of the three endangered plants that currently occur at the site can be monitored and compared with baseline data already collected. Natural recruitment of these three species should also be watched for and measured. Benefits to more common plant species, such as mamane, sandalwood, and akoko, should also be monitored by measuring seed predation, germination rate, seedling survival, and amount of gnawing and browsing inside and outside the predator fence. This could be accomplished by establishing a grid of plots systematically across the proposed fence area and making quarterly measurements of extent of gnawing and browsing, numbers of damaged and undamaged seeds or fruit, and any seedlings. The size and shape of plots is difficult to determine without information on existing plant densities, but plots should be large enough so that most plots contain several individuals of each species of interest, perhaps 5x5 meters. Distance between plots should be such that there are at least 20 plots within the proposed fence area. Plots should be distributed in a grid pattern at regular distances throughout the proposed fence area to ensure adequate coverage of all sections.

In addition, most of the endangered plant species in the area have been grown in the greenhouse at PTA, but survival during outplantings has been poor. Comparison of outplanting results within the predator fence would provide more information about the effect of predator exclusion. If sufficient seeds and/or seedlings are available, comparison of simultaneous outplanting results inside and outside the predator fence would be an inferentially superior method of demonstrating the effect of predator and ungulate exclusion. However, some, perhaps all, seeds and seedlings placed outside the fence would be killed, so if such an experiment was done with an endangered species it might require an endangered species permit. Since survival during previous outplantings has been poor, that is what is already happening anyway, so it could be argued that continuing the same practice in an experimental manner should not be problematic.

There may be a time window during which this site will provide an opportunity to make a series of comparisons that could separate the impacts to plants from ungulates and predators. Depending on the order in which fences are completed, data may be collected in the absence of any fencing, within an ungulate fence but outside a predator fence, and within a predator fence that excludes both ungulates and predators. Comparisons of seed predation rates, germination rates, seedling survival rates, and amount of gnawing and browsing under these different conditions would make it possible to separate the effects on plants from browsing and trampling by ungulates and those from gnawing and seed predation by rodents. Such a project would make an excellent graduate thesis or dissertation. The fencing schedule should be watched in order to determine if such a time window will exist.

Table 6. Summary of biological monitoring recommendations for Pohakuloa Training Area *Solanum incompletum* site.

Taxon	Monitoring Method	Recommendations
Birds	Spot-mapping	Not applicable. No suitable species currently present.
	Variable circular plot	Appropriate, but may not detect changes for several years. Establish at least 15 sampling points inside proposed fence area and 15 outside; survey in March at least one year before fence construction, then annually afterward.
	Artificial nest experiments	Best method for detecting decreases in predation. At least 20 artificial nests inside fence and 20 outside. Use tree nests to simulate predation on Elepaio and Amakihi, ground nests to simulate predation on Nene and Hawaiian Petrel.
Invertebrates	Pit-fall traps	Appropriate. 10 traps inside fence and 10 outside. May be difficult in some areas due to rocky substrate.
	Malaise traps	Appropriate. At least 3 nights of sampling at different seasons, with paired traps inside and outside fence.
	Burlese funnels	May be difficult in some areas due to rocky substrate.
	Picture-winged flies	Not applicable.
Snails		Not applicable.
Plants	Wild plants	Monitor number, status, damage, and recruitment of existing *Solanum incompletum*, *Silene lanceolata*, and *Zanthoxylum hawaiiense* before and after fencing. Establish grid of plots and collect quarterly data on plant abundance, gnawing and browsing damage, seed predation, and recruitment of mamane, akoko, and sandalwood to determine ecosystem integrity.
	Outplanting	All species available from greenhouse at PTA. Compare results with previous outplantings of same species before fence. Could outplant inside and outside fence.
	Seed/fruit predation experiments	Yes, could be done with *Solanum incompletum* and dominant species important to habitat, including mamane, sandalwood.

Pohakuloa Training Area *Zanthoxylum hawaiiense* site, Hawaii (Army)

This site is similar in most respects to the *Solanum* site discussed above except for the following differences: this site contains a larger number of *Zanthoxylum hawaiiense* but does not currently contain *Solanum incompletum*; the substrate consists of more pahoehoe than aa, which will be more difficult to prepare and may contain more lava tubes that could be more difficult to seal against rodents; it is directly adjacent to a good roadway and an existing ungulate fence.

Monitoring recommendations for this site are also similar to those for the *Solanum* site with the following differences: Monitoring of existing *Zanthoxylum* trees may provide sufficient information for that species because more wild individuals exist; outplanting of other species may be required because the site currently contains only two endangered species.

Kahanahaiki, Makua Military Reservation, Oahu (Army)

This site in the northern Waianae Montains supports diverse native mesic forest and several endangered plant species, including *Schidea obovata, Cenchrus agrimonioides, Schiedea nuttallii,* and *Cyanea superba,* a large and important population of the endangered tree snail *Achatinella mustelina.* A single female of the endangered Oahu Elepaio (*Chasiempis sandwichensis* ssp. *ibidis*) occupies a territory just outside the preferred fencing site. The Oahu Amakihi (*Hemignathus flavus*) has been observed occasionally at the site but is rare. Apapane (*Himatione sanguinea*) are uncommon in the area. There has been extensive monitoring of plants, snails, birds, and pest species at this site since 1996. Pest species present in the area are *Rattus rattus, Rattus exulans, Mus musculus, Felis catus,* small Indian mongoose (*Herpestes javanicus*), and the predatory snail *Euglandina rosea.* Kahanahaiki is already protected from feral ungulates by a hogwire mesh fence. Because the site has been managed and monitored intensively since 1996, it provides an excellent opportunity to compare the costs of predator fencing with methods currently in use, and also to evaluate improvements in resource protection provided by predator fencing. It is also large enough to begin examining ecosystem effects of predator fencing such as pollination rates, seed dispersal rates, floristic diversity, and abundance and diversity of native arthropods.

Baseline data on nesting success of Elepaio in Kahanahaiki when rodents, cats, and mongoose were controlled is available for comparison from 1996-2005. Only a single breeding pair of Elepaio was present during this time, so only a limited amount of information is available, though this could be supplemented with similar information from nearby areas, including elsewhere in Makua Valley and in adjacent Makaha Valley. Because there is limited baseline data and because Kahanahaiki currently contains only a single female Elepaio, artificial nest experiments will be needed to help demonstrate the efficacy of predator fencing at reducing nest predation. The site is large enough that it eventually could provide sufficient habitat for a small population of Elepaio consisting of approximately 10 breeding pairs (VanderWerf and Smith 2002). If the site is fenced and predators are eradicated, it would be an excellent spot in which to reintroduce Elepaio, using either rear and release techniques or release of captive bred birds. Whether nest predation has been reduced could be tested prior to any reintroductions by conducting an artificial nest experiment with replicates inside and outside the fence.

A demographic study of the endangered native tree snail *Achatinella mustelina* is currently being conducted in Kahanahaiki by University of Hawaii graduate student Kevin Hall, and this study will provide excellent baseline information on the status of the species prior to predator fencing and under current management conditions. This type of detailed study is labor intensive but should be continued using the same methods after construction of a predator fence. Snails were also marked and counted in study plots in the past, but the methods have been less consistent and less information has been recorded. Two snail exclosures have been attempted at Kahanahaiki, using a salt barrier, copper flashing, and electrification to exclude *Euglandina*. One is known not to have been effective due to design flaws and failure to clear overhanging vegetation. Effectiveness of the other exclosure is less well known and inconsistent maintenance may have compromised its effectiveness at times. It is possible that a standard predator fence could be constructed first, using existing technology that would exclude rats, and that it could be retro-fitted with a snail excluding device at a later date. Comparison of *Achatinella* demography before rat exclusion, after rat exclusion but before *Euglandina* exclusion, and after both rats and *Euglandina* have been excluded would provide a valuable means of evaluating the relative impacts of these two predators.

Hundreds of plants of several species have been outplanted in Kahanahaiki, including several endangered species, and extensive baseline data exists on survival of wild plants and results of outplantings. Improvements in plant protection following construction of a predator fence can be measured in part by continuing the existing monitoring and comparing results with baseline data before the fence. Additional information would help to supplement existing monitoring, such as comparison of outplanting success, seed predation, and fruit predation inside and outside the fence. Benefits to more common native plant species, such as koa, lama, and *Pisonia*, should also be monitored by measuring seed predation, germination rate, seedling survival, and amount of gnawing and browsing inside and outside the predator fence. This could be accomplished by establishing a grid of plots systematically across the proposed fence area and making quarterly measurements of extent of gnawing and browsing, numbers of damaged and undamaged seeds or fruit, and any seedlings. The size and shape of plots is difficult to determine without information on existing plant densities, but plots should be large enough so that most plots contain several individuals of each species of interest, perhaps 5x5 meters. Distance between plots should be such that there are at least 20 plots within the proposed fence area. Plots should be distributed in a grid pattern at regular distances throughout the proposed fence area to ensure adequate coverage of all sections. Seed and fruit predation experiments could be conducted with several species, such as Cyanea superba, using treatment and control sites located inside and outside the fence and would provide a powerful method of demonstrating the improved protection provided by predator fencing.

Table 7. Summary of biological monitoring recommendations for Kahanahaiki.

Taxon	Monitoring Method	Recommendations
Birds	Spot-mapping	Currently done for Oahu Elepaio and should be continued, but only a single bird remains.
	Variable circular plot	Not useful yet. Bird species of interest are currently too rare to be adequately sampled with this method. Might be useful in future if any native forest birds increase in abundance.
	Artificial nest experiments	Best method for detecting decreases in predation. At least 20 artificial nests inside fence and 20 outside. Use tree nests to simulate predation on Elepaio.
Invertebrates	Pit-fall traps	Appropriate. At least 10 traps inside fence and 10 outside. Should choose areas to reflect diversity of substrate in area.
	Malaise traps	Appropriate. At least 3 nights of sampling at different seasons, with paired traps inside and outside fence.
	Burlese funnels	Appropriate. At least 3 sets of samples from 3 areas inside and outside fence.
	Picture-winged flies	Possible. The presence of these species in the area should be investigated before any lethal collecting methods are used.
Snails	Mark-recapture	Very important. Site contains large population of *Achatinella mustelina*. Intensive demographic study currently being conducted, should be continued or repeated after fencing. If predator fence retrofitted at later date with device to exclude predatory snail *Euglandina rosea* there may be opportunity to compare impact of predation by rodents vs. *Euglandina*.
Plants	Wild plants	Extensive baseline data available on several listed species. Continue monitoring using same methods. Establish plots to monitor density, damage, seed predation, and recruitment of dominant species in habitat, such as koa and *Pisonia*.
	Outplanting	Extensive previous outplantings of several listed species, such as *Cyanea superba*. Compare results with previous outplantings of same species before fence, outplant additional species available from greenhouse.
	Seed/fruit predation experiments	Yes, could be done with several species, including *Cyanea superba* and dominant species such as koa, lama, and Pisonia.

Niulii Ponds, Oahu (Navy)

Niulii Ponds are a small, locally important wetland used by endangered Hawaiian Stilts, Hawaiian Coots, Hawaiian Moorhen, and the Pueo or Hawaiian Short-eared Owl. Black-crowned Night-herons and koloa x Mallard hybrids also use the wetland. Bird surveys have been conducted by Navy Natural Resource personnel every two weeks since 2003. The site also supports two small populations of the endangered plant *Abutilon menziesii*, a single individual located about 100m east of the wetland and another population of 10 individuals about 200m south of the wetland. The perimeter of the ponds is fenced with a 12 year old four foot high chainlink fence and locked gates to keep out dogs, feral ungulates and people. The fence is in good shape with little corrosion, but has several holes, and dogs regularly jump or dig under the fence making it essentially ineffective. Predator control for cats, mongoose, dogs, and Barn Owls occurs every other day (no rat control) by USDA Wildlife Services.

Because waterbird numbers have been monitored regularly for several years there is excellent baseline data available for comparison after fence construction and predator eradication. The same methods can be used to continue monitoring waterbird numbers. If not already being done, extra effort should be made to search for and determine the outcome of all nesting attempts by waterbirds at the site, and an artificial nest experiment

Table 8. Summary of biological monitoring recommendations for Niulii Ponds.

Taxon	Monitoring Method	Recommendations
Birds	Spot-mapping	Best method for obtaining population data on waterbirds using the wetlands. Currently being done, should be continued using same methods. Nests of each species should also be located and their success monitored.
	Variable circular plot	Not appropriate for the bird species present at this site.
	Artificial nest experiments	Would be useful for documenting increases in nest success, especially if the number of natural nests is too small to yield conclusive results. At least 20 artificial nests on the ground, once before and once after fence construction.
Invertebrates	Pit-fall traps	Not necessary. No native invertebrates known from this site.
	Malaise traps	Not necessary. No native invertebrates known from this site.
	Burlese funnels	Not necessary. No native invertebrates known from this site.
	Picture-winged flies	Not necessary. No native invertebrates known from this site.
Snails		Not necessary. No native snails known from this site.
Plants	Wild plants	Monitor number, status, damage, and recruitment of existing *Abutilon menziesii.*
	Outplanting	Could outplant additional *Abutilon menziesii* if a source is available.
	Seed/fruit predation experiments	Could be done with *Abutilon menziesii*.

could be conducted to simulate predation on waterbird nests in order to augment information on predation rates. Monitoring of *Abutilon* could consist of counting the number of mature plants and recording their condition, and counting of any seedlings. Seed predation experiments could involve placing a known number of *Abutilon* seeds inside and outside the fence and monitoring how many are removed or damaged over time. Outplanting of additional Abutilon would be desirable to increase the sample size of plants available for monitoring.

Waieli Bench, Oahu (Army)

This small site on the eastern slope of the central Waianae Mountains contains a dense concentration of the endangered tree snail *Achatinella mustelina*. It also supports other extremely rare mollusks that that are not listed, including *Cookeconcha* sp., *Helicinid* sp., *Amastra micans*, and *Laminella sanguinea.* Several species of critically endangered plants have been outplanted at the site, including *Cyanea grimesiana subsp. obatae, Cyanea pinnatifida, Delissea subcordata, Phyllostegia hirsuta, Phyllostegia mollis, Plantago princeps var. princeps, Schiedea hookeri, Solanum sandwicense,* and *Urera kaalae.* The primary pest species at the site are *Rattus rattus, Rattus exulans, Mus musculus* and the predatory snail *Euglandina rosea.* Rats are controlled through baiting. Feral cats and mongoose are probably present, but are not known to impact snails or plants and are not currently managed. Because feral cats are a threat primarily to birds and the area is too small to be of significant benefit to forest birds, Xcluder suggested that a fence at this site need only be 1.3 meters tall, the minimum height needed to exclude rats, rather than the two-meter height needed to exclude cats, which would result in substantial cost savings in materials.

Because the site has been intensively managed and monitored by The Nature Conservancy and more recently by the Army, it would provide a good opportunity to compare the costs and benefits of predator fencing versus other management methods. However, because the technology has not yet been perfected to exclude *Euglandina* and eradicate it from a fenced area, a predator fence at this site would have to be viewed as experimental.

Snails are known to be more abundant at this site than at Kahanahaiki, but status of snail populations, the severity of impacts by rodents and *Euglandina*, and the efficacy of current management at Waieli Bench are unknown. It would be desirable to obtain more information about snail populations at Waieli to allow more extensive comparisons after a predator fence was constructed. Information such as approximate population size, rates of predation, and use of different plant species and substrates would aid future comparisons. Conducting a detailed demographic study like that being done by Kevin Hall at Kahanahaiki would provide extremely valuable information about the status of the population and the nature of any threats by which it may be impacted.

Table 9. Summary of biological monitoring recommendations for Waieli Bench.

Taxon	Monitoring Method	Recommendations
Birds	Spot-mapping	Not necessary. The site is too small to support significant bird populations.
	Variable circular plot	Not necessary. The site is too small to support significant bird populations.
	Artificial nest experiments	Not necessary. The site is too small to support significant bird populations.
Invertebrates	Pit-fall traps	Appropriate. At least 10 traps inside fence and 10 outside. Should choose areas to reflect diversity of substrate in area.
	Malaise traps	Appropriate. At least 3 nights of sampling at different seasons, with paired traps inside and outside fence.
	Burlese funnels	Appropriate. At least 3 sets of samples from 3 areas inside and outside fence.
	Picture-winged flies	Possible. The presence of these species in the area should be investigated before any lethal collecting methods are used.
Snails	Mark-recapture	Very important. Site contains large population of *Achatinella mustelina* and several other rare snail species. Ideally should use same intensive methods currently being used for *A. mustelina* at Kahanahaiki, before and after fence construction. If fence divides some populations could compare inside vs. outside.
Plants	Wild plants	Extensive baseline data available on several listed species. Continue monitoring using same methods. Establish plots to monitor density, damage, seed predation, and recruitment of dominant species in habitat.
	Outplanting	Extensive previous outplantings of several listed species. Compare results with previous outplantings of same species before fence, outplant additional species available from greenhouse.
	Seed/fruit predation experiments	Yes, could be done with several species, including *Cyanea superba* and dominant species such as lama and Pisonia.

As with Kahanahaiki, extensive baseline data exists on survival of outplantings of several species that can be used for comparison. For its size, Waieli contains more outplantings than Kahanahaiki so temporal comparison of survival and recruitment before and after construction of a predator fence could be relied on more heavily to demonstrate improvements in resource protection. Experiments on seed and fruit predation with treatment and control sites inside and outside the fence would help to supplement information from outplantings.

COST BENEFIT ANALYSIS

Analyzing the costs of building predator proof fences is relatively straight forward and this report has presented these costs in detail for four high priority demonstration sites in Hawaii. Assessing how these costs compare to alternative techniques for addressing similar issues is more problematic. The main techniques for mitigating impacts of damaging invasive species are eradication, control or fencing. The simplest method to compare these methods is a direct cost estimate where costs per year are added cumulatively. More complex costing models can be developed that take into account the biological impacts of the different methods. These could include increase in lambda (growth rate) for the protected populations, value of re-introduced animals into a protected area, value of area as a source population, costs of ongoing control in terms of non-target impacts and social concerns (animal welfare of one time action vs. ongoing control), etc.

If eradication is an option it will almost always be the preferred and most cost effective alternative. This is because eradication is a complete solution where none of the targeted damaging invasive species remain and it is permanent in time so that natural restoration can occur and natural ecological processes can resume in function. Biologically, eradication of pests from an area almost always provides greater conservation benefits to threatened wildlife than control since even at low densities many pest species still have a significant impact (Long and Robley, 2004). Economically eradication is a one time expense so over time control will eventually eclipse eradication in cost and this break even point will be reached even sooner if costs are attributed to the biological benefits of eradication over control.

In some situations eradication will not be an option, especially on very large islands with large human populations and where the threat of reintroduction is high and effective quarantine is not possible. In these situations the only options are control or predator-proof fencing a subset of the island’s habitat. Over time, predator-proof fencing is usually more cost effective than invasive species control methods and provides greater conservation benefits (Clapperton and Day 2001). A simple cost benefit analysis done for a proposed predator proof fence at Kaena Point on Oahu, Hawaii estimated a maximum cost of $168,000 to build a fence, $64,000 to remove all introduced predators from within the fenced area and $18,000 a year to maintain the fence over time (Xcluder Pest Proof Fencing Co 2006, figure 2). Currently the annual budget to conduct predator-control activities is $32,000, which means that a fence of this nature will break-even financially after 9 years. If a more complex costing model was used, incorporating the value of the added ecological benefit of fencing, the pay off would be significantly sooner.

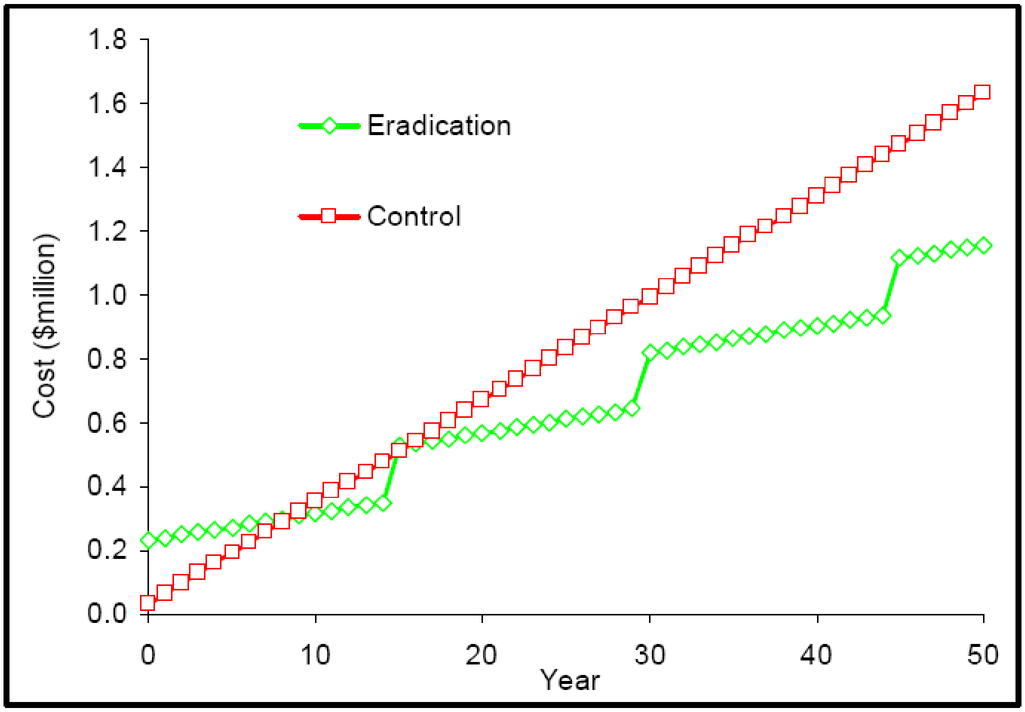


Figure 2. Simple cost benefit analysis of a predator proof fence proposed for Ka`ena Point, Hawaii. The large jumps in the green line represent fence replacement costs every 15 years, which is a conservative estimate as the fence may last 25 years before replacement is needed. This cost estimate does not take into account the increased biological benefit of exclusion fencing or social benefits associated with stopping controversial control techniques.

Clapperton and Day (2001) provide a detailed analysis of cost benefits for pest exclusion fencing in comparison to control efforts for stoat (Mustelidae) in New Zealand. They completed a traditional cost benefit analysis without considering costs associated with biological benefits or social issues. They found that in fences of 5000 ha or more the cumulative cost of control would exceed that of building and maintaining a fence in as few as four years. For areas between 100 and 1000 ha fencing can be a cost effective method if a cost efficient fence can be built- i.e. few stream crossings or gates and good access for building and maintenance. If these calculations were to include costs for biological benefits or social issues the fencing would become cost effective for even smaller areas and the break even point would be reached sooner.

Conducting cost benefit analyses for projects in Hawaii is more problematical because cost estimates of pest control are not as well established as in New Zealand. In addition, many of the techniques New Zealand used for multi-species pest control are not legal in the US thereby necessitating much more costly pest control operations in the US. For example, the estimated costs for multi-species control at the Ka'ena Point reserve, Hawaii is ~

\$1,300/ ha yr^{-1} (24 ha at a cost of \$32,000 yr^{-1}), whereas costs in New Zealand are estimated at ~ \$100-150 per ha (Clapperton and Day 2001). Part of this difference is a higher labor cost which also translates into higher fence costs in the US.

Nevertheless, we believe that a simple cost benefit analysis comparing actual costs of building a fence in the US compared to actual costs of multi-species pest control will provide dramatic cost benefits (i.e. break even in 5 to 6 years) to projects over 5,000 ha in size. Using the very high cost/ha of pest control from Ka'ena Point even very small fences would become cost effective.

One way to increase the cost benefit ratio in favor of predator proof fencing would be to retrofit some of the many existing ungulate fences within Hawaii to serve as predator proof fences. The new fence being built at Pohakaloa Training Area was examined and it was determined that the fence could be retrofitted to meet necessary specifications. This is possible because this fence is being built to a very high standard and to a height (2 m) sufficient for mouflon. However, even in the very short area of fence examined there were areas identified where considerable alterations would be needed because the fence passed by rock outcrops or went over steep areas that would require flattening to maintain efficacy. Ideally, if retrofitting of existing ungulate fencing is a goal, the fence should be designed in advance so that certain specifications are maintained. Retrofitting of traditional pig fencing or other fencing less than 1.2 m in height, is unlikely to be cost effective.

Although not a traditional cost benefit analysis in the monetary sense, it is also important to assess the cost of building a predator proof fence in terms of habitat disturbance and loss. A predator proof fence requires a 4 to 5 meter wide clearing to keep invasive mammals from breaching the fence. Without this clearing, invasive animals can use vegetation as a platform to jump or climb over the fence. In locations where high quality native forest is extremely limited, such as in most of Hawaii, it is recognized that there will be significant opposition to the clearing of this forest to build a fence. Ideally a fence line would utilize clearings, edges and other low quality habitat. However, it is likely that almost any predator proof fence would require the clearing of some native forest to create an effective barrier. Given that invasive mammals are among the greatest threat to Hawaiian forests it can be expected that excluding them from areas will result in dramatic recovery of the protected habitat. The proposed demonstration fences are designed to help measure these impacts. With those data it is expected that land managers in Hawaii can make informed decisions as to whether the cost of clearing a small area to build a fence is offset by the expected benefits to the large area of forest inside the fenced area.

Developing these cost benefit analyses is beyond the scope of this report, primarily because the data are not available to build a reasonable costing model. However, one goal of the proposed biological monitoring inside the test fences would be to provide some of the data necessary to develop these models. Incorporating a value for the increase in rare species could significantly change the cost benefit analysis in favor of fencing.

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LIST OF APPENDICES

Organizational Meeting for Legacy Predator Fencing on DoD Lands
May 1, 2007
10:00 am – 12:00 pm, The Federal Building, Honolulu

Meeting Minutes

1. **Introductions and sign in sheet**

Name	Agency	E-mail
Lindsay Young	University of Hawaii	lindsayc@hawaii.edu
Brad Keitt	Island Conservation	brad.keitt@islandconservation.org
Eric VanderWerf	☺	ewerf@hawaii.rr.com
Craig Rowland	USFWS	Craig_rowland@fws.gov
Aaron Hebshi	Air Force	Aaron.hebshi.ctr@hickam.af.mil
Vanessa Pepi	Navy	Vanessa.pepi@navy.mil
Christine Volinski	MCBH	Christine.volinski.ctr@usmc.mil
Lane Bookless	MCBH	Lance.bookless@usmc.mil
Julie Rivers	NAVFAC Pac	Julie.rivers@navy.mil
Stephen Mosher	Army	Stephen.m.mosher@us.army.mil
Aaron Nadig	USFWS	Aaron_nadig@fws.gov
Michelle Mansker	Army	Michelle.mansker@us.army.mil
Kapua Kawelo	Army	kawelok@schofield.army.mil
Joby Rohrer	Army	rohrerjl@schofield.army.mil
Lanky Morrill	National Guard	Lanky..morrill@us.army.mil
Karl Buermeyer	USFWS	Karl_buermeyer@fws.gov
Jeff Burgett	USFWS	Jeff_burgett@fws.gov

2. **Project background and summary- Brad Keitt**
   Island Conservation received a legacy grant from DoD to prioritize sites within Hawaii DoD land holdings that would be candidates for predator proof fencing. The prioritization will be done by Island Conservation with assistance from Eric VanderWerf and Lindsay Young, using a 7 step process:
   i. Review of fence projects worldwide
   ii. Data collection for suggested sites in Hawaii
   iii. Prioritization of Hawaiian DoD installation sites for conservation
   iv. Site visits for ground truthing and further assessment (5-10 sites, striving to include 1 or 2 sites from each of Army, Navy, AF, USMC and National Guard).
   v. Development of plans for construction and monitoring, including cost analysis
   vi. Outlining of NEPA requirements for fence construction
   vii. Development of implementation plans for priority sites with detailed budgets (~4 sites). All branches of the military will have at least 2 sites suggested for the initial prioritization process and we will strive to visit 1 or 2 sites from each branch. Final implementation plans will be based on the prioritization process and may not necessarily represent each branch. Prioritization

deliverables are at the end of Jan 2008, no funding for implementation is guaranteed.

Implementation plans for the top 4 sites will include:

- Budgets for fence construction and maintenance
- Detailed descriptions of fence locations
- Detailed plans and budgets for monitoring the biological impacts of the fences, with the goal to utilize and expand upon existing research where possible. We will try and work through the HPI-CESU to conduct biological monitoring when possible. In addition to standard monitoring protocols the project would also like to do manipulative experiments ie/ seed predation, nest predation with dummy nests etc to enable a potentially quicker way to assess impacts of the fences.

Note: If funding and plans already exist for fencing projects, these plans should go ahead and can coordinate with the legacy grant if they happen to be a top priority site.

3. Presentation on predator proof fencing and update on current Hawaii fencing projects- Lindsay Young

Please see attached power point presentation.

Funding for the Kaena Point Ecosystem Restoration Project came from the U.S. Fish and Wildlife Service (FWS) in December 2006 when a planned predator proof fence project on the island of Hawaii was cancelled, leaving funding available for other projects.

Jeff Burgett provided a valuable discussion about a demonstration predator enclosure fence that was built on TNC land on the Big Island to test the feasibility of excluding mammalian predators on an ‘a’a substrate. It was found that mice were able to penetrate the fence by following the space between the buried skirt of the fence and the rocks underneath. The problem was solved by cementing the skirt to the surrounding rock and this appears to effectively exclude mice. However, because of the differences between ‘a’a and pahoehoe substrates, it was decided that the area to be fenced had too many potential breach sites and was cancelled.

4. Discussion of prioritization process- Eric VanderWerf

- Factors to consider (see below)
- Preliminary discussion of sites
- Site evaluation worksheet example- please see attached excel spreadsheet
- After preliminary prioritization, set site visits for top 5 to 10 for August 2007
- Incorporate data from site visits into prioritization matrix and for short list sites develop detailed implementation plans (budget, schedule, monitoring protocols, existing management and monitoring)

Factors that were suggested for use in the ranking process so far are:

- Substrate type
- Accessibility- road access for material delivery
- Ability to create desired canopy break
- Potential to modify or retrofit any existing ungulate fences
- Compatibility with existing natural resources e.g. seabird collisions

- Compatibility with training- access for personnel and vehicles
- Diversity of species present
- Ecosystem/habitat benefits- diversity of habitats, restoration of ecosystem function
- Cost/benefit advantages- will building a fence complete your objectives and save money?
- Potential for restoration
- Applicability of existing fence technology- snails?
- Current levels of predation and degree of impacts from predators
- Expected benefit (ie/ native species response?)
- Opportunity for partnership between agencies/branches/landowners
- Local capacity to build
- Likelihood of CO supporting the project
- Existing monitoring and infrastructure information- ability to compare efficacy with other management in the long term
- Area protected relative to linear fence length
- Potential for constructing a demo fence within full fence line
- Potential for vandalism or security breaches
- Expected difficulty in obtaining NEPA documents

The issue of defining why we are building these fences and what our goals are with the project was raised, and this clearly relates to the prioritization process. We suggest that the #1 goal of this project is to select sites where fences will best demonstrate the efficacy of this technology.

- Thus the number 1 ranking priority will be sites where a benefit to T and E species or a rare ecosystem is expected, measurable and some results are likely to occur in a reasonable amount of time.
- The second priority criterion will be to select sites where T and E species occur (higher priority for sites with more T and E species) and current management and monitoring is ongoing, with the idea being that demonstrating a benefit to these sites will create the most interest within the military.
- The additional criteria listed above and refined over time will be incorporated to select the top sites. Thus, some of the top sites biologically may not make it to the final list if issues such as feasibility (terrain etc.) make it unlikely to happen.

5. Potential sites suggested by each branch

Navy:

- Makaha Ridge
- Niulii Pond
- Lualualei *Amastra* snail site
- Expansion of 2 existing snail sites in Lualualei
- Waiawa National Wildlife Refuge
- Honouliuli National Wildlife Refuge

Marine Corps:
- Nuupia pond Complex, Marine Corps Base Hawaii, Kaneohe
- Sag Harbor, Marine Corps Base Hawaii, Kaneohe
- Salvage Yard Wetland, Marine Corps Base Hawaii, Kaneohe
- Camp Smith

Air Force:
- Mt. Kaala (in partnership with Army and State NARS)

National Guard:
- Keaukaha Military Reservation on Hawaii
- Ukumehame on Maui
- Kekaha on Kauai
- Bellows on Oahu

Army:
- Kipuka Kalawamauna, Pohakuloa Training Area
- Kahanahaiki, Makua Military Reservation
- Kaluakauila, Makua Military Reservation
- Mt Kaala
- Schofield Barracks West Range
- Schofield Barracks East Range
- Schofield Barracks South Range (*Amastra* snails)
- Kahuku Training Area

Each agency will be asked to complete a short information sheet for each of their suggested sites. This will include site location, total area, habitat type(s), vegetation information, vertebrate pest species present, listed species present, current management and monitoring activities, existing threats and pest species to exclude and any other pertinent information. A template and example sheet will be provided for this activity which will be completed over e-mail.

6. Attachments

- Power point of predator proof fencing
- Example decision worksheet
- References on different types of fencing
- Site information sheet template

Hawaii DoD Predator Fence Site Selection Worksheet

INSTRUCTIONS:

Enter a score from 1 (worst) to 5 (best) for each criterion at each site. Be Honest!

Weighting: Criteria can be weighted based on their importance by multiplying the score by a prescribed factor.

The total scores provides an indication of the overall favorability of each site.

This worksheet is intended to help explore the positive and negative aspects of various sites. The results of this worksheet alone will not be used to choose a site

Site	Owner	# Listed species	Urgency of listed species	Size (ha)	Cost (US$)	Feasibility	Compatibility with training	Ecosystem benefits	Public support	Ordnance hazard	?	Total score
												0
												0
												0
												0
												0
												0
												0
												0
												0

APPENDIX 2: Candidate Predator Fence Site Description

This description is intended to provide information on potential fencing sites so that participants have the necessary information to rank the sites. The goal is to keep the description under 2 pages while still providing all necessary information.

Site Name:

Location: (Island, region, latitude and longitude of approximate center point or edge, attach map if necessary)

Ownership:

Approximate area to be fenced: (hectares)

Habitats/Ecosystem types: Please list all major habitat types present within the site (e.g. dry forest, mesic forest, wetland, coastal dune, etc.)

Vegetation composition: Please briefly describe the dominant vegetation, both native and non-native species.

Threatened and Endangered species: Please list all T&E species present at the site, and their approximate numbers if known. Place "CR" before any species that are critically endangered.

Other important native species: Please list any other important populations of plants, vertebrates, or invertebrates present.

Pest species: Please list all species of predators and ungulates present.

Existing threats: Briefly describe the threats caused by predators and ungulates at the site.

Current management and monitoring: Please briefly list or describe current management (weeding, trapping, baiting, hunting, outplanting, etc) and monitoring conducted at the site, including duration and frequency.

Vision statement/Fencing Need: Why do you want to build a fence? To protect a certain species? An ecosystem? A demonstration of feasibility?

APPENDIX 3

Candidate Predator Fence Site Description

Site Name: Kahanahaiki Gulch Management Unit

Location: Oahu, Northern Waianae Mountains, UTM 0583509 2381811, see attached map.

Ownership: U.S. Army

Approximate area to be fenced: 10 hectares, 1,300 meters linear distance (just the maile flats portion of the management unit)

Habitats/Ecosystem types: Lowland Mesic Forest and Shrubland

Vegetation composition: The dominant vegetation within the proposed site at Kahanahaiki is *Metrosideros polymorpha* and *Acacia koa*. There are many other canopy tree components as is characteristic of Oahu mesic forests such as *Pisonia sandwichensis, Nestegis sandwichensis, Psydrax odoratum, Xylosma hawaiiensis, Diospyros sandwichensis, Hibiscus arnotianus* and *Sapindus oahuensis*. There are also scattered monotypic patches of *Psidium cattelianum*.

Threatened and Endangered species: CR *Schidea obovata* (1 mature), *Cenchrus agrimonioides* (122 mature/18 immature), CR *Schiedea nuttallii* (5 mature), CR *Cyanea superba* (1 mature/10 immature), *Achatinella mustelina*(>300 individuals), and *Chasiempis sandwichensis* ssp. *ibidis* (1 female).

Other important native species: *Melicope sandwichensis, Platydesma cornuta* var, *decurrens, Rhynchogonous fuscus, Dictyophorodelphax mirabilis, Drosophila* spp. (native picture wing flies).

Pest species: *Rattus rattus, Rattus exulans, Mus musculus, Felis catus, Herpestes javanicus,* and *Euglandina rosea.*

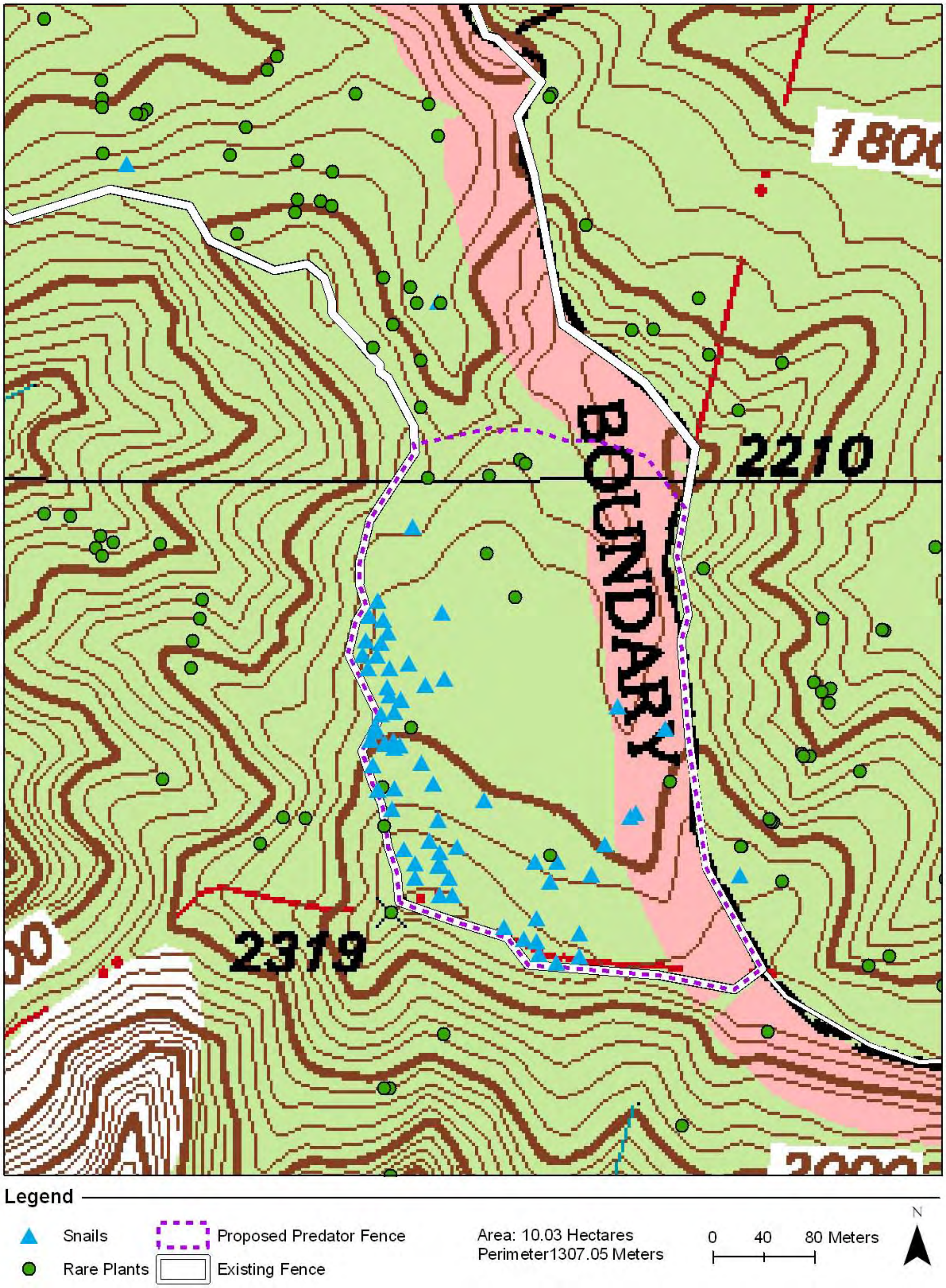
Existing threats: Kahanahaiki is already protected from feral ungulates by a hogwire mesh fence (see attached map for overlay of existing ungulate fence). The remaining threat to the ecosystems and species within Kahanahaiki are predation on plant parts and endangered tree snails by rats (both species) and predation on plant parts by mice. Fruit predation and predation on leaves and stems has been observed on federally listed plant taxa within Kahanahaiki. *E. rosea* predate the endangered tree snail. The lone elepaio female is susceptible to rat, mongoose and cat predation.

Current management and monitoring:
Kahanahaiki has received intensive management attention since 1996. Construction of an ungulate exclosure to protect 26 hectares was completed early in 1997. Since fence completion, ungulate control has been conducted surrounding the management unit to keep pressure off of the fenceline. Intensive weed control is conducted throughout the management unit using a clip and drip or girdle technique and the cut surface is treated with herbicide. Often, weed control is combined with outplanting of common natives.

Kahanahaiki is the first location where reintroductions of endangered plants were performed on Army lands in Hawaii and it has been a focal point for outplanting projects ever since. During the nesting season each year between 1995 and 2004, Army Natural Resource Staff have been conducting rat control using snap traps and bait across the territory of the lone Oahu Elepaio pair within Kahanahaiki gulch. In addition, rat bating and small predator exclosures are in place to protect *A. mustelina* from predation by rats and *Euglandina rosea*. The existing predator exclosure is approximately 20m x 15m. Currently rat baiting is conducted around this exclosure, six bait stations and 12 snap traps are maintained. *A. mustelina* occurs across maile flats but rat baiting is not feasible at this scale at current staffing levels. Monitoring includes quarterly visits to rare plant populations, mark and recapture tree snail monitoring annually and vegetation plot monitoring every three years.

Kahanahaiki is relatively accessible via the NIKE site paved road and thus has become a site frequently chosen for conducting research projects. On going research at the site by University of Hawaii graduate students includes rat density and home range studies, rat seed predation studies, native seedling monitoring to compare an ungulate free site to one with ungulates, *A. mustelina* dispersal and genetics research and *E. rosea* ecology and habitat use research. In house staff conduct research on alien slug impacts and control techniques in addition to black twig borer impacts and control studies.

Vision statement/Fencing Need: Management within Kahanahaiki is done to satisfy Endangered Species Act requirements outlined in the Makua Implementation Plan (MIP). The Army must fully fund the MIP which outlines species and habitat stabilization steps for Makua training threatened taxa in order to avoid jeopardy. The MIP includes a budget for fencing but only to exclude ungulates and does not address other predators. Cost estimates are currently based on ground-based predator control only. A demonstration project at a MIP site and a favorable cost benefit analysis would support the application of this technology to MIP goals. The MIP could be revised to include predator fencing at other MIP project sites. The Army must fully fund the MIP to be in compliance with the ESA.


1800
2210
BOUNDARY
2319
2000
Legend
Snails
Rare Plants
Proposed Predator Fence
Existing Fence
Area: 10.03 Hectares
Perimeter1307.05 Meters
0
40
80 Meters
N

Candidate Predator Fence Site Description

Site Name: Kaluakauila Gulch Management Unit

Location: Oahu, Northern Waianae Mountains, UTM 0579965 2382791, see attached map.

Ownership: U.S. Army

Approximate area to be fenced: 2.9 hectares, 668 meters linear distance

Habitats/Ecosystem types: Lowland Dry Forest and Shrubland

Vegetation composition: The dominant vegetation within the proposed site at Kaluakauila is *Diospyros sandwichensis*. There are many other dry forest canopy tree components such as *Psydrax odoratum, Sapindus oahuensis, Erythrina sandwicensis, Reynoldsia sandwicensis, Eugenia reinwardtiana* and *Rauvolfia sandwicensis*. There are also scattered patches of *Psidium cattelianum* in Kaluakauila and *Syzygium cumini* is a common canopy weed.

Threatened and Endangered species: CR *Neraudia angulata var. dentata, Melanthera tenuifolia, Euphorbia haeleeleana, Bonamia menzesii, Hibiscus brackenridgei, CR Delissea subcordata,* and *Abutilon sandwicensis.*

Other important native species: *Bobea sandwicensis*, *Asio flammeus*

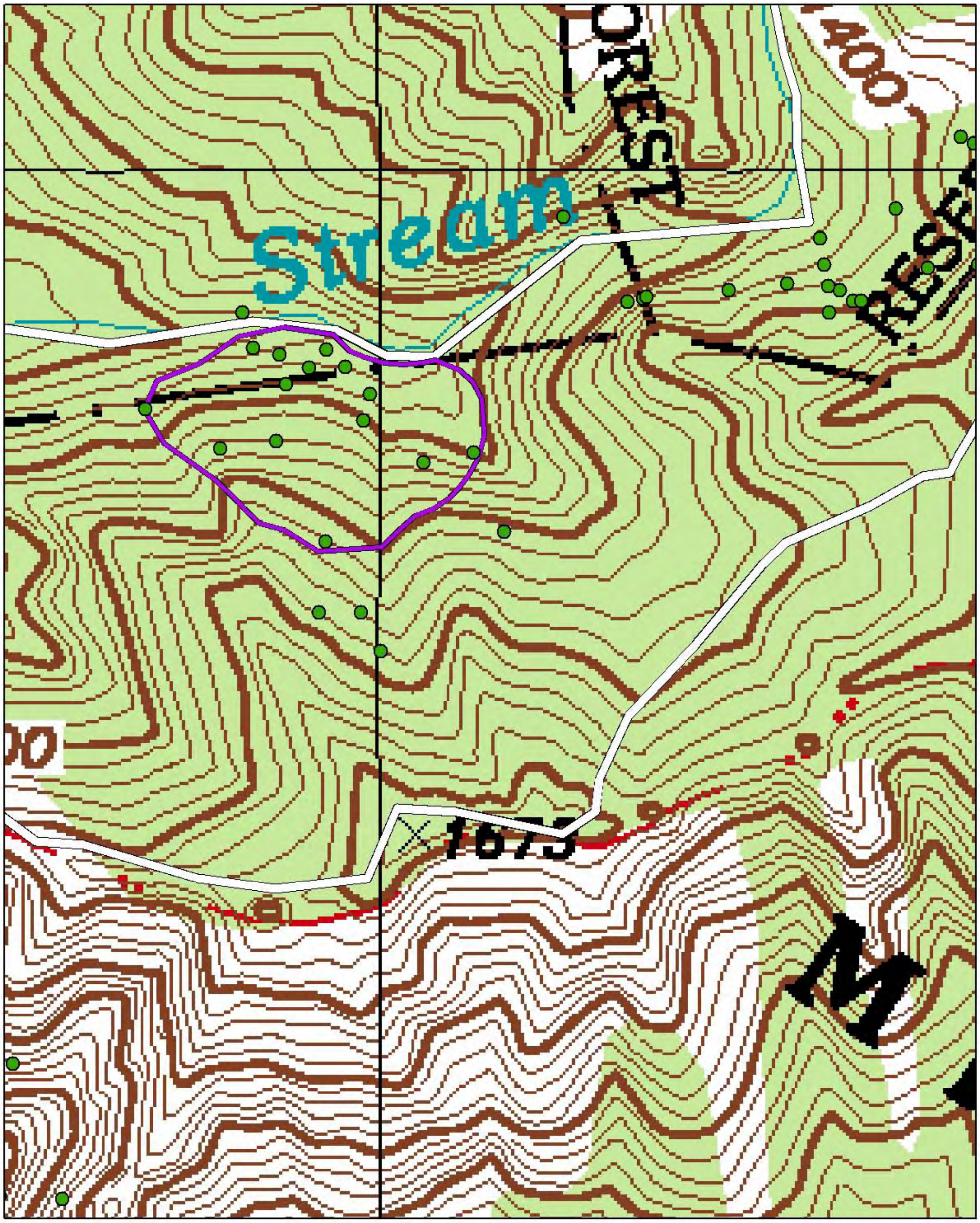
Pest species: *Rattus rattus, Rattus exulans, Mus musculus, Felis catus,* and *Herpestes javanicus.*

Existing threats: Kaluakauila is already protected from feral ungulates by a hogwire mesh fence (see attached map for overlay of existing ungulate fence). Wildfire threatens the remaining forest at Kaluakauila through burning the back the forest perimeter. The remaining threat to the ecosystems and species within Kaluakauila are predation on plant parts by rats and mice. Fruit predation and predation on leaves and stems has been observed on federally listed plant taxa within Kaluakauila. Nesting *A. flammeus* are susceptible to mongoose and cat predation.

Current management and monitoring:
Kaluakauila has received intensive management attention since 1997. Construction of an ungulate exclosure to protect 102 hectares was completed in 2001. Since fence completion, ungulate control has been conducted surrounding the management unit to keep pressure off of the fenceline. Intensive weed control is conducted throughout the management unit using a clip and drip or girdle technique and the cut surface is treated with herbicide. Often, weed control is combined with outplanting of common natives. *Panicum maximum* has invaded the forest perimeter in light gaps. Control of this grass is conducted to reduce the fuel for wildfire and to improve ecosystem health. Reintroductions of four endangered plant taxa have been conducted at Kaluakauila.

Extensive rat control is currently conducted using baits and snap traps. Two grids are maintained mainly to protect fruit of the endangered *Euphorbia haeleeleana* and to reduce predation on native dryland tree taxa. A total of 57 bait stations and 32 snap traps are maintained within the Kaluakauila Management Unit. Of those, 39 bait stations and 20 snap traps fall within the proposed project site. Rat control trips are conducted every 6 weeks and it takes two personnel all day to restock the grid. Existing monitoring includes quarterly visits to rare plant populations and vegetation plot monitoring every three years.

Vision statement/Fencing Need: Management within Kaluakauila is done to satisfy Endangered Species Act requirements outlined in the Makua Implementation Plan (MIP). The Army must fully fund the MIP which outlines species and habitat stabilization steps for Makua training threatened taxa in order to avoid jeopardy. The MIP includes a budget for fencing but only to exclude ungulates and does not address other predators. Cost estimates are currently based on ground-based predator control only. A demonstration project at a MIP site and a favorable cost benefit analysis would support the application of this technology to MIP goals. The MIP could be revised to include predator fencing at other MIP project sites. The Army must fully fund the MIP to be in compliance with the ESA.



Legend

- Rare Plants
- Proposed Predator Fences
- Existing Fence

Area: 2.94 Hectares
Perimeter 668.54 Meters

0 40 80 Meters

N

Candidate Predator Fence Site Description

Site Name: Poamoho Cabin

Location: Oahu, Northern Koolau Mountains, UTM 0611829 2381234, see attached map.

Ownership: State of Hawaii

Approximate area to be fenced: 0.38 hectares, 254 meters linear distance

Habitats/Ecosystem types: Lowland Wet Forest and Shrubland

Vegetation composition: The dominant vegetation within the proposed site at Poamoho is *Metrosideros polymorpha*. There are many other canopy tree components such as *Metrosideros tremuloides, Metrosideros rugosa, Elaeocarpus bifidis, Hedyotis terminalis, Psychotria faurei, Cheirodendron platyphyllum* and *Prichardia martii*. Very little alien canopy vegetation exists at the proposed project site. The main weed species present are *Axonopus fisifolius, Clidemia hirta, Paspalum conjugatum* and *Pterolepis glomerata*.

Threatened and Endangered species: This fence is proposed for construction in order to facilitate a reintroduction of *Achatinella lila* from a laboratory population.

Other important native species: *Zanthoxylum oahuensis*

Pest species: *Rattus rattus, Rattus exulans, Mus musculus* and *Euglandina rosea.*

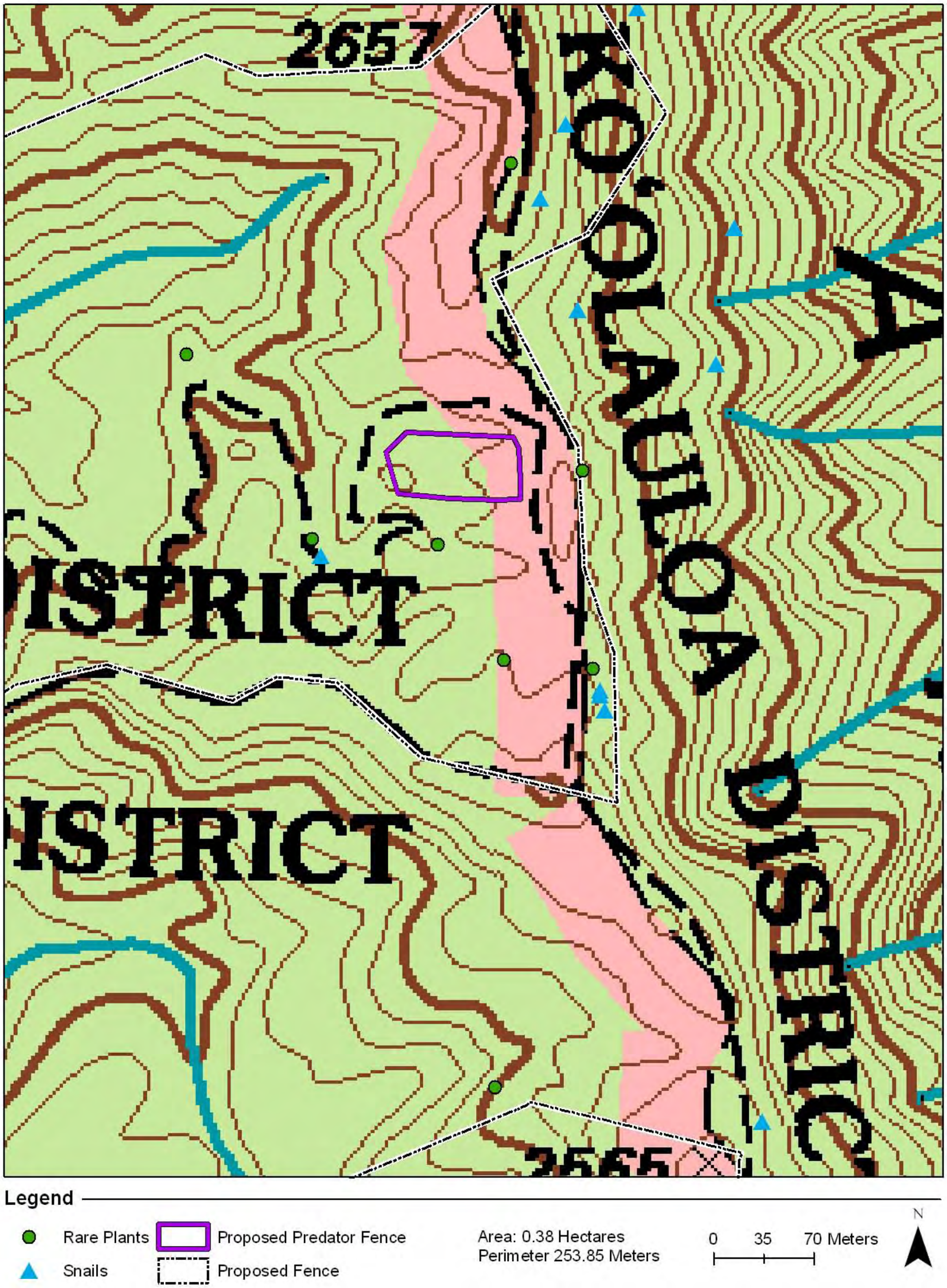
Existing threats: Rat and *Euglandina* predation on *Achatinella spp* is well documented. *A. lila* used to exist in relatively high numbers at the top of the Poamoho trail and none exist in that location today. It is believed that *E. rosea* exterminated *A. lila* from this site. Remaining *A. lila* are on the windward cliffs of Punaluu Valley.

Current management and monitoring:
An ungulate fence is planned for construction under the Oahu Implementation Plan (OIP) for the protection of rare snails and plants (see attached map). The Poamoho Summit project site falls within this proposed fence. Within this management unit ecosystem scale *Psidium cattleianum* control will be conducted. In addition rare plant reintroduction maybe required. Additional predator exclosures may be constructed if the tool is successful under the extreme weather conditions of the Koolau Summit.

Army Natural Resource Staff maintain a rat control grid to the north of the proposed project site. The grid composed of eight bait stations and 16 snap traps is centered on a high density *Achatinella* site. This grid has been maintained since 2004. Access trips are conducted at six week intervals via helicopter to re-stock the grid. Predator exclosure maintenance could be added to these trips already being conducted. Captive populations of *Achatinella* are maintained at the University of Hawaii campus in order to ensure their long-term survival. One species in particular is very fecund in lab and there are a total of over 400 snails. Some of these snails are in excess of needed offsite representation. The tree snail laboratory wants to reintroduce these into a protected site near the original collection site. This is the Poamoho Summit. Of particular interest is the application of predator control technologies at high wind and rainfall sites and to control *E. rosea* in addition to rodents.

Army staff have been conducting control of *Leptospermum scoparium* along the Poamoho trail and into the Helemano and Poamoho drainage systems since 1996. In some locations along the Poamoho trail this weed was almost monotypic. *L. scoparium* can be conducted by simply cutting the tree near the base. Application of herbicide is not necessary.

Vision statement/Fencing Need: Management of the Poamoho Summit area *Achatinella* is done to satisfy Endangered Species Act requirements outlined in the Oahu Implementation Plan (OIP). The Army must fully fund the OIP which outlines species and habitat stabilization steps for Oahu training area threatened taxa in order to avoid jeopardy. The OIP includes a budget for fencing but only to exclude ungulates and does not address other predators. Cost estimates are currently based on ground-based predator control only. A demonstration project at an OIP site and a favorable cost benefit analysis would support the application of this technology to OIP goals. The OIP could be revised to include predator fencing at other OIP project sites. The Army must fully fund the OIP to be in compliance with the ESA.


2657
KO'OLAULOA
DISTRICT
DISTRICT
DISTRICT
2565
Legend
Rare Plants
Snails
Proposed Predator Fence
Proposed Fence
Area: 0.38 Hectares
Perimeter 253.85 Meters
0 35 70 Meters
N

Candidate Predator Fence Site Description

Site Name: Waieli Bench

Location: Oahu, Southern Waianae Mountains, UTM 0592954 2374022, see attached map.

Ownership: Campbell Estate (leased to the Nature Conservancy managing Honouliuli Preserve)

Approximate area to be fenced: 3.35 hectares, 789 meters linear distance.

Habitats/Ecosystem types: Lowland Mesic Forest and Shrubland

Vegetation composition: The dominant canopy tree within the proposed Waieli site is *Metrosideros polymorpha*. There are many other native components as is characteristic of Oahu mesic forests such as *Pisonia umbelifera, Pouteria sandwicensis, Psychotria hathewayi, Claoxylon sandwicensis, Urera glabra, Myrsine lessertiana* and *Freycinetia arborea*. There are also scattered monotypic patches of *Psidium cattelianum* and *Schinus terebinthifolius* is a common canopy component.

Threatened and Endangered species: *Achatinella mustelina*(>400 individuals), CR *Cyanea grimesiana subsp. obatae,* CR *Cyanea pinnatifida,* CR *Delissea subcordata*, CR *Phyllostegia hirsuta*, CR *Phyllostegia mollis,* CR *Plantago princeps var. princeps, Schiedea hookeri, Solanum sandwicense,* and CR *Urera kaalae.*

Other important native species: Other extremely rare mollusks that occur at the project site include CR *Cookeconcha* sp., CR *Helicinid* sp., CR *Amastra micans* and CR *Laminella sanguinea.* Additionally, the Waieli Bench site contains host plant species for a number of the endangered *Drosophila* flies. Surveys have not yet been conducted in the project area to update the status for *Drosophila*.

Pest species: *Rattus rattus, Rattus exulans, Mus musculus* and *Euglandina rosea.*

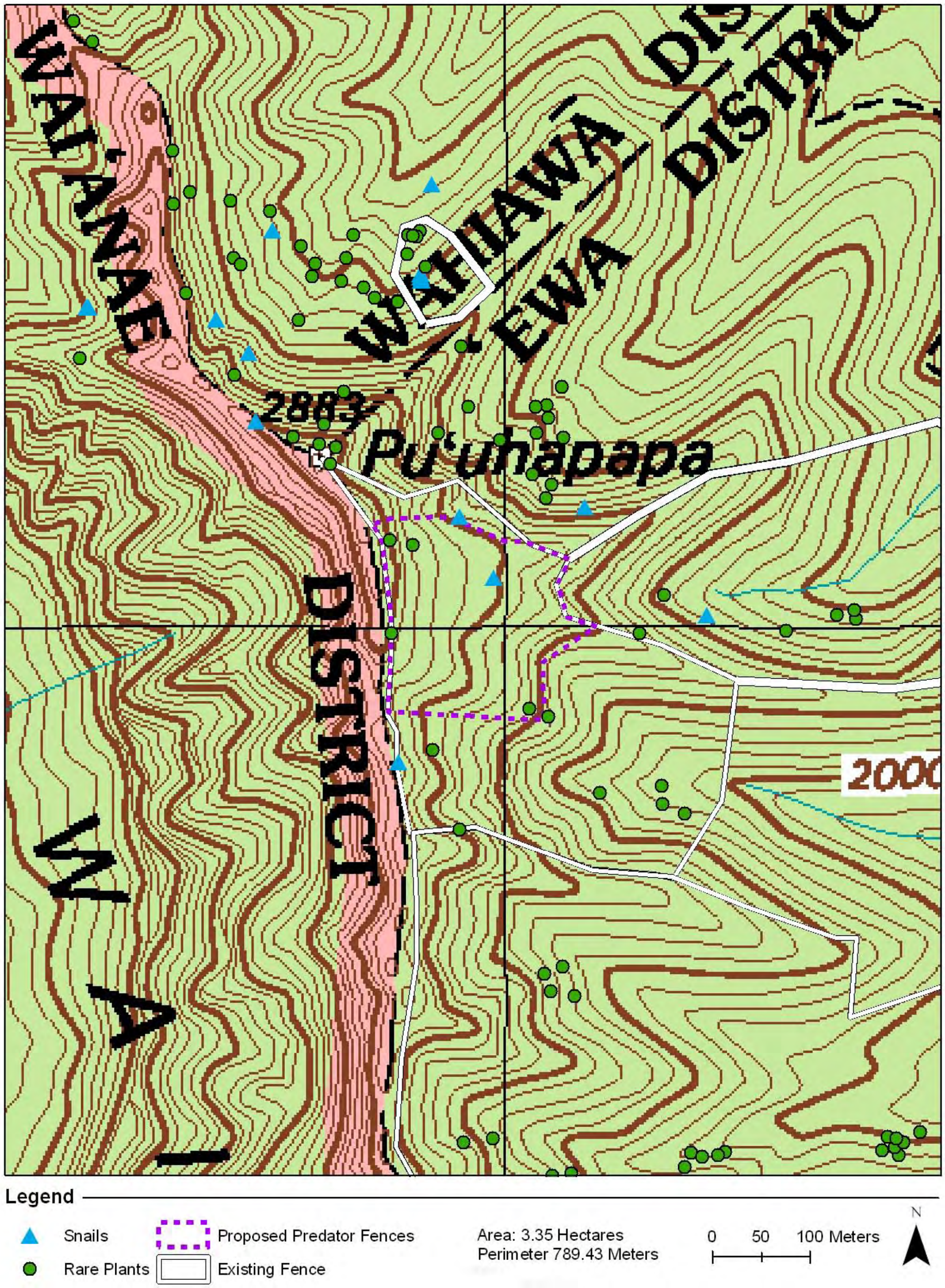
Existing threats: The Waieli Bench site is already protected from feral ungulates by a hogwire mesh fence (see attached map for overlay of existing ungulate fence). The remaining threat to the ecosystems and species at Waieli are predation on plant parts and on endangered tree snails and other rare snails by rats (both species) and predation on plant parts by mice. Fruit predation and predation on leaves and stems has been observed on federally listed plant taxa at the Waieli Bench site. *E. rosea* predate all snails in the area.

Current management and monitoring:
Waieli has received intensive management attention since 2003. Construction of an ungulate exclosure to protect 24.3 hectares was completed early in December 2005. Since fence completion, ungulate control has been conducted surrounding the management unit to keep pressure off of the fenceline. Intensive weed control is conducted throughout the management unit using a clip and drip or girdle technique and the cut surface is treated with herbicide.

Intensive common native outplanting has been conducted in the bench area by the Nature Conservancy.

Numerous reintroductions of endangered plants have been done at the Waieli Bench site by Nature Conservancy Staff. A number of these taxa are in the Campanulaceae which is notoriously susceptible to rat predation. The high density of native snails has led the project site's nickname "the land of 10,000 snails" coined by Botanist Ken Wood. The Nature Conservancy and Army Staff have been conducting rat control using snap traps and bait across the bench area since 2004. A total of 16 bait stations and 32 snap traps are maintained at this site. This grid is maintained at six week intervals. Monitoring includes quarterly visits to rare plant populations, mark and recapture tree snail monitoring annually, ground shell plot monitoring to detect predation and vegetation plot monitoring every three years.

Vision statement/Fencing Need: Management within Waieli has been done under Nature Conservancy conservation mandates and has been subsumed into the Army's Natural Resource Program. Currently, work at the Waieli site is done to satisfy Endangered Species Act requirements outlined in the Makua Implementation Plan (MIP). The Army must fully fund the MIP which outlines species and habitat stabilization steps for Makua training threatened taxa in order to avoid jeopardy. These actions occur both on and off Army-owned lands. Extensive stabilization work occurs at Honouliuli Preserve. The MIP includes a budget for fencing but only to exclude ungulates and does not address other predators. Cost estimates are currently based on ground-based predator control only. A demonstration project at a MIP site and a favorable cost benefit analysis would support the application of this technology to MIP goals. The MIP could be revised to include predator fencing at other MIP project sites. The Army must fully fund the MIP to be in compliance with the ESA.


WAIʻANAE
WAHIAWĀ DIS
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WAHIAWĀ
EWA
2883
Puʻuhapapa
DISTRICT
2000
WA
Legend
Snails
Rare Plants
Proposed Predator Fences
Existing Fence
Area: 3.35 Hectares
Perimeter 789.43 Meters
0 50 100 Meters
N

Candidate Predator Fence Site Description

Site Name: Pohakuloa Training Area

Location: Hawaii Island, PTA, Training Area 22, MP 41, NAD 83 UTM N0216944, E2179597 (see attached map). The area is adjacent to a four-wheel drive road for access.

Ownership: U.S. Army

Approximate area to be fenced: 0.5 to 1 ha

Habitats/Ecosystem types: Upper elevation dry forest. The area is comprised of a`a and pahoehoe substrates.

Vegetation composition: The vegetation is Sparse Metrosideros treeland with sparse native shrub understory**. W**eed species densities are very low.

Threatened and Endangered species: CR: *Schiedea hawaiiensis***.** This is the site of the only naturally occurring *S. hawaiiensis* plant in the world. There is only one individual currently at the site. Germination has been noted at the site, but seedlings are not persisting. This species has no federal protection. *Zanthoxylum hawaiiense:* There is a single location of within the proposed fence. This individual is dead, but protecting the area may allow for this species to regenerate. CR: *Neraudia ovata*. There is an outplanting of the critically endangered *N. ovata* in proximity to the *S. hawaiiensis*. There are five individuals at this location. State-wide there are about 160 naturally occurring individuals of *N. ovata*.

Other important native species: The native vegetation is relatively intact in this area and includes such species as *Dubautia linearis, Tetramolopium consanguineum, Chenopodium oahuense, Myrsine laniensis, Osteomeles anthyllidifolia, Coprosma Montana, Wikstromia phillyreifolia,* and *Dodnea viscosa*. Many of these species are negatively impacted by ungulates and it is unclear how rodent affect them.

Pest species: *Rattus rattus, Mus musculus, Ovis ovis, Ovis musimon, Capra hicrus, Sus scrofa,* and a whole host of introduced game birds.

Existing threats:
S. hawaiiensis is impacted by a host of species including ungulates, introduced game birds and rodents. An emergency fence was constructed for S. hawaiiensis to keep the ungulates from consuming the plant. Because browse was still noted on the plant a small cage constructed of fine wire mesh was place around the plant to prevent birds and rodents from eating it. The portions of the plant that grow through the cage are continually nipped off.

A single location of a former *Z. hawaiiense* is in proximity to *S. hawaiiensis.* The *Z. hawaiiense* population at PTA is almost exclusively adults with little or no regeneration of young trees. Ungulate browse has been noted on individuals and ungulates are suspected of eating young trees that manage to sprout. Mice have been observed foraging under *Z. hawaiiense* and taking seed.

Rat impacts are unknown, but suspected. By enclosing some *Z. hawaiiense*, we may be able to design some studies to look at the role rodents and ungulates play in the almost non-existent recruitment of young trees into the population.

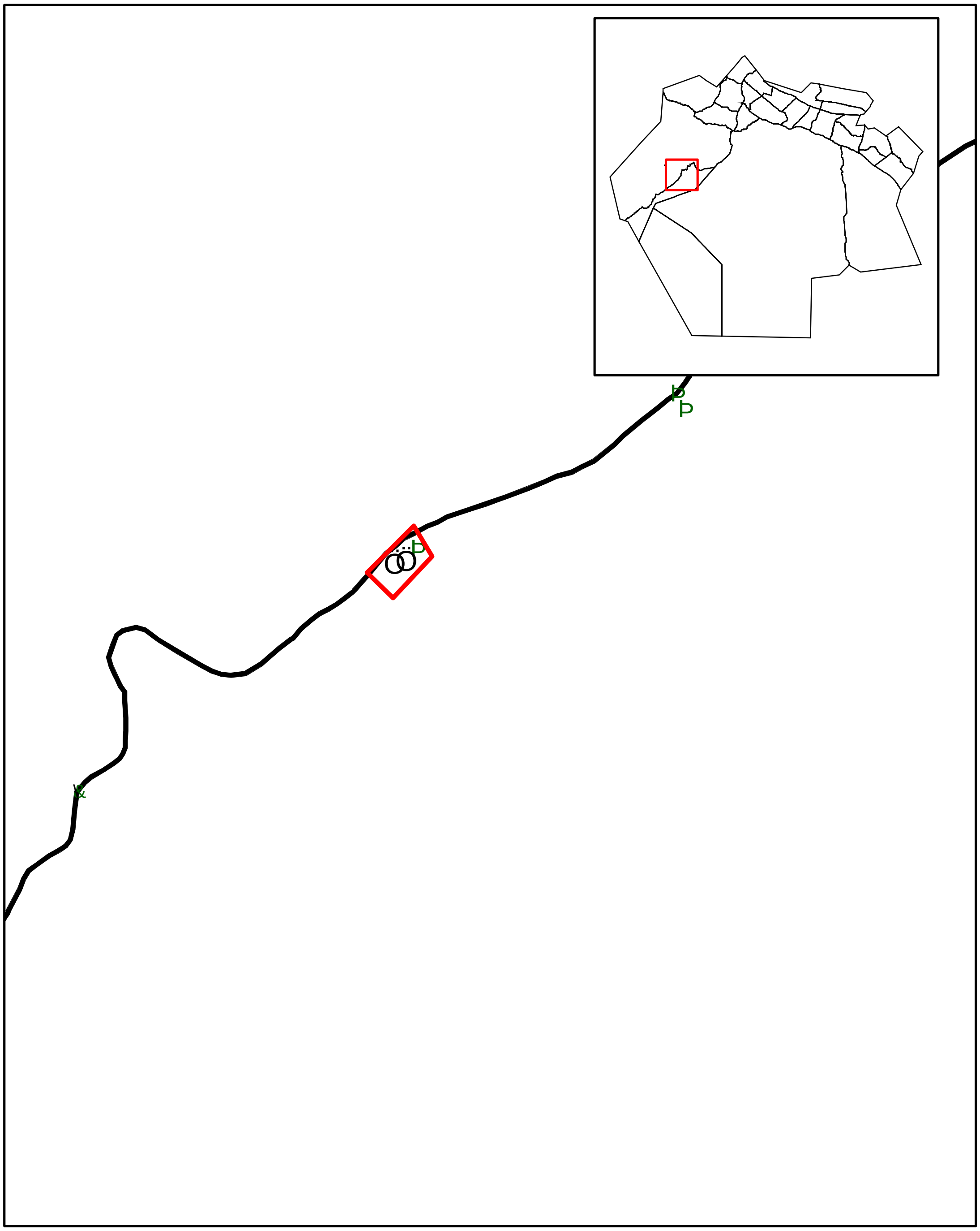
N. ovata is also impacted by several animals including ungulates and rodents. Ungulates have been documented eating the foliage and consuming almost the entire plant. Rodents have been documented chewing through the stems of young plants effectively killing the plants. Rodent impacts to fruit and seed have long been suspected but have not been documented.

Current management and monitoring: There are 25 meter weed-free buffers around the *S. hawaiiensis* and *N. ovata* plants, which are maintained every four months. There is a 75X100 meter rodent control grid around the *S. hawaiiensis* and *N. ovata*. Both *S. hawaiiensis* and *N. ovata* are monitored for population viability annually. There is currently no management for the *Z. hawaiiense*.

Vision statement/Fencing Need:
Threat control is a requirement in the 2003 Biological Opinion issued by the U.S. Fish and Wildlife Service to the U.S. Army for Legacy and Transformation related training at PTA. Threats to the endangered plant species in this area include sheep, goats, pigs, rats, and mice. Both the *S. hawaiiensis* and *N. ovata* are protected by small emergency fences, but the surrounding habitat continues to be degraded. A large-scale fence that will enclose the area is pending construction with the subsequent removal of ungulates. Although ungulates maybe removed from the area in the future, rodents will remain a constant threat. We envision the main purpose of this fence is to protect the resources from rodent predation and impacts. These fences may also provide us an opportunity to study how rodents impact the habitat of these endangered plants.

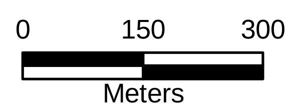
Constructing the predator proof fencing will not only help to immediately protect the plants and their habitat, but we can explore the feasibility of using such a fence in more remote locations where other critically endangered plants exist. Year-round rodent control for critically endangered plants is costly and the predator proof fencing may prove to be a viable option.

Predator Proof Fencing Site Proposal in Training Area 22 at Pohakuloa Training Area for *Schiedea hawaiiensis*



Endangered Plants

E	Asp. peruviana insulare	Ö	Schiedea hawaiiensis		Stenogyne angustifolia
é	Haplostachys haplostachya	Õ	Silene hawaiiensis		Tetramolopium arenarium
	Hedyotis coriacea	Õ	Silene lanceolata	«	Tetramolopium sp. 1
	Neraudia ovata	e	Solanum incompletum	Þ	Zanthoxylum hawaiiense
	Portulaca sclerocarpa	#	Spermolepis hawaiiensis		Highway
	Proposed Predator Proof Fencing Site				Minor Trail
					Road
					Trail



Candidate Predator Fence Site Description

Site Name: Pohakuloa Training Area

Location: Hawaii Island, PTA, Training Area 22, MP 13, NAD 83 UTM N0217565, E2185643 (see attached map). The area is adjacent to a four-wheel drive road for access.

Ownership: Land leased to the Army by the State of Hawaii

Approximate area to be fenced: 9 ha

Habitats/Ecosystem types: Upper elevation dry forest. The area is comprised of an a`a substrate.

Vegetation composition: The vegetation is Open Metrosideros treeland with sparse native shrub understory**.** *Pennisetum setaceum* and *Senecio madagascariensis* are the major weed species present, but densities are low to moderate.

Threatened and Endangered species: CR: *Solanum incompletum* there are four at this site, which is one of the two populations at PTA. There are approximately 70 *S. incompletum* State-wide and all are found at PTA or on adjacent State land. *Silene lanceolata* there are approximately 21 individuals within the proposed fence. There are five *Zanthoxylum hawaiiense* within the proposed fence.

Other important native species: The native vegetation is relatively intact in this area and includes such species as *Bidens menziesii, Dubautia linearis, Tetramolopium consanguineum, Chenopodium oahuense, Myrsine laniensis, Osteomeles anthyllidifolia, Coprosma Montana, Wikstromia phillyreifolia*, and *Dodnea viscosa*. Many of these species are negatively impacted by ungulates and it is unclear how rodent affect them.

Pest species: *Rattus rattus, Mus musculus, Ovis ovis, Ovis musimon, Capra hicrus, Felis catus, Sus scrofa,* and *Herpestes javanicus*

Existing threats:

Rodent control is extremely important for *S. incompletum* because it is an extremely rare plant and this is one of three naturally occurring locations. There are only four plants at this location and recently one plant was found severely damaged by rodents (i.e. it was girdled.) We are not certain if this plant will survive. Loosing one plant to rodent damage is a significant loss to the entire population and the species as a whole. Also, it is unclear how rodents may be impacting seeds and seedlings of this species. Rodent feeing stations with depredated fruits have been documented for a closely related plant species, *Solanum puesdocaspicum*. With low numbers of plants and low natural germination, loosing any fruit and seeds to rodents could have potentially serious impacts to the entire *S. incompletum* population. Ungulates find S. incompletum extremely palatable and consume unprotected plants.

Z. hawaiiense is in proximity to *S. incompletum* and several occurrences could potentially be enclosed within the fence. The *Z. hawaiiense* population at PTA is almost exclusively adults with little or no regeneration of young trees. Ungulate browse has been noted on individuals and ungulates are suspected of eating young trees that manage to sprout. Mice have been observed foraging under *Z. hawaiiense* and taking seed. Rat impacts are unknown, but suspected. By enclosing some *Z. hawaiiense*, we may be able to design some studies to look at the role rodents and ungulates play in the almost non-existent recruitment of young trees into the population.

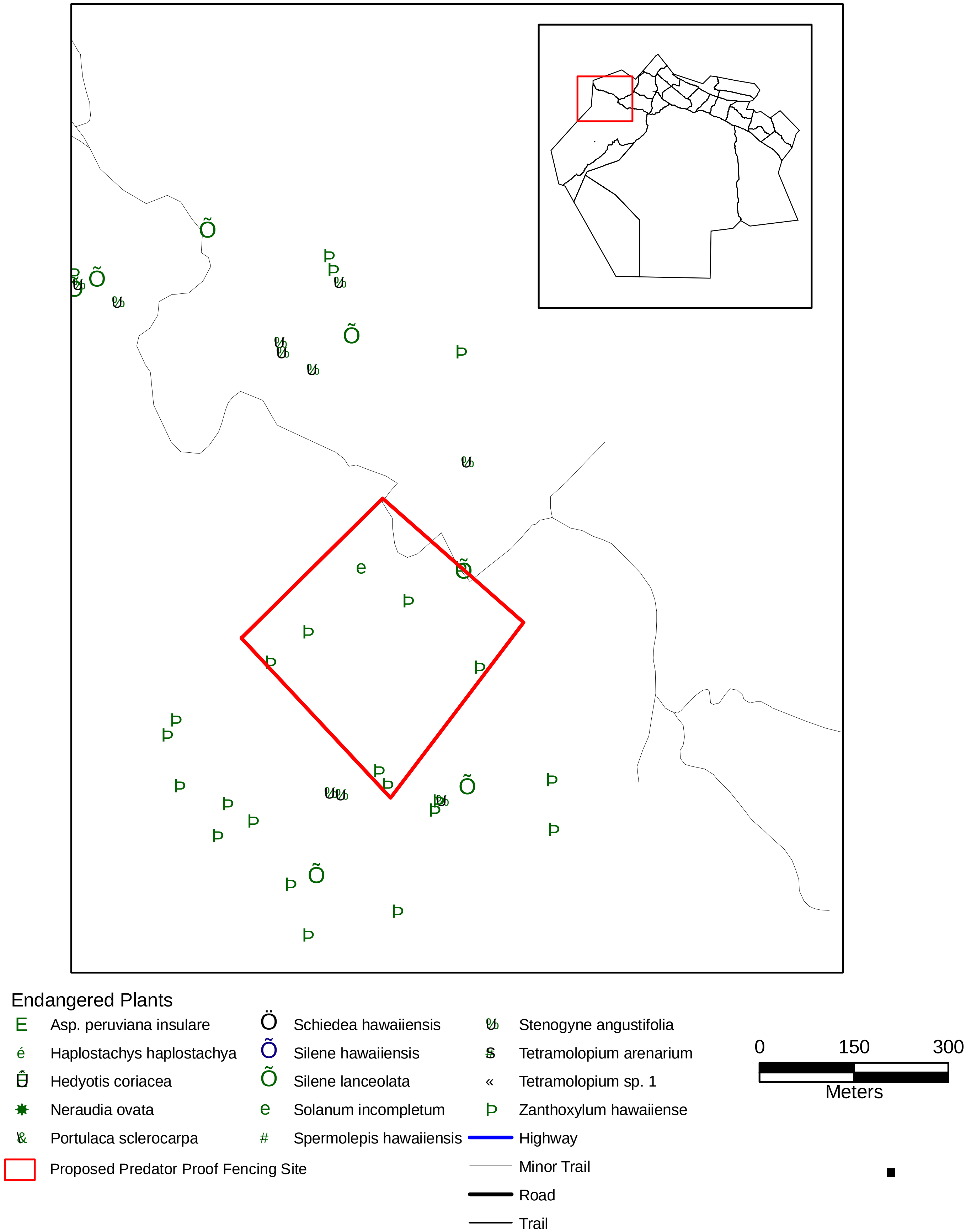
S. lanceolata is also proximate to *S. incompletum* and it may be possible to enclose several individuals. Ungulates find this plant highly palatable and will eat any unprotected plant they find. These plants are currently protected by an emergency fence. Low levels of foliage damage attributed to rodents have been documented on *S. lanceolata*. Other impacts are suspected, but are unknown. As with *Z. hawaiiense*, we may be able to use this fence to study the response of this species to the removal of rodents.

Current management and monitoring: There are 25 meter weed-free buffers around the *S. incompletum* and *S. lanceolata* plants, which are maintained every four months. There is a 75X100 meter rodent control grid around the *S. incompletum*. Both *S. incompletum* and *S. lanceolata* are monitored for population viability annually. There is currently no management for the *Z. hawaiiense*.

Vision statement/Fencing Need:
Threat control is a requirement in the 2003 Biological Opinion issued by the U.S. Fish and Wildlife Service to the U.S. Army for Legacy and Transformation related training at PTA. Threats to the endangered plant species in this area include sheep, goats, pigs, rats, and mice. Both the *S. incompletum* and *S. lanceolata* are protected by small emergency fences, but the surrounding habitat continues to be degraded. A large-scale fence that will enclose the area is pending construction with the subsequent removal of ungulates. Although ungulates maybe removed from the area in the future, rodents will remain a constant threat. We envision the main purpose of this fence is to protect the resources from rodent predation and impacts. These fences may also provide us an opportunity to study how rodents impact the habitat of these endangered plants.

Constructing the predator proof fencing will not only help to immediately protect the plants and their habitat, but we can explore the feasibility of using such a fence in more remote locations where other critically endangered plants exist. Year-round rodent control for critically endangered plants is costly and the predator proof fencing may prove to be a viable option.

Predator Proof Fencing Site Proposal in Training Area 22 at Pohakuloa Training Area
For *Solnanum incompletum*



Candidate Predator Fence Site Description

Site Name: Pohakuloa Training Area

Location: Hawaii Island, PTA, Training Area 22, MP 25, NAD 83 UTM N0215762, E2178623 (see attached map). The area is adjacent to a four-wheel drive road for access.

Ownership: U.S. Army

Approximate area to be fenced: 11 ha

Habitats/Ecosystem types: Upper elevation dry forest. The area is comprised of an pahoehoe substrate.

Vegetation composition: The vegetation is considered a Mixed treeland Kipuka and is one of the richest areas at PTA in terms of tree species. Several species within in this vegetation type are found no where else on PTA. This habitat type is rare at PTA. *Pennisetum setaceum* is the major weed species present and densities can be moderate to high.

Threatened and Endangered species: There are approximately 40 individuals of *Silene lanceolata* within the proposed fence. There are four *Zanthoxylum hawaiiense* within the proposed fence. There is one former location of *Portulaca sclerocarpa* within the proposed fence.

Other important native species: The native vegetation is relatively intact in this area. There are many native trees that are found in this area that are relatively rare on other parts of PTA such as *Exocarpos gaudichaudii* and *Pittosporum terminaliodies*. *Santalum paniculatum* is very abundant in this area. Other notable species in this area include *Festuca hawaiiensis*, which is proposed for listing as endangered, *Exocarpos menziesii*, *Eragrostis deflexa*, and *Tertamolopium consanguineum*. More common species in the area includes such species as *Dubautia linearis, Chenopodium oahuense*, *Myrsine laniensis*, *Osteomeles anthyllidifolia*, *Coprosma Montana*, *Wikstromia phillyreifolia*, and *Dodnea viscosa*. Many of these species are negatively impacted by ungulates and it is unclear how rodent affect them.

Pest species: *Rattus rattus, Mus musculus, Ovis ovis, Ovis musimon, Capra hicrus, Sus scrofa,*

Existing threats:

This habitat has been extremely impacted by ungulates and rodents. Ungulate browse is often seen on *Osteomeles anthyllidifolia* and *Wikstromia phillyreifolia*. Sheep are often sighted in this area during routine work. Rodent feeding stations have been documented under almost all the S. paniculatum. Rodents will also consume the seeds in the trees leaving the hollow shell on the branch.

The *Z. hawaiiense* population at PTA is almost exclusively adults with little or no regeneration of young trees. Ungulate browse has been noted on individuals and ungulates are suspected of eating young trees that manage to sprout. Mice have been observed foraging under *Z. hawaiiense* and taking seed. Rat impacts are unknown, but suspected. By enclosing some *Z. hawaiiense*, we may be able to design some studies to look at the role rodents and ungulates play in the almost non-existent recruitment of young trees into the population.

Ungulates find *S. lanceolata* highly palatable and will eat any unprotected plant they find. The plants within the proposed fence are not currently protected. Low levels of foliage damage attributed to rodents have been documented on *S. lanceolata.* Other impacts are suspected, but are unknown. As with *Z. hawaiiense*, we may be able to use this fence to study the response of this species to the removal of rodents.

Browse from ungulates has been noted on *P. sclerocarpa* and recent greenhouse evidence indicated that mice eat its seeds. Impacts from rats are unknown.

Ungulates also impact *P. terminalioides*, which is relatively rare tree at PTA. There is a distinct browse line on trees. Fruits are also consumed by rodents and hollow fruits can be found under or still attached to trees.

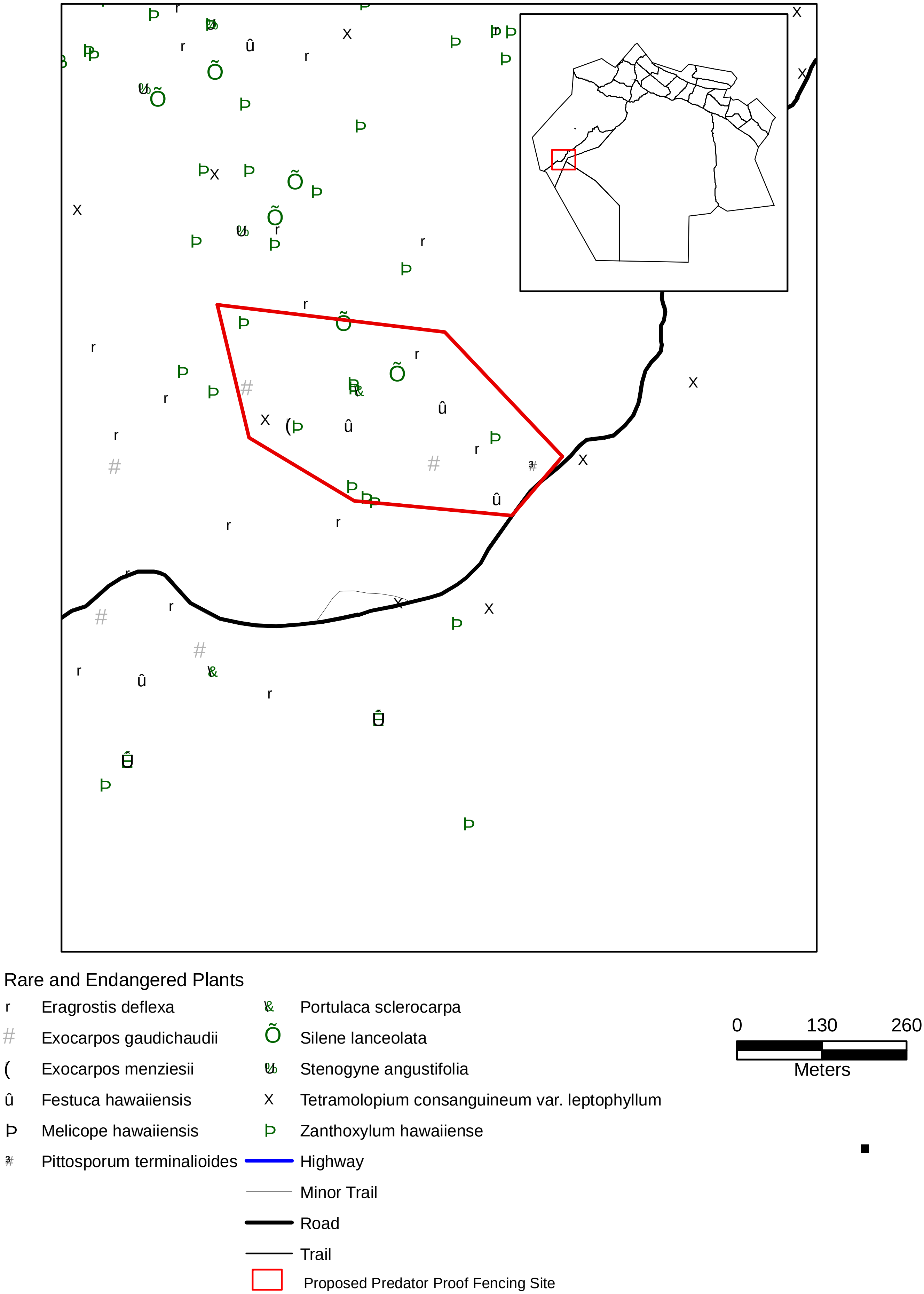
Mice are suspected in having an impact on the rare grass species located in this area including *F. hawaiiensis* and *E. deflexa*, but this has not been documented.

Current management and monitoring: Currently there is no management in this area. In May 2007, annual monitoring plots for *S. lanceolata* will be established. A least two *P. terminalioides* are protected by a single emergency fence.

Vision statement/Fencing Need:
Threat control is a requirement in the 2003 Biological Opinion issued by the U.S. Fish and Wildlife Service to the U.S. Army for Legacy and Transformation related training at PTA. Threats to the endangered plant species in this area include sheep, goats, pigs, rats, and mice. A large-scale fence that will enclose the area is pending construction with the subsequent removal of ungulates. Although ungulates maybe removed from the area in the future, rodents will remain a constant threat. We envision the main purpose of this fence is to protect the resources from rodent predation and impacts. These fences may also provide us an opportunity to study how rodents impact the habitat of these endangered plants.

Constructing the predator proof fencing will not only help to immediately protect the plants and their habitat, but we can explore the feasibility of using such a fence in more remote locations where other critically endangered plants exist. Year-round rodent control for critically endangered plants is costly and the predator proof fencing may prove to be a viable option.

Predator Proof Fencing Site Proposal in Training Area 22 at Pohakuloa Training Area for the Mixed Treeland Kipuka



Candidate Predator Fence Site Description

Site Name: Mt. Kaala

Location:
\`Oahu, Wai\`anae range, top of Mt. Ka\`ala – see map

Ownership: Air Force, Army

Approximate area to be fenced: 2.21 hectares; perimeter approximately 686 meters.

Habitats/Ecosystem types: Wet montane bog

Vegetation composition: Native-dominated forest, Ohi\`a as the dominant canopy species – with diverse native understory and ground cover. Invasive plants include blackberry and kahili ginger (as an aside, rats have also been documented at other sites depredating kahili ginger seeds and possibly reducing its spread).

Threatened and Endangered species: *Schiedea trinervis* (13 individuals) (CR), *Labordia cyrtandrae* (CR), *Cyanea acuminata* (CR), and *Drosophila substenoptera.*

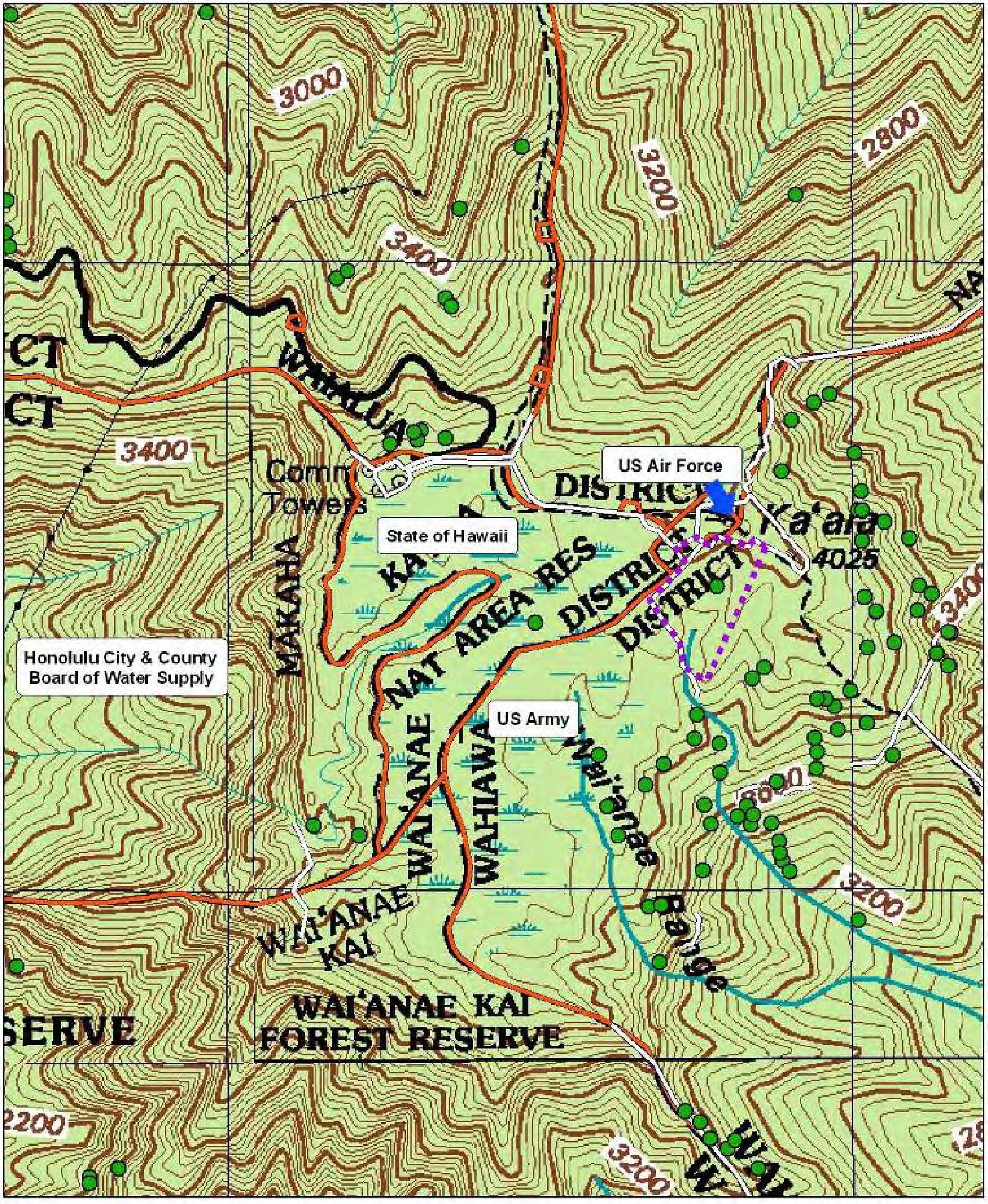
Other important native species: Table 1 is a list of rare species found in the greater bog area, many of which would be found within the fenced area. Additionally, I\`iwi may still use Mt. Kaala. Rare plants including Melicope christophersenii, *Anoectochilis sandwicensis* and *Liparis hawaiiensis. The long-horned woodborer Plagithmysus haasi exist within the project site.* Rare snails historically on Mt. Ka\`ala include *Auriculella castanea* and *Auriculella tenella*, which could theoretically be reintroduced to the exclosure if predatory snail-proofing were added to the fence.

Pest species: Pigs already excluded from bog area. Mongoose and rats are present. The predatory snail *Euglandina rosea* is present.

Existing threats: Seed predation by rats has been documented on *Cyanea acuminata*, *Labordia cyrtandrae*, and the non-endangered *Freycenetia arborea*. Extent of threats by mongoose and rats on vegetation and entemofauna is not understood. Snail predation on native snails likely an important threat.

Current management and monitoring: Pig exclusion fences surround the bog area, and kahili ginger (*Hedychium gardernarium*) and *Psidium cattleianum* control is on going. All mature kahili ginger plants have been removed since 2003. Sphagnum moss control research is underway. Other incipient weeds such as Festuca arundiacaea are being controlled.

Vision statement/Fencing Need: Prevent rats from depredating seeds of native species, while at the same time assessing the largely unknown effects of rats in this ecosystem.



Proposed Location of Predator Control Fence, Kaala

Legend

- Rare Plant
- Proposed Predator Fence
- Parcels
- Existing Fences

Area: 2.21 Hectares
Perimeter 686.07 Meters

0 70 140 Meters

N

Marine Corps Base Hawaii (MCBH)'s Candidate Predator Fence Site Description With Attachments 1 and 2

Site Name: **Nu'upia Ponds Wildlife Management Area (WMA)**

Location: **Island of O'ahu, windward Ko'olaupoko Region, Mokapu Peninsula, between Kane'ohe Bay and Kailua Bay. Noteworthy: Hawaii State's Implementation Plan for Polluted Runoff Control lists this region as Priority One for watershed restoration attention.**

Ownership: **Marine Corps Base Hawaii (MCBH)**

Approximate area to be fenced: **Approx. 40 hectares in 2 areas (see Attachment 1): (a) 20 hectares of "central" Nu'upia Ponds where endangered waterbird nest and/or forage; (b) 20 acres in the "eastern" Nu'upia Ponds complex where similar bird nesting/foraging occurs. Note: Only the northern pond perimeter to be fenced. Shoreline-facing portion of these areas to remain unfenced since mammalian predators less likely to enter from this side. Also, undesirable to fence in mud along the water-facing border—Hawaiian stilt chicks would be trapped and prevented from foraging here. Attachment 2 shows concentrated nesting/foraging here—why areas critical to be fenced.**

Habitats/Ecosystem types: **Predominantly shallow water open mudflat within poikilohaline wetland habitat along northern perimeter of the ponds. Nu'upia Ponds is a unique tidally-influenced coastal wetland with variable salinity, ranging from saline (34ppt) on the Kane'ohe Bay side to hyperhaline (up to 130 ppt) on the Kailua Bay side, with dynamic salinity levels that vary with the rainfall regime. There are several man-made tributaries (e.g., stormwater runoff channels, culverts) and fresh ground-water upwelling locations, primarily along northern ponds perimeter, near where the birds congregate. A series of shallow, freshwater "potholes" (1 to 3 ft. deep, 15-20 ppt salinity, 10-20 feet in radius) occur in these areas. These provide valuable foraging grounds for endangered waterbirds & other waterfowl that feast on invertebrates here. Eastern pond margins are bordered by coastal sand dunes covered with healthy native beach strand vegetation, containing nesting burrows of protected wedge-tailed shearwaters. (Note: dunes to be excluded from fenced area, due to concern about shearwaters being trapped).**

Vegetation composition: **Within delineated wetland, (Attachment 2), predominant ground cover is invasive, non-native pickleweed (*Batis maritima*), with scattered clumps of other invasive, plant species, such as red mangrove (*Rhizophora mangle*), and Indian fleabane (*Pluchea indica*), which are controlled by management actions listed below. After significant removal of 25 acres of mangrove from the ponds over the past 25 years, native plants are recolonizing some mudflat areas: e.g., Milo (*Thespesia populnea*); native sedges (e.g., *Fimbristyllis cymosa)* and 'Akulikuli (*Sesuvium portulacastrum* or Sea purslane). The northern perimeter of the wetland habitat area (where fencing will be placed) is comprised of a band of scrub forest, which acts as a vegetative buffer between upland developed areas and the pond wetland habitat. This scrub forest grows on a slightly elevated band of fill land dominated by introduced vegetation: trees, e.g., koa haole (*Leucaena leucocephalas*), kiawe (*Prosopis pallida*); invasive shrubs and grasses (e.g., Christmas berry (*Schinus terebinthifolius*); California grass (*Brachiaria mutica*) and Guinea grass (*Panicum maximum*). Fencing to be anchored in upland area bordering the wetland perimeter.**

Threatened and Endangered species: **Shallow wetland mudflats of Nu'upia Ponds WMA comprise: a primary breeding/foraging habitat for endangered Hawaiian stilt; a documented foraging habitat for 3 other endangered Hawaiian waterbirds (i.e., H. Duck/Mallard hybrid; H. Coot, and H. Gallinule); and a recently documented nesting habitat for H. Coots and H. Duck/Mallard Hybrids.** ***Note: US Fish and Wildlife Service considers Nu'upia Ponds to be among several "core wetland areas on O'ahu for protection and management in order to recover" all 4 endangered waterbird species (2005, Second Draft Revised Recovery Plan for Hawaiian Waterbirds). It hosts about 120 stilts or nearly 10% of the state's total estimated population of these birds.***

Approx. Nos. of Each Species found at Nu'upia Ponds

Average totals from Counts over last 5 Yrs:	Approx. Range of Birds Counted Diff. Times of Year
Hawaiian Stilt – 120	60 to 160
Hawaiian Duck (Kola/Mallard Hybrids) – 21	6 - 99
Hawaiian Coot – 2	2 - 6
Hawaiian Gallinule – 2	2 - 6

(*Note: One reason for smaller numbers of Coot & Gallinule is their preference for freshwater wetlands elsewhere, while Stilt can tolerate a broader range of salinity).

Other important native species:

Vertebrate Birds: Nu'upia Ponds is an important foraging area for other birds such as Black Noddy (*Anous minutus melanogenys*);Black-crowned Night Heron (*Nycticorax nycticorax hoactli*);Bristle-thighed Curlew (*Numenius tahitiensis*); Long-billed Dowitcher (*Limnodromus scolopaceus*); Northern Pintail (*Anas acuta*); Northern Shoveler (*Anas clypeata*) ;Pacific Golden Plovers (*Pluvialis fulva*); Ruddy Turnstone (*Arenaria interpres);* Sanderling (*Calidris alba*);Wandering Tattler (*Heteroscelus incanus*); Wedge-tailed Shearwater (*Puffinus pacificus*); Pueo, Short-eared Owl (*Asio flammeus sandwichensis*)

Important, Migratory, but Less-Frequent Pond Visitors: Up to 50 different species recorded over about 50 years of records. Recent highlights: Caspian Tern (*Sterna caspia*);Black Brant (*Branta bernicula*); American Wigeon (*Anas americana*); Black-bellied Plover (*Pluvialis squatarola*);Blue-winged Teal (*Anas discors*);Bufflehead (*Bucephala albeola*);Common Tern (*Sterna hirundo*) ;Dunlin (*Calidris alpina*);Franklin's Gull (*Larus pipixcan*);Great Blue Heron (*Ardea herodios*);Greater Yellowlegs (*Tringa melanoleuca*);Green-winged Teal (*Anas crecca*);Hooded Merganser (*Lophodytes cucullatus*) ;Laughing Gull (*Larus atricilla*);Lesser Scaup (*Aythya affinis*);Lesser Yellowlegs (*Tringa flavipes*);Ring-billed Gull (*Larus delawarensis*);Semipalmated Plover (*Charadrius semipalmatus*); Whimbrel (*Numenius phaeopus*) ;White-faced Ibis (*Plegadis chihi*);Willet (*Catoptrophorus semipalmatus*)

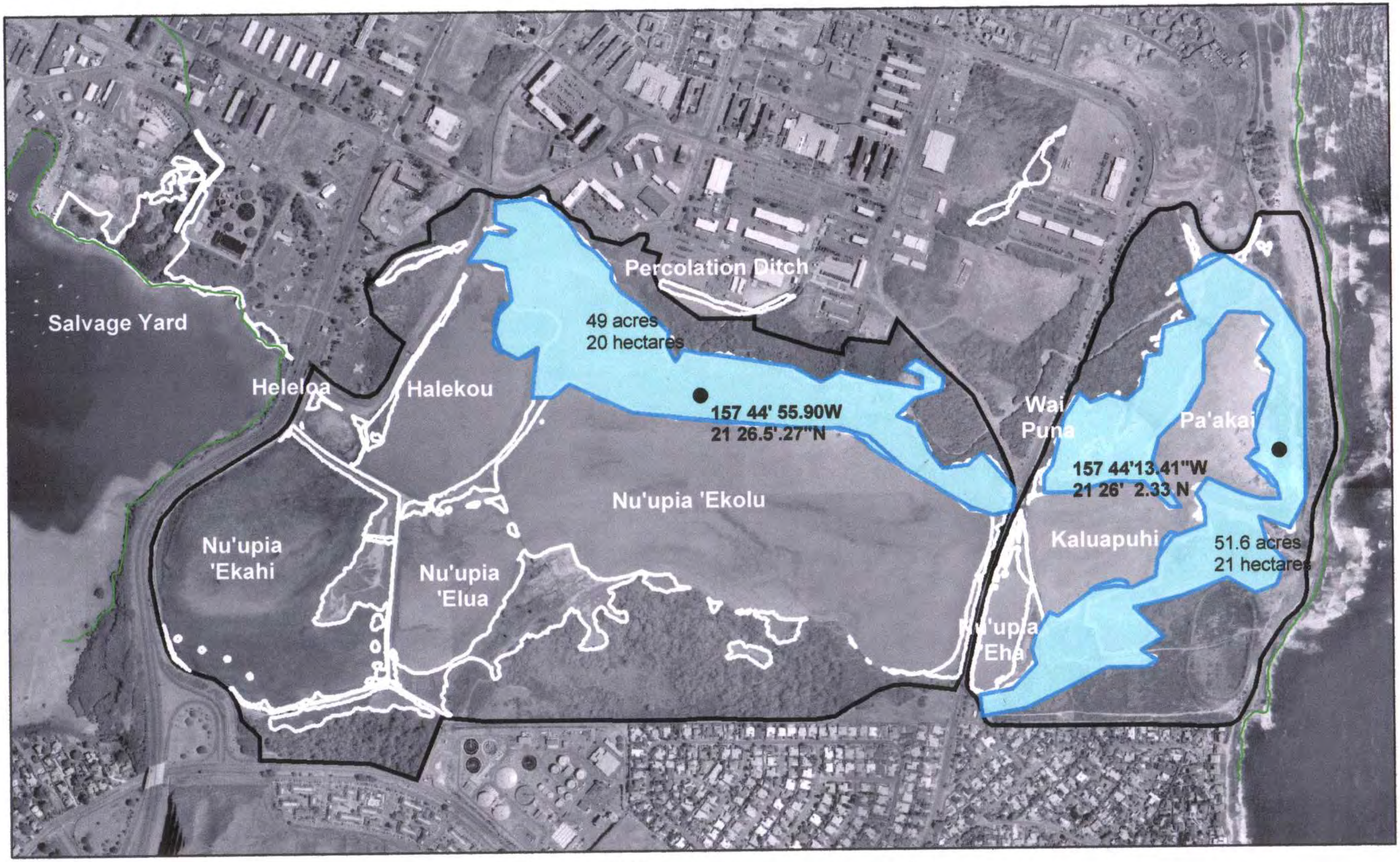
Aquatic Vertebrates: At least 16 species of native fish have been found in Nu'upia Ponds (Brock, 1994); commonly observed natives in/near this mudflat area are: 'Ama'ama Striped Mullet (*Mugil cephalus*), 'Aholehole (*Kuhlia sandvicensis*) and 'Awa (Milkfish, *Chanos chanos*). However, the predominant fish in the mudflat area are smaller non-native species (e.g., Mollies, P*oecilia Mexicana,* and Tilapia (*Oreochromis mossambica*), which are a food source for many birds.

Pest species: Primarily Mammalian Species: Mongoose (*Herpestes javanicua*); Rats (*Rattus exulans*; *Rattus norveicus*, and *Rattus rattus*);Cats (*Felis catus*);Dogs (*Canis familiaris*). Other predators: Cattle Egret (*Bulbulcus ibis*), Black-crowned Night Heron (*Nycticorax nycticorax hoactli*) and Pueo, Short-eared Owl (*Asio flammeus sandwichensis*) – These native birds can prey on waterbird birds and eggs.

Existing threats: Predation by pest species on endangered waterbird eggs and young.

Current management and monitoring: 25-year track record of regular manual weeding of invasive plant species (e.g., mangrove removal; pickleweed-plowing with tracked military vehicle assist); weekly predator trapping (feral cats, rats, mongooses); weekly bird monitoring (contractor project); bi-annual State-sponsored waterbird counts; annual Audubon Christmas counts; regular patrolling/enforced restrictions on unescorted human entry into area; prohibition of domestic pets (e.g., dogs, cats); boundary fence maintenance; signage, escorted tours/service projects.

Vision statement/Fencing Need: Fencing in one or both areas depicted would help support MCBH's Vision, Goals, Objectives detailed in our MCBH Integrated Natural Resources Management Plan (INRMP) Update (2006) pertaining to support of Hawaii endangered waterbird species recovery; restoration of healthy Hawaiian watersheds & wetlands; reduction of reliance on more costly labor-intensive manual trapping activities; and will support the INRMP-embraced ecosystem management principle of adaptive management by constantly seeking to use the latest available technological innovations and best management practices to improve effectiveness and reduce costs of INRMP actions we implement.



Blue Areas show
proposed areas protected
by predator fencing at Nuupia Ponds WMA

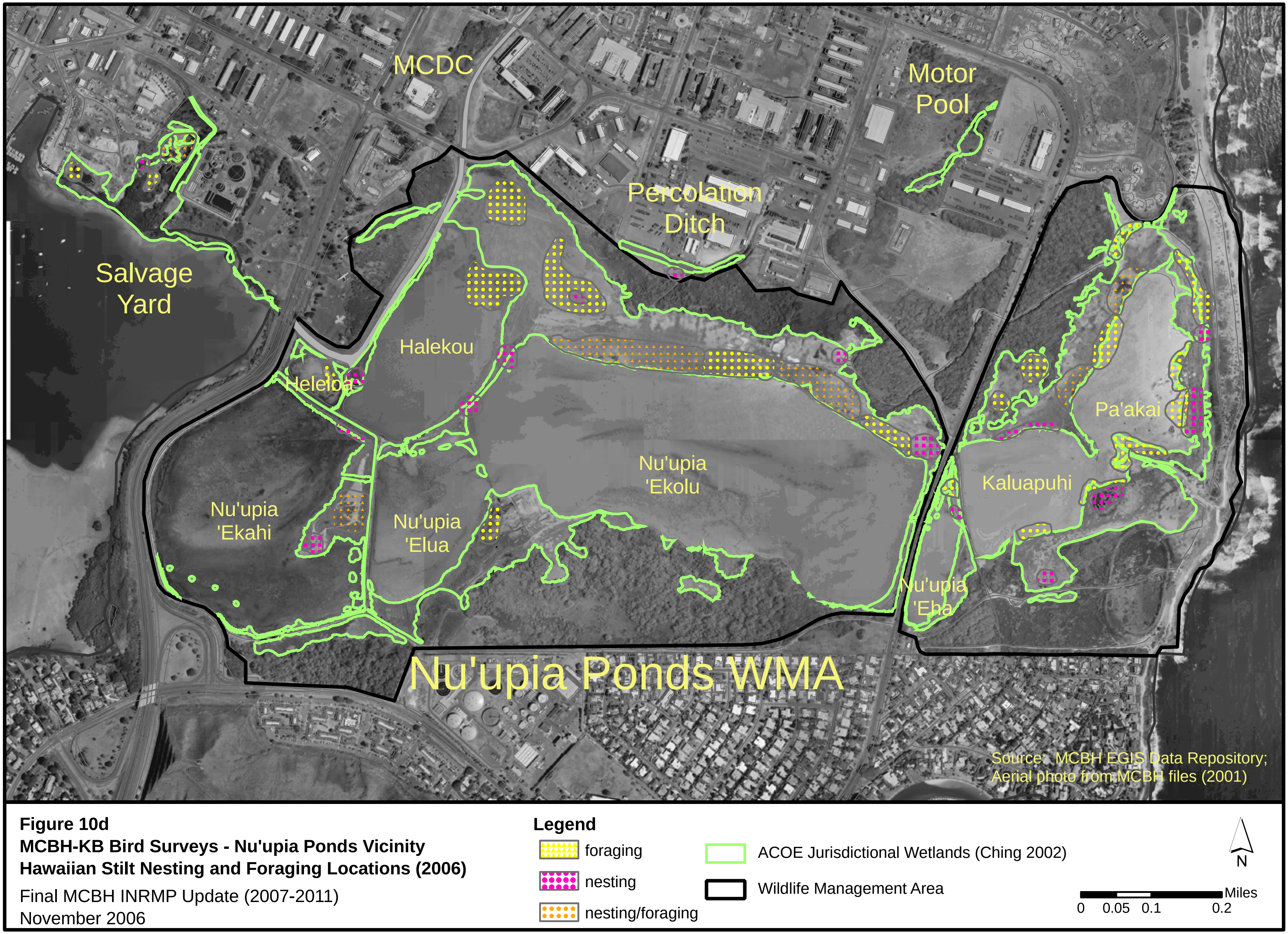


Figure 10d
MCBH-KB Bird Surveys - Nu'upia Ponds Vicinity
Hawaiian Stilt Nesting and Foraging Locations (2006)
Final MCBH INRMP Update (2007-2011)
November 2006

Candidate Predator Fence Site Description

This description is intended to provide information on potential fencing sites so that participants have the necessary information to rank the sites. The goal is to keep the description under 2 pages while still providing all necessary information.

Site Name: Mikilua *Amastra cylindrical* and *Achatinella mustelina* area.

Location: (Island, region, latitude and longitude of approximate center point or edge, attach map if necessary) Oahu, Mikilua Region of Lualualei Valley, Waianae Mountains.

Ownership: U.S. Navy

Approximate area to be fenced: (hectares) 3 hectares

Habitats/Ecosystem types: Please list all major habitat types present within the site (e.g. dry forest, mesic forest, wetland, coastal dune, etc.)

Mesic forest

Vegetation composition: Please briefly describe the dominant vegetation, both native and non-native species.

The A. mustelina and A. cylindrica areas are separated by tens of meters. The mesic forest contains both native and non native species including kolea (*Myrsine lessertiana*), maua (*Xylosma hawaiiense*), Christmas berry (*Schinus terebinthifolius*), papala kepau (*Pisonia sandwicensis*), kokio`keo`keo (*Hibiscus arnottianus*), and opuhe (*Urera glabra*).

Threatened and Endangered species: Please list all T&E species present at the site, and their approximate numbers if known. Place “CR” before any species that are critically endangered.

Achatinella mustelina
Amastra cylindrica (not listed, but this is considered the only extant population since it’s so rare. A listing has been suggested to FWS by other parties)

Other important native species: Please list any other important populations of plants, vertebrates, or invertebrates present.

Listed plant species are found nearby but none in this specific location.

Pest species: Please list all species of predators and ungulates present.
Euglandina sp.
Rats
Mongoose
Pigs
Goats (possible as some have been heard in the far side (Halona) of the valley).

Existing threats: Briefly describe the threats caused by predators and ungulates at the site.

The *A. cylindrica* population is very critical as it is considered the only extant population of this species on Oahu. During surveys only very few live snails have been found, along with several shells. Alien snails have been found at the *A. cylindrica* site and are strongly suspected to be predating on rare snails. Rats and mongoose are thought to be the main predators of both snails as rat damaged *A. cylindrica* shells (empty) have been found at the site. There are also pigs in the Mikilua district of Lualualei Valley, along with a few goats on the far (Halona) side of the valley.

Current management and monitoring: Please briefly list or describe current management (weeding, trapping, baiting, hunting, outplanting, etc) and monitoring conducted at the site, including duration and frequency.

The *Achatinella* population is not undergoing any current management. In the spring of 2007, trapping for rat and mongoose began for the *A. cylindrica* colony. Non-systematic surveys have been conducted in the area and more systematic surveys are planned for summer 2007. A landslide that occurred sometime during 2003/early 2004 impacted the mauka section of the *A. cylindrica* colony and the site has been evaluated for the value of a retaining wall or fence. A final decision has not been made about this, however, there is a concern about how robust the fence would have to be withstand another slide.

Vision statement/Fencing Need: Why do you want to build a fence? To protect a certain species? An ecosystem? A demonstration of feasibility?

A fence that would protect both rare snail colonies from predators, particularly the A. cylindrical colony, appears essential to manage the area. Although the *A. cylindrica* are not listed they are so rare that they were considered extinct in the wild. Ideally, the fence would protect the snails from alien snails, however, if this weren't feasible, it would still be very helpful to exclude rats and mongoose from the predator equation. The current predator control is limited by a long hike to the site and limited funds; a fence would allow us to do more for the two species on a long term and less costly manner.

Candidate Predator Fence Site Description

This description is intended to provide information on potential fencing sites so that participants have the necessary information to rank the sites. The goal is to keep the description under 2 pages while still providing all necessary information.

Site Name: Makaha Ridge

Location: (Island, region, latitude and longitude of approximate center point or edge, attach map if necessary): Kauai, Kokee region, adjacent to Kokee State Park and forest reserve.

Ownership: State of Hawaii, long term lease to U.S. Navy. DoD is responsible for management.

Approximate area to be fenced: (hectares) 99 hectares, but only need a fence running along the mauka side of the property (state forest edge, near the guard shack), ending at the cliff edge.

Habitats/Ecosystem types: Please list all major habitat types present within the site (e.g. dry forest, mesic forest, wetland, coastal dune, etc.) : *Myoporum sandwicense* (naio) dry cliff community and *Pinus elliottii* (slash pine) dry shrubland/grassland

Vegetation composition: Please briefly describe the dominant vegetation, both native and non-native species.

Thirteen endemic species include: *Artemisia australis* (ʻāhinahina), *Bidens sandwicensis* (koʻokoʻolau), *Carex wahuensis, Gahnia beecheyi, Pteridium aquilinum* var. *decompositum, Acacia koa* (koa), *Scaevola gaudichaudii* (naupaka kuahiwi), *Eragrostis variabilis* (kāwelu), *Panicum torridum* (hākonakona), *Doryopteris decipiens* (kumuniu), *Selaginella arbuscula* (lepelepe a moa), *Spermolepis hawaiiensis,* and *Wilkesia hobdyi* (dwarf iliau). Besides *Spermolepis hawaiiensis,* and *Wilkesia hobdyi* which are listed as Endangered by the U.S. Government (USFWS 1999), the other eleven endemics are quite common with the majority of them occurring on many of the other high islands of Hawai`i.

The fourteen indigenous species include: *Cyperus polystachyos, Leptecophylla tameiameiae* (pūkiawe), *Dianella sandwicensis* (ʻukiʻuki), *Sida fallax* (ʻilima), *Cocculus orbiculatus* (huehue), *Myoporum sandwicense* (naio), *Digitaria setigera* (kūkaepuaʻa), *Psilotum nudum* (moa), *Psydrax odorata* (alaheʻe), *Dodonaea viscosa* (ʻaʻaliʻi), *Chrysopogon aciculatus* (mānienie ʻula), *Heteropogon contortus* (pili), *Solanum americanum* (pōpolo), and*Waltheria indica* (ʻuhaloa).

Threatened and Endangered species: Please list all T&E species present at the site, and their approximate numbers if known. Place "CR" before any species that are critically endangered.

There is a small population of nene at the site (highest number of 10). Recent monitoring has found that they are not attempting to nest at Makaha Ridge any longer, as their habitat is so dessimated by goats.

In April 2006 Ken Wood observed and mapped eleven colonies of *Wilkesia hobdyi* in and adjacent to the Makaha PMRF boundaries. These colonies ranged between 1320–1680 ft (402–512 m) elevation and totaled 214 individuals. 126 of those individuals were within the facility boundaries and the remaining 88 were just outside. All plants were confined to vertical regions of the cliffs and most were seen clustered in small groupings.

During that same survey, two significant colonies of *Spermolepis hawaiiensis* on north facing, precipitous slopes around the PMRF Makaha site were found. The first colony occurred along the north-northeast facing cliffs over Makaha Valley and was in association with *Wilkesia hobdyi*. This colony contained approximately 500 individuals which grew at elevations between 1300–1500 ft (ca. 396–457 m). The colony of *Spermolepis* ran a distance of ca. 975 m. The second colony occurred on steep north facing valley walls to the south of the PMRF Helicopter Landing Zone. This grouping contained around 200 individuals. No plants were observed on the western facing cliffs.

Other important native species: Please list any other important populations of plants, vertebrates, or invertebrates present.

Pest species: Please list all species of predators and ungulates present : Goats

Existing threats: Briefly describe the threats caused by predators and ungulates at the site.

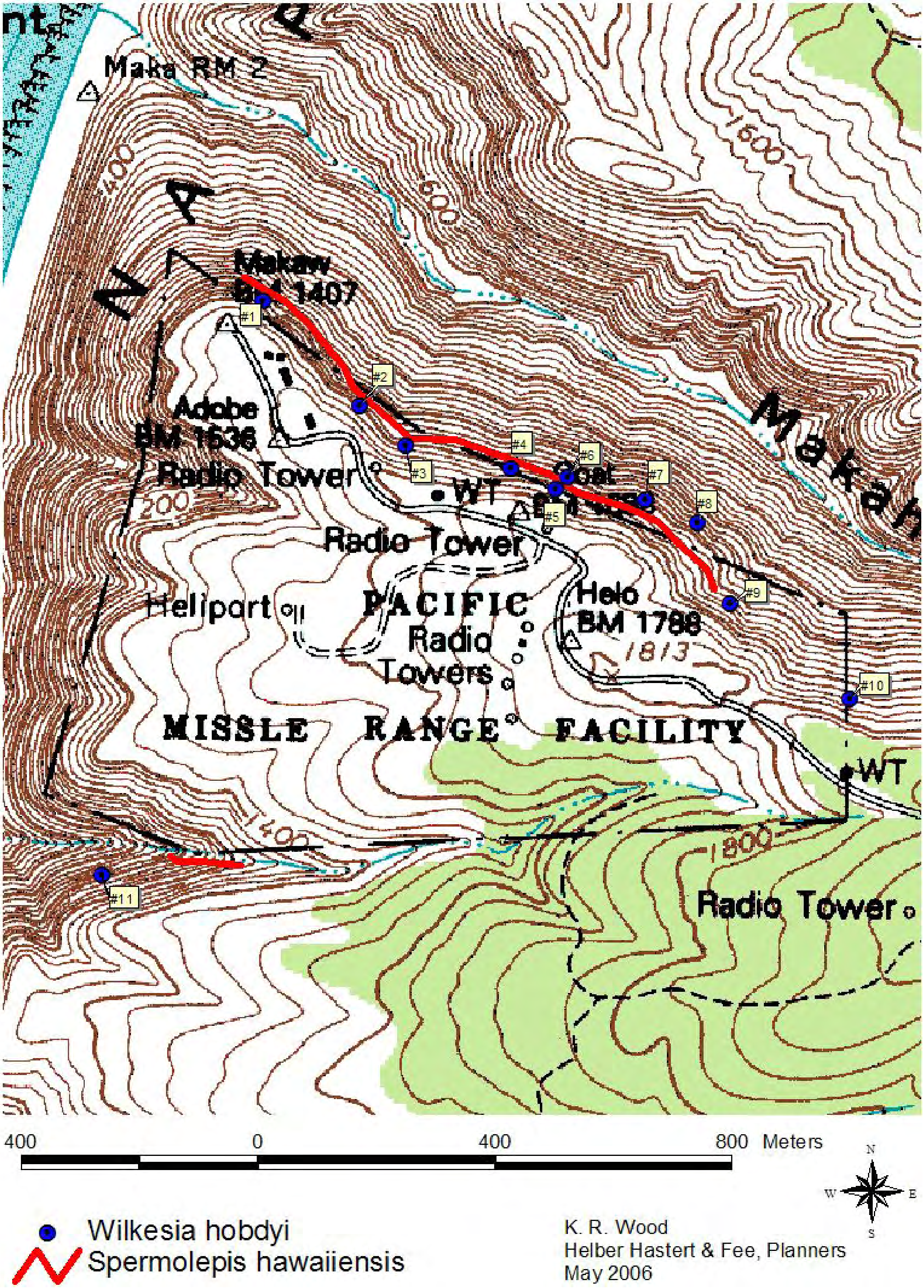
Goats are present in high numbers at the site and have caused extensive erosion. The W. hobdyi and S. hawaiiensis, along with virtually all dry cliff plant species are not present until areas far enough down the cliff sides that the goats cannot reach them. The flat area of Makaha Ridge is also barren in large areas due to grazing. The goats also harass the nene and trample their nests.

Current management and monitoring: Please briefly list or describe current management (weeding, trapping, baiting, hunting, outplanting, etc) and monitoring conducted at the site, including duration and frequency.

No hunting is currently allowed at the site, however, this policy is being reevaluated. Nene are monitored and most have bands (done in cooperation with the state. Suggested management has included installing small “test” exclosures to collect data (proof) for the command that goats are indeed the cause of the erosion. Very little management is currently being done at this site.

Vision statement/Fencing Need: Why do you want to build a fence? To protect a certain species? An ecosystem? A demonstration of feasibility?

We would like to build a fence to exclude goats from the site and allow for us to restore the area to native vegetation. The fencing will protect both listed flora and fauna from goats and the resulting erosion. The goat situation has become so severe that the nene have stopped nesting and the dry cliff communities have been reduced to sparse naio (the goats don’t like the way it tastes) where the goats can reach. The goats come and go between the adjacent state managed land and the Navy property. The protection of this rare ecosystem is important not only to the three listed species, but to protect the infrastructure at the site close to the cliff edge.


Maka RM 2
Makaw BM 1407
Adobe BM 1536
Radio Tower
WT
Goat
Radio Tower
Heliport
PACIFIC
Radio
Towers
Helo BM 1788
1813
MISSLE RANGE FACILITY
WT
Radio Tower
Makah
1600
600
400
200
1400
1800
#1
#2
#3
#4
#5
#6
#7
#8
#9
#10
#11
400 0 400 800 Meters
N
W
E
S
Wilkesia hobdyi
Spermolepis hawaiiensis
K. R. Wood
Helber Hastert & Fee, Planners
May 2006

Candidate Predator Fence Site Description

This description is intended to provide information on potential fencing sites so that participants have the necessary information to rank the sites. The goal is to keep the description under 2 pages while still providing all necessary information.

Site Name: Puu Hapapa Exclosure

Location: (Island, region, latitude and longitude of approximate center point or edge, attach map if necessary) Mikilua district of Lualualei Valley, see attached map for location of exclosure (vertex of points 1, 6, and 17).

Ownership: U.S. Navy

Approximate area to be fenced: (hectares) 2-3 (cliff on mauka side)

Habitats/Ecosystem types: Please list all major habitat types present within the site (e.g. dry forest, mesic forest, wetland, coastal dune, etc.)

Mesic forest

Vegetation composition: Please briefly describe the dominant vegetation, both native and non-native species.

The current Puu Hapapa exclosure is on a steep, north-facing slope, and surrounds a lama (*Diospyros sandwicensis*) forest. This exclosure has been experiencing encroachment by invasive non-native species which are competing with the endangered plants. Predominant plant species in the Puu Hapapa exclosure are: Native canopy species: lama, hao *(Rauvolfia sandwicensis)*, and *Hibiscus arnottianus* var. *arnottianus.* Non-native canopy species: Christmas berry (*Schinus terebinthifolius*) and silk oak (*Grevillea robusta*). Native understory species: nioi (*Eugenia reinwardtiana*), halapepe (*Pleomele forbesii*), `awikiwiki (*Canavalia galeata*), ko`oko`olau (*Bidens torta)* and papala (*Charpentiera obovata*). Non-native understory species: air plant (*Kalanchoe pinnata),* coral berry ((Ra*vina humilis*), and passion flower (*Passiflora suberosa*).

Threatened and Endangered species: Please list all T&E species present at the site, and their approximate numbers if known. Place "CR" before any species that are critically endangered.

- Mehamehame (*Flueggea neowawraea*) – one (marginal health but hanging on)
- *Bonamia menziesii*: one (has not been confirmed alive since 2002 when it was observed flowering).
- *Nototrichium humile*: four
- *Abutilon. sandwicense*: approximately 20 in the fenced exclosure and another 20-30 just mauka outside the fence. Few are adults.
- *Lipochaeta lobata*: This population has not been observed in the exclosure since 1996.

Other important native species: Please list any other important populations of plants, vertebrates, or invertebrates present.

The Mikilua subdistrict of Lualualei has many other species of rare plants in the near vicinity (see attached figure).

Pest species: Please list all species of predators and ungulates present.

The area is fenced (installed in 1994) to exclude ungulates, but does not currently exclude rats, mongoose and alien snails.

Existing threats: Briefly describe the threats caused by predators and ungulates at the site.

Predators such as rats and mongoose are suspected of eating the seeds of the listed plants limiting their recruitment inside and outside the exclosure. The fence is aging, so ungulates may become a problem in the near future.

Current management and monitoring: Please briefly list or describe current management (weeding, trapping, baiting, hunting, outplanting, etc) and monitoring conducted at the site, including duration and frequency.

An approximately one-half acre parcel was fenced in 1994. The fence is aging, but looks to be in pretty good shape. It excludes ungulates but not rats or mongoose. The surrounding forest contains *Hibiscus arnottianus*, more *Pleomele forbesii*, and many more *A. sandwicense*. Currently, the Navy and contractors regularly visit the site to control invasive plant species (mostly *Passiflora*) in the exclosure. No predator control is underway and invasive plant species are not controlled outside of the exclosure. Monitoring, tagging and collection of samples (cuttings and seeds) are conducted at least yearly by Navy and Army biologists. Cuttings from the *F. neowawraea* and *N. humile* are represented at the Army nursery; *A. sandwicense* is represented at Lyon Arboretum.

Vision statement/Fencing Need: Why do you want to build a fence? To protect a certain species? An ecosystem? A demonstration of feasibility?

We would like to expand and improve our current fence to include the large population of *A. sandwicense* outside the exclosure, as these plants are currently not under any protection. Due to our limited management budget, a longer-lived and more exclusive fence would allow for better protection for four species of listed plants and hopefully more natural recruitment of seedlings with the exclusion of rats and mongoose.

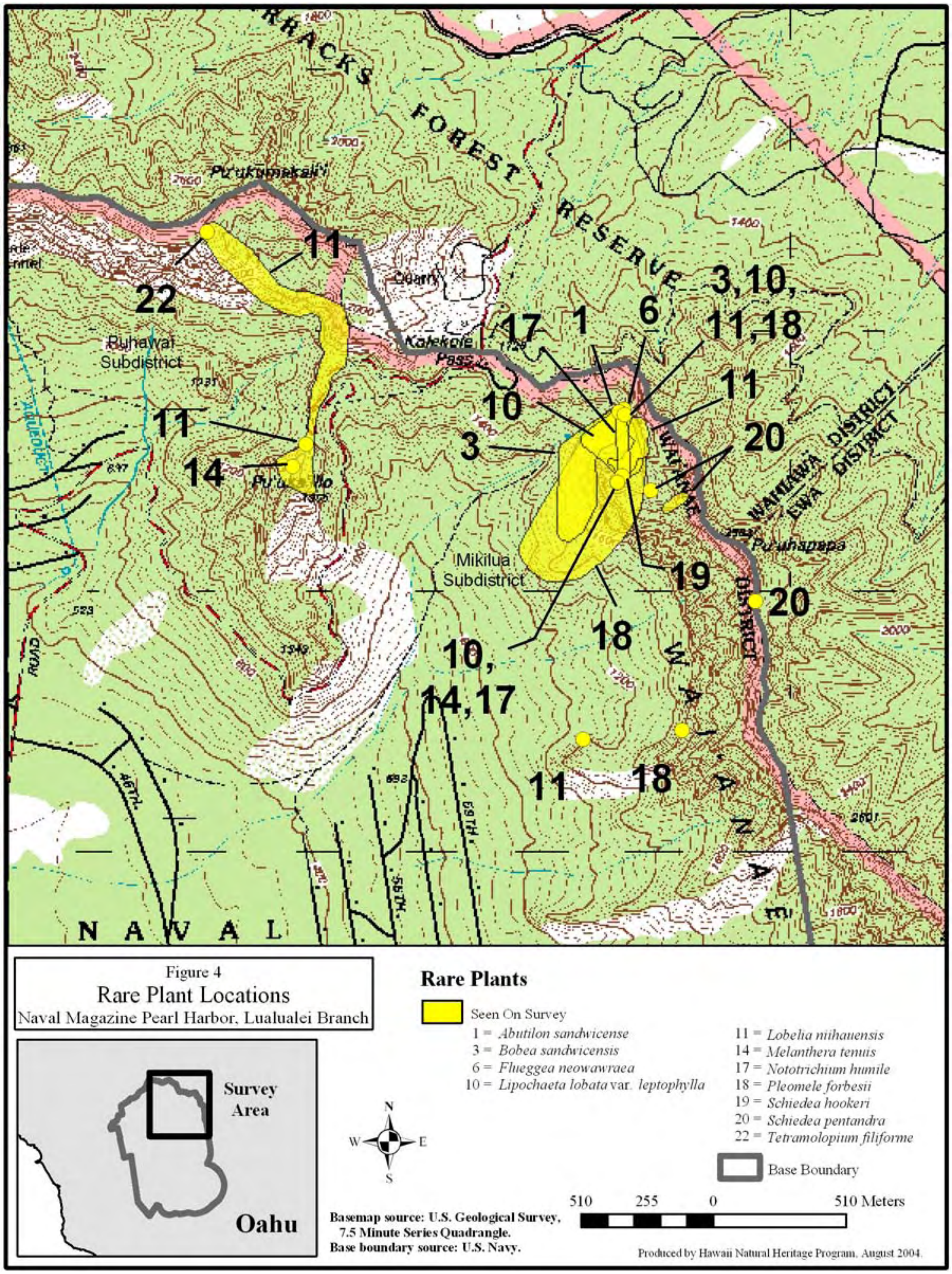


Figure 4
Rare Plant Locations
Naval Magazine Pearl Harbor, Lualualei Branch

Candidate Predator Fence Site Description

This description is intended to provide information on potential fencing sites so that participants have the necessary information to rank the sites. The goal is to keep the description under 2 pages while still providing all necessary information.

Site Name: Niulii Ponds Wildlife Refuge (and adjacent area)

Location: (Island, region, latitude and longitude of approximate center point or edge, attach map if necessary): Oahu, Lualualei Valley, NCTAMS RTF and edge of NAVMAG LLL installations.

Ownership: U.S. Navy

Approximate area to be fenced: (hectares) about 40 hectares

Habitats/Ecosystem types: Please list all major habitat types present within the site (e.g. dry forest, mesic forest, wetland, coastal dune, etc.): Dry forest and manmade wetland

Vegetation composition: Please briefly describe the dominant vegetation, both native and non-native species.

1. Predominantly kiawe-bufflegrass community contains *Prosopis pallida, Cenchrus ciliaris, Pluchea indica, Gossypium tormentosum, Sida fallax, Waltheria indica.*
2. Wetland (a sewage oxidation pond). There are two ponds, both of which are surrounded by a road. Vegetation includes *Gossypium tormentosum, Sida fallax, Jacquemontia sandwicensis, Leonitis nepetifolia, Sida fallax, Bacopa monnieri* and *Waltheria indica*.

Threatened and Endangered species: Please list all T&E species present at the site, and their approximate numbers if known. Place "CR" before any species that are critically endangered.

Abutilon menziesii (10 adult plants), *Anays wyvilliana* (hybridized with *Anas platyrhynchos*)
Fulica alai, Gallinula chloropus sandvicensis, Himantopus mexicanus knudseni

Other important native species: Please list any other important populations of plants, vertebrates, or invertebrates present.

Adjacent to (within 100m) of areas containing *Cyperus trachysanthos* and *Marsilea villosa.* These fall within the antenna fields and are not fenceable.

Pest species: Please list all species of predators and ungulates present.

Nycticorax nycticorax hoactli
Bubulcus ibis
Rattus rattus
Felis catus
Herpestes auropunctatus
Adoretus sinicus

Tilapia mozambique (when introduced to the ponds)

Existing threats: Briefly describe the threats caused by predators and ungulates at the site.

The most numerous predator found at the pond area is the mongoose, followed by cats and rats. Dogs occasionally enter the fenced area and harass or kill the waterbirds using the pond. The number of cattle egrets that utilize the ponds vary. There are plenty of prey items for the cattle egrets at Lualualei as the follow the tractors mowing the large antenna fields and also roost in a kiawe over the ponds. Black-crowned night herons utilizing the ponds are in low numbers (typically 1-2). Tilapia were introduced into the ponds in 2005 and controlled by 2007. However, the potential for re-introduction remains high.

Insects like Chinese rose beetle impact the *A. menziesii* leaves and seeds. Pigs have not been observed in the immediate area, but appear to be moving down into lower LLL since hunting has not been allowed in the valley since 9/11. This is an ongoing concern.

Current management and monitoring: Please briefly list or describe current management (weeding, trapping, baiting, hunting, outplanting, etc) and monitoring conducted at the site, including duration and frequency.

The area immediately surrounding Niulii Ponds wetland (and perimeter road) is fenced. However, the rest of the refuge and the areas around the *A. menziesii* are not. USDA is under contract ($20k/year) to conduct every-other-day site visits to the ponds to check their live traps. NAVFAC Pacific biologists have been conducting water bird counts twice monthly since 2003. The ponds are dependent on the flow of storm water runoff and wastewater effluent from the naval magazine. Personnel are no longer housed on the base, so the inflow of water decreased significantly in the past 10 years. A waterline to one of the ponds was established in April 2005.

All listed plants in this area and adjacent areas are monitored twice monthly. Ongoing management includes both manual and power tool removal of invasive species that are encroaching on the listed plants, and collection of seeds for storage and research at Lyon Arboretum. Protective fences to demarcate the area against inadvertent impacts (e.g. from people) are planned for summer 2007 but will not protect from ungulates.

Vision statement/Fencing Need: Why do you want to build a fence? To protect a certain species? An ecosystem? A demonstration of feasibility?

As mentioned, Niulii Ponds is fenced, but the fence design is such that many predators still make it through. The rest of the refuge is not fenced, and contains one of the only wild populations of *A. menziesii* on Oahu. We'd like to fence the entire refuge to provide protection for the 5 listed flora and fauna species. This would allow us to more effectively manage these species with our limited resources. If the area is proven to be too large or the area too complex for one fence, it would be feasible to install three different fences (*A. menziesii* are separated by several hundred meters). The terrain is relatively flat and all areas are easily accessible by roads.

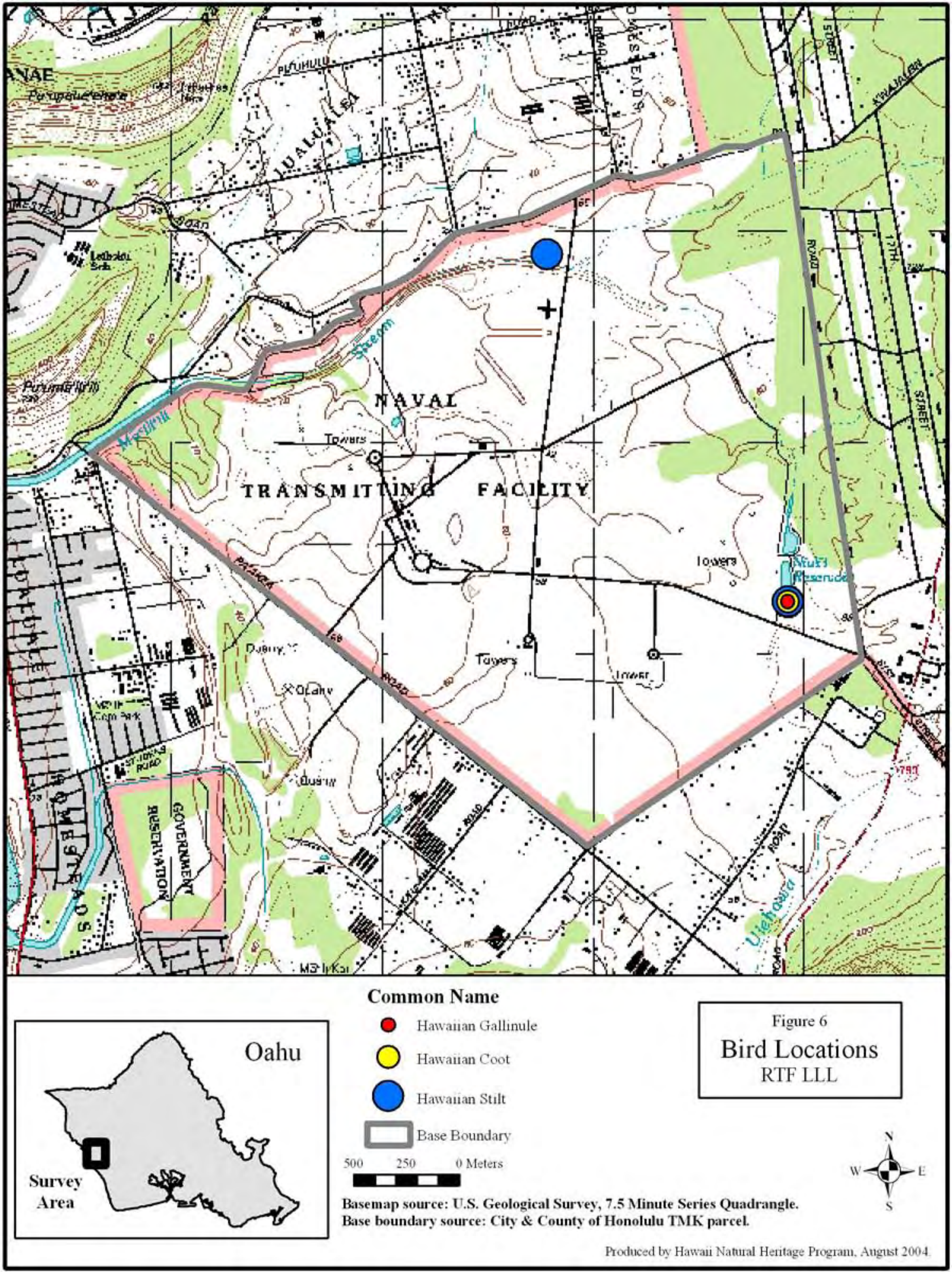
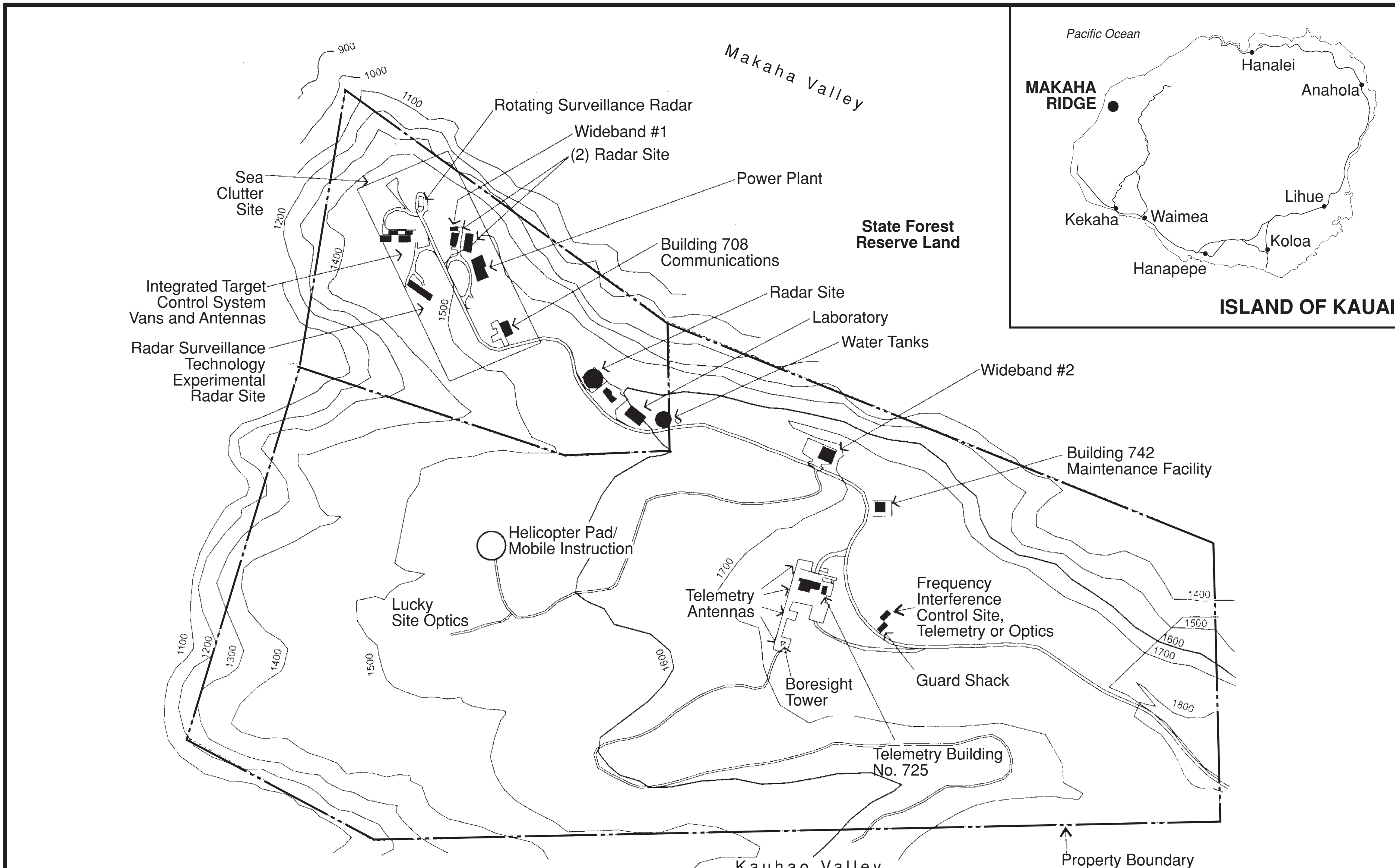


Figure 6
Bird Locations
RTF LLL



Source: Department of the Navy. 1998. *PMRF Enhanced Capability FEIS. Vol. 1.*

1999.82.0603/001-2 k5/24/01

NORTH

0 200 400
SCALE IN METERS

0 300 600 1200
SCALE IN FEET

LEGEND

Existing Facilities/Landmarks

Contour Lines (ft)

Note: All locations are approximate.

Figure 2-1
PMRF SUPPORT FACILITIES, MAKAHA RIDGE

Integrated Natural Resource Management Plan
Pacific Missile Range Facility

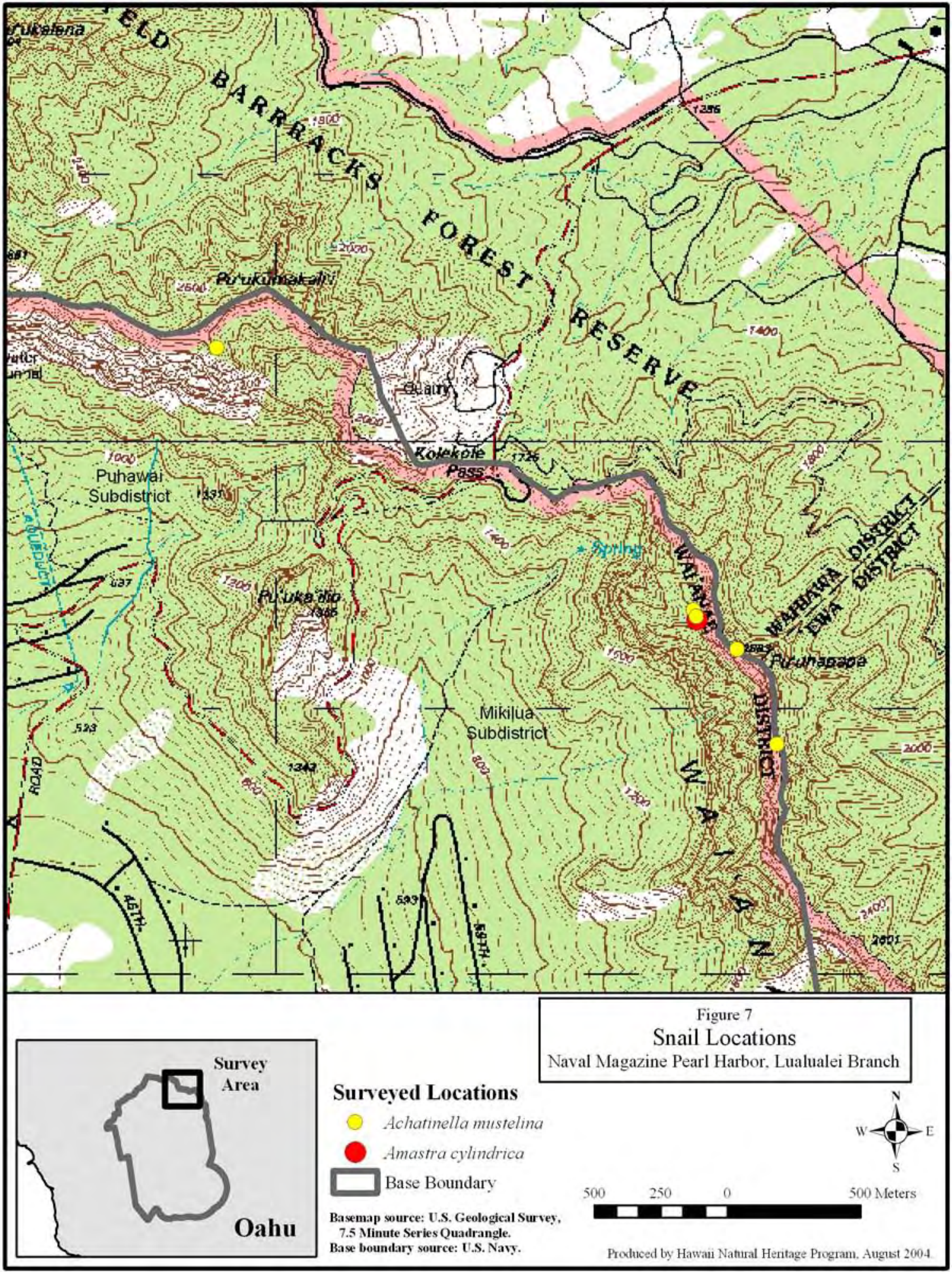


Figure 7
Snail Locations
Naval Magazine Pearl Harbor, Lualualei Branch

APPENDIX 4: SITE PRIORITIZATION CRITERIA

1. Number of Listed Species Scale: 0-total # species Weighting: 1.0

Protection and recovery of species listed under the U.S. Endangered Species Act is one of the primary goals of the Legacy predator fencing project. The number of listed species present at a site is therefore an important factor in considering which sites are of highest priority. One point is awarded for each listed species present. This should include only species present in the portion of the installation being considered for fencing, which may not be the same as the total found on the installation as a whole.

2. Urgency of Listed Species Scale: 0-total # species Weighting: 1.0

Species under greater threat of extinction should be considered higher priority than species for which extinction risk is less urgent. One additional point is awarded for each species considered to be critically endangered. The IUCN Red List classifies animal species into levels of urgency. The IUCN list does not include plants, so whether a plant is critically endangered may be more subjective. Species that are extinct in the wild obviously are critically endangered, and those with only a few individuals, perhaps fewer than 100, also should be considered critical. Other species may qualify if the entire population faces serious imminent threats. Information useful for making this judgment should have been provided on the site description forms.

3. Other At-risk or Sensitive Species Scale: 0-total # species Weighting: 0.5

Not all species in need of protection are listed under the U.S. Endangered Species Act. These species also deserve some consideration, though they may be lower priority. Examples of such species include candidates for listing, species of concern, species that have been overlooked by regulatory agencies, and populations or varieties that are unusual or ecologically important in some way. One point is awarded for each sensitive species present at a site, but this criterion is weighted by a factor of 0.5.

4. Species Diversity Scale: 1-5 Weighting 1.0

Sites that support a variety of native plants, invertebrates, and vertebrates should be ranked higher than sites that support only a few native species. For example, sites dominated by alien species and that support few or no native plants or animals should be scored 1, sites that have some native plants but are lacking native animals (and vice versa) might scored 2 or 3, and sites with more intact native ecosystems composed of numerous native plants and animals should be scored 5.

5. Sensitive or Important Habitats Scale: 1-5 Weighting 1.0

Another important goal of the Legacy predator fencing project is protection and restoration of native habitats. Many of the listed and sensitive species considered in the previous criteria cannot survive unless the habitat(s) on which they depend are also protected or restored. Habitats may be considered sensitive if they are rare (e.g., wetlands) or if much of that habitat type has been lost (e.g., dry forest). Habitats also may be important if they support numerous native species (e.g., native mesic and wet forest). Sites should be ranked higher if they contain a substantial amount of a sensitive native habitat. Sites with little or no native habitat should be ranked lower.

6. Restoration Potential Scale: 1-5 Weighting 0.5

Some sites may not currently contain important native habitats or endangered species but may have potential for habitat restoration and species reintroduction. However, this criterion is weighted by a factor of 0.5 because the goal is to identify the highest priority sites where fencing will produce the greatest benefits. Habitat restoration and species reintroduction are valuable long-term goals but would require an additional step and additional costs. Sites where restoration or reintroduction would be easier should be ranked higher, and sites where it may be possible to restore more habitat or reintroduce a larger number of species also should be ranked higher.

7. Need/Severity of Impacts Scale: 1-5 Weighting 1.0

The effects of invasive species are more serious at some sites than at others. Just because alien species are present at a site does not mean a fence is needed to exclude them. Sites where listed species or sensitive habitats are currently experiencing serious impact from predators should be ranked higher. Sites where impacts are less severe or where there is only potential for impact should be ranked lower. Sites where impacts are unknown might receive a moderate score.

8. Substrate Scale: 1-5 Weighting 1.0

Existing predator fence technology was developed for sites with a soil or solid rock subtrate. Soil is the easiest subtrate to work with. Solid rock is difficult but feasible. Other substrates may require modification of existing technology, but until modifications are tested their effectiveness cannot be guaranteed. For example, mice may be able to travel under a fence using interstitial spaces present in `a`a lava. Cementing the underground fencing skirt to the substrate appears to solve this problem, but this technology has been tested on only a limited basis. Pahoehoe lava may present a similar but more serious problem because it may contain larger and more irregular underground passages that could allow access for larger animals such as rats. It may be possible to locate and seal such underground passages or come up with another solution, but this might pose a problem.

9. Accessibility Scale 1-5 Weighting 1.0

Greater accessibility will obviously make it easier and cheaper to construct a fence and may influence the effectiveness of the fence. Accessibility includes ability to deliver fence materials and equipment to the site, ease of construction by fencing crews, and ability to follow prescribed fencing specifications. Road access would make it easier and cheaper to deliver materials, fencing crews could reach the site faster and move around the site more quickly, and might allow use of heavy equipment to prepare the site. Narrow ridges or steep slopes would preclude vehicle access and might make it difficult to create the desired vegetation clearance around the fence. Helicopter access may be an option for delivery of materials, but would be more costly and could present additional logistical difficulties, and use of heavy equipment might be precluded.

10. Technical Feasibility Scale 1-5 Weighting 1.0

Appropriate technology or designs may not exist yet for all desired fence applications. For example, there is an urgent need to protect native snails from predation by the alien predatory snail *Euglandina rosea*, but the technology needed to eradicate and then exclude *Euglandina* has not been perfected. Similarly, slugs may be important predators on endangered plant seedlings, but methods for excluding and eradicating slugs are not yet available. Presence of unexploded ordnance also may make some sites technically challenging. Sites where there is known to UXO that could inhibit ground disturbance for fence construction and use of equipment should be ranked lower.

11. Existing Management and Monitoring Scale 1-5 Weighting 1.0

It will be necessary to measure the effectiveness and success of a fence. Measures of success should include exclusion of the pest species in question, improvement in targeted native species or habitats, and cost-effectiveness compared to other management methods. If monitoring and management programs already exist at a site, then base-line data on the resources present and the cost of previous management can be used to better measure the success of a predator fence. Sites with long-term monitoring of the species or habitats of interest and efficacy of existing management should be ranked 5, sites where there has been no monitoring to date should be scored 1, sites with some level of monitoring should be given an intermediate score.

12. Compatibility with Military Training Scale 1-5 Weighting 1.0

All sites being considered are owned or used by the U.S. military, and some sites are used for active training and other purposes. It is possible construction of fences in certain areas could interfere with training. Sites with higher potential for conflict between fencing and training should be ranked lower.

13. Environmental Compliance Approval Scale 1-5 Weighting 1.0

Before a fence can be constructed it may be necessary to complete an environmental review, including NEPA documents and State of Hawaii environmental documents. This may have already been completed for some sites, which would speed the process. For example, sites where the compliance process has not been started could be scored 1, sites where compliance has been started or will be easily achieved could be scored 3, and sites where compliance documents are done would be a 5.

14. Cost/Benefit Advantage Scale 1-5 Weighting 1.0

Predator fences are expected to be more cost-effective than perpetual predator removal, but the degree of benefit may vary among sites depending on the size of the site, the species of predators to be excluded, difficulty of eradication within the exclosure, and other factors. It is possible that some species or habitats can be managed as cost-effectively using other methods. Sites should be ranked higher if predator fences are expected to result in greater savings for the same benefit to native species.

15. Potential for vandalism or other damage Scale 1-5 Weighting 1.0

Fences may be vandalized or accidentally damaged, which would incur repair costs and possibly increase the chance of predators getting inside. Vandalism may be more likely in areas with public access or lower security, and accidental damage may be more likely if fences are immediately adjacent to active roadways or training areas.

Cost. Cost should not be used to prioritize sites at this time. The current prioritization process will be based on biological, technological, and logistical factors. Cost obviously will have to be considered if and when a fence is constructed, but the current goal is to identify sites with the greatest need for predator fencing and where fencing would provide the greatest advantage, regardless of cost.

APPENDIX 5: SITE VISIT SUMMARIES

Pohakuloa Training Area *Solanum incompletum* site, Hawaii (Army)

Existing predator control and impacts:
This site is not currently enclosed in an ungulate fence, but fencing is underway. Rats are controlled using diphacinone in bait stations, but the efficacy is not well known.

Native species present and existing monitoring:
The proposed fence is 9 hectares in size and includes three endangered plant species: *Solanum incompletum* (four individuals), *Silene lanceolata* (approximately 21 individuals), and *Zanthoxylum hawaiiense* (five individuals). The terrain is similar throughout the area and the fencing route and area could easily be shifted to include additional rare plants and maximize cost-effectiveness. Three of four Solanum plants in the small existing exclosure were recently killed. The last live plants has gnaw marks indicative of rodents, probably rats. The only native bird that is regularly present in the area is the Hawaii Amakihi (Hemignathus virens), and it is common. Other native bird species that have been observed nearby include Apapane (*Himatione sanguinea*), Nene (*Branta sandvicensis*), Pueo (*Asio flammeus*), and Hawaii Elepaio (*Chasiempis sandwichensis*). The site could provide a good opportunity for testing the efficacy of predator fencing at reducing nest predation for these and other bird species by conducting artificial nest experiments with nests placed on the ground and in trees inside and outside the fence.

Potential as a demonstration site:
The site is readily accessible by somewhat rough but passable crushed lava road and has high potential to be a suitable demonstration site. There is a good time window in which to make a variety of comparisons about the impacts of predators and ungulates by collecting data inside and outside the predator fence, and before and after the ungulate fence is completed. Most of the endangered plant species in the area have been grown in the greenhouse, but survival of outplantings has been poor. The predator fence would provide a suitable location in which to outplant all of the endangered plants from PTA, including several not currently found in the immediate fenced area, thereby advancing conservation of numerous plant species.

Kahanahaiki, Makua Military Reservation, Oahu (Army).

Existing predator control and impacts:
Pest species present in the area are *Rattus rattus, Rattus exulans, Mus musculus, Felis catus,* the small Indian mongoose (*Herpestes javanicus*), and the predatory snail *Euglandina rosea.* Kahanahaiki is already protected from feral ungulates by a hogwire mesh fence.

Native species present and existing monitoring:
This site in the northern Waianae Mountains supports diverse native mesic forest and supports several endangered plant species, including *Schidea obovata, Cenchrus agrimonioides, Schiedea nuttallii,* and *Cyanea superba,* a large an important population of the endangered tree snail *Achatinella mustelina,* and a single female of the endangered

Oahu Elepaio (*Chasiempis sandwichensis* ssp. *ibidis*). There has been extensive monitoring on plants, snails, birds and pest species at this site.

Potential as a demonstration site:
Because the Kahanahaiki area has been managed and monitored intensively since 1996, it provides an excellent opportunity to compare the costs of predator fencing with methods currently in use, and also to evaluate any improvements in resource protection provided by predator fencing. It is also large enough in size to begin to examine ecosystem effects of predator proof fencing and would be an excellent demonstration site.

The size of the fenced area originally proposed by the Army was 10 hectares, with a perimeter of approximately 1300 meters. The route follows the existing ungulate fenceline on the east, south, and west sides. This portion of the fence would be relatively easy to construct because much of the ground is relatively level and has already been prepared to some degree. Three options were considered for the northern boundary: 1) the maile flats area as proposed; 2) a larger area that would include the upper portion of Kahanahaiki Gulch; and 3) a still larger area that would encompass even more of Kahanahaiki Gulch. Based on examination of the terrain on foot, Xcluder strongly recommended the first option, but determined that, if desired, a slightly larger area could be fenced more cost effectively by moving the northeast corner to the north. A fence in this area would require a medium amount of maintenance, minimal vegetation clearing and has good access for crews and equipment. The army crew are also very enthusiastic and supportive of this project and likely would have a fencing crew that could be available to help with site preparation.

The Elepaio territory now contains only a lone female, there are no Elepaio pairs in Kahanahaiki. However, this site is large enough that it could provide sufficient habitat for a small population of Elepaio consisting of approximately 10 breeding pairs. If the site is fenced and predators are eradicated, it would be an excellent spot in which to reintroduce Elepaio, using either rear and release techniques or release of captive bred birds. Whether nest predation has been reduced could be tested prior to any reintroductions by conducting an artificial nest experiment with replicates inside and outside the fence.

Niulii Ponds (Navy)
Native species present and existing monitoring:
Niulii Ponds is a locally important site for several species of waterbirds and the Hawaiian Short-eared Owl. Night heron, koloa hybrids, coots, stilts, moorhen and pueo all utilize the wetland area. Bird surveys are conducted every two weeks and have been since 2003. There are two populations of *Abutilon menseii*- one individual about 100m east of the wetland, and another population of ten individuals about 200m south of the wetland.

Existing predator control and impacts:
The perimeter of the ponds are fenced with a 12 year old four ft high chainlink fence and locked gates to keep out dogs, feral ungulates and people. The fence is in very good shape with little corrosion, but does have several holes. Dogs regularly jump or dig

under the fence to access the wetland making it essentially ineffective. The two Abutilon populations are located several hundred meters away from the fenced area in the Kiawe forest and are not protected. Predator control for cats, mongoose, dogs, barn owls occurs every other day (no rat control) and all mammals are live trapped and/or shot by USDA WS.

Predator impacts include take of adults, chicks and eggs of T&E waterbirds by mammals and barn owls. Cattle egrets (>20) roost in the wetland and may also take eggs and chicks. Tilapia consume invertebrates and limited food. Rose beetles have been observed consuming the abutilon.

Potential as a demonstration site:
While there is limited public access for outreach purposes, it would provide easy access for agencies to inspect the concept. The chances of success are high because of the easy terrain, complete encirclement, minimal maintenance and vandalism risk and the current high impacts from predation.

There is an excellent flat, existing road along current fence that could be used and would require little prep work other than filling in and compacting sinkholes. Maintenance would be minimal, and staff are highly supportive and enthusiastic about the concept. The site can be accessed entirely by vehicle and would not require a helicopter drop. It would be both a time and cost effective site. Since the abutilon populations were located a significant distance from the wetland, 2 separate rodent exclosures directly around the plants were suggested.

Waieli Bench, Oahu (Army).
Native species present and existing monitoring:
This small site on the eastern slope of the central Waianae Mountains contains a dense concentration of the endangered tree snail *Achatinella mustelina*. It also supports other extremely rare mollusks that that are not listed, including *Cookeconcha* sp., *Helicinid* sp., *Amastra micans*, and *Laminella sanguinea.* Several species of critically endangered plants have been outplanted at the site, including *Cyanea grimesiana subsp. obatae, Cyanea pinnatifida, Delissea subcordata, Phyllostegia hirsuta, Phyllostegia mollis,* CR *Plantago princeps var. princeps, Schiedea hookeri, Solanum sandwicense,* and *Urera kaalae.*

Existing predator control and impacts:
The primary pest species at the site are *Rattus rattus, Rattus exulans, Mus musculus* and the predatory snail *Euglandina rosea.* Rats are controlled through baiting.

Potential as a demonstration site:
Because the site has been intensively managed and monitored by The Nature Conservancy and more recently by the Army, it would provide a good opportunity to compare the costs and benefits of predator fencing and other management methods. However, because the technology has not yet been perfected to exclude *Euglandina* and eradicate it from a fenced area, a predator fence at this site would have to be viewed as

experimental. This site provides an excellent opportunity to help develop these methods, but the exclusion and eradication of *Euglandina* could not be guaranteed at this time.

There are other factors that should be seriously considered before choosing to construct a predator fence at this site. Snails are currently abundant in this area. In order to better inform this decision it would be desirable to have more information about the status of snail populations, the severity of impacts by rodents and *Euglandina*, and the efficacy of current management. If snail populations are already stable or increasing, then continuing the current management might be more appropriate. It is possible that a fence might actually have unintended detrimental effects on the habitat and the species it supports. Clearing forest along the perimeter of the fenceline might affect the microclimate preferred by snails and host plants, and because the site is small this edge effect could degrade habitat quality over a significant portion of the area. Some snails occur just outside the preferred fence route, such as the large concentration of *Achatinella mustelina* in the patch of ‘ie’ie (*Freycinetia arborea*) along the bottom edge. A fence would effectively cut these snails off from the main population, which could have negative demographic consequences. The fence could be routed away from the edge of the slope to avoid having to directly cut the ‘ie’ie, but clearing nearby vegetation might still affect the ‘ie’ie.

Nuupia Ponds, Oahu (Marines)

Native species present and existing monitoring:

Nuupia Ponds are an important site for native and migratory waterfowl, shorebirds and seabirds. Night heron, koloa hybrids, coots, stilts, moorhen, pacific golden plovers, black noddies, great frigatebirds and a large variety of migratory shorebirds, waterbirds and seabirds all utilize the wetland area. Wedge-tailed Shearwaters use the dune areas adjacent to the wetland. Waterbird surveys have been conducted regularly for the last 18 months.

Existing predator control and impacts:

The perimeter of Kahluapuhi pond is fenced with a 20 year old four ft high aluminum chainlink fence to keep out dogs, feral ungulates and people. The fence is in very good shape with little corrosion. As the fence is not completely closed it only prevents vehicles and people from accessing the wetland. Staff have observed cats, mongoose and dogs regularly jumping over, through or swimming around the existing fence.

Predator control for cats, mongoose, dogs and rats occurs regularly. All mammals are live trapped and/or shot by USDA WS. Rats are baited in stations with Diphacinone. Predator impacts include take of adults, chicks and eggs of T&E waterbirds and MBTA protected seabirds and migratory birds by mammals.

Potential as a demonstration site:

The proposed fenced area is quite large and would require all if not more than the money available in the budget for a demonstration fence. Biologically (at least for vertebrates) this is an important site to protect and there is the potential for public viewing. However, if the open sea end alignment is chosen, there is a higher reinvasion potential as pets from the residential areas on either side are present in high numbers, and people could still walk their dogs along the beach.

Even with a closed alignment and a successful eradication, the potential for reinvasion remains high as the semi annual amphibious assault vehicle training can allow pests through the open gate, or as stowaways in the vehicles. It also increases the chance of the vehicles colliding with and damaging the fence which appears to happens regularly on base.

Finally, despite the high biological potential, the NEPA documentation required would be significant in both time and cost for this site. At a minimum, an EA would be required as well as an SMA permit (~1 year timeline). In addition, MCBH is legally required to consult with over 20 cultural groups and would be required to consult with civilian neighbors on the south border of the fence. There are many burials on the beach by the dunes which would require archaeological surveys and OHA (office of Hawaiian affairs) consultations. The dunes by the WTSW colony are on the National Historic register which would also require a permit.

Mt. Ka`ala, Oahu (Army, Air Force)

Native species present and existing monitoring:

This small site encompasses a portion of the summit of Mt. Ka`ala in the northern Waianae Mountains, which is the highest point on Oahu at 4025 feet. The Army and Air Force each own portions of the area proposed for fencing. Adjacent areas are onwed by the State of Hawaii. The site contains a portion of an unusual montane bog habitat that fills the summit crater of Ka`ala, and native forest on adjacent ridges and slopes. There is a single endangered plant in the proposed fence area, *Schiedea trinervis* (13 individuals).

Existing predator control and impacts:

The pest species present in the area are mongoose, rats, and the predatory snail *Euglandina rosea*. Pigs have already been excluded from the bog area. The effects of pest species on *S. trinervis* are not well documented, but rodents probably have widespread effects of on a variety of plants and invertebrates that are currently not documented.

Potential as a demonstration site:

A fence here could serve as an example of ecosystem protection. However, this site may be less attractive because there is only a single listed species in the proposed fence area and little management that could provide baseline data to compare with the costs and benefits of predator fencing. Compared to other sites, this was not a high priority site due to it's small size and potential negative construction impacts.

The size of area originally proposed for fencing was 2.21 hectares, with a perimeter of approximately 686 meters. Xcluder expressed serious concerns about feasibility of constructing a fence on such soft substrate. It would not be possible to use any heavy equipment to prepare the site, and the fence posts might not be solid enough to withstand vandalism in such soft soil. The depth of the boggy soil is unknown, and it might be necessary to dig deeply to adequately anchor the fence posts, which could cause significant damage to this sensitive habitat.

Pohakuloa Training Area *Zanthoxylum hawaiiense* site, Hawaii (Army)
This site is similar in size, habitat composition, and other factors to the *Solanum* site except for the following differences:

- This site contains a larger number of *Zanthoxylum hawaiiense* but does not currently contain *Solanum incompletum*.
- The area proposed for fencing is 11 hectares, but again the route and size could be easily modified to maximize protection of rare plants and cost-effectiveness.
- The substrate consists of more pahoehoe than aa, which will be a little more difficult to prepare and may contain more lava tubes that could be more difficult to seal against rodents.
- It is directly adjacent to a good roadway and an existing ungulate fence. It might be possible to use the existing ungulate fence as one side of the predator fence, but this would require installation of two gates to allow continued vehicle access along the road.
- Overall it is somewhat less preferable than the solanum site as a demonstration site because of the substrate and fewer endangered plant species.

Pohakuloa Training Area *Schiedea hawaiiensis* site, Hawaii (Army)
This was a very small site that contains the last known wild individual of *Schiedea hawaiiensis*. The last wild plant is enclosed in a small wire mesh cage and the immediate area is surrounded by razor wire to discourage ungulates. Seeds have been collected and have grown well in the greenhouse, but outplanting survival has been very poor.

Unfortunately, it is not practical to construct a predator fence at the site where the last wild individual is located. The ground consists of extremely uneven aa and pahoehoe lava with many cracks and small lava tubes that would require extensive preparation and would be difficult to seal against rodents. To get away from this difficult terrain the fence would have to be greatly expanded. The site is also directly adjacent to an active roadway that has a steep bank. The fence would either have to go on top of the roadway, or the steep bank would have to be filled in. The best management strategy for this individual plant is probably to continue to protect it with a wire mesh cage, but to use a larger cage that would not entangle the plant itself, and which would be more carefully constructed to exclude mice.

Kaluakauila, Oahu (Army)
This small site in the very northwestern Waianae Range supports a rare dry forest remnant, including the endangered plants *Neraudia angulata var. dentata, Melanthera tenuifolia, Euphorbia haeleeleana, Bonamia menzesii, Hibiscus brackenridgei, CR Delissea subcordata*, and *Abutilon sandwicensis.* Unfortunately, the remote location and steep terrain in this area make construction of a predator fence impractical. It would impossible to use heavy equipment to prepare the ground because there is no access and equipment could not be operated safely due to risk that it would tip over. The steep, rocky ground would be difficult to prepare by hand, and rockfall would make it unsafe

for workers and would subject the fence to frequent damage. Continued management using current methods seems like the best option at this time.

APPENDIX 6: ADDITIONAL XCLUDER SITE REPORTS
Nuupia Ponds
<u>Option 1:</u>

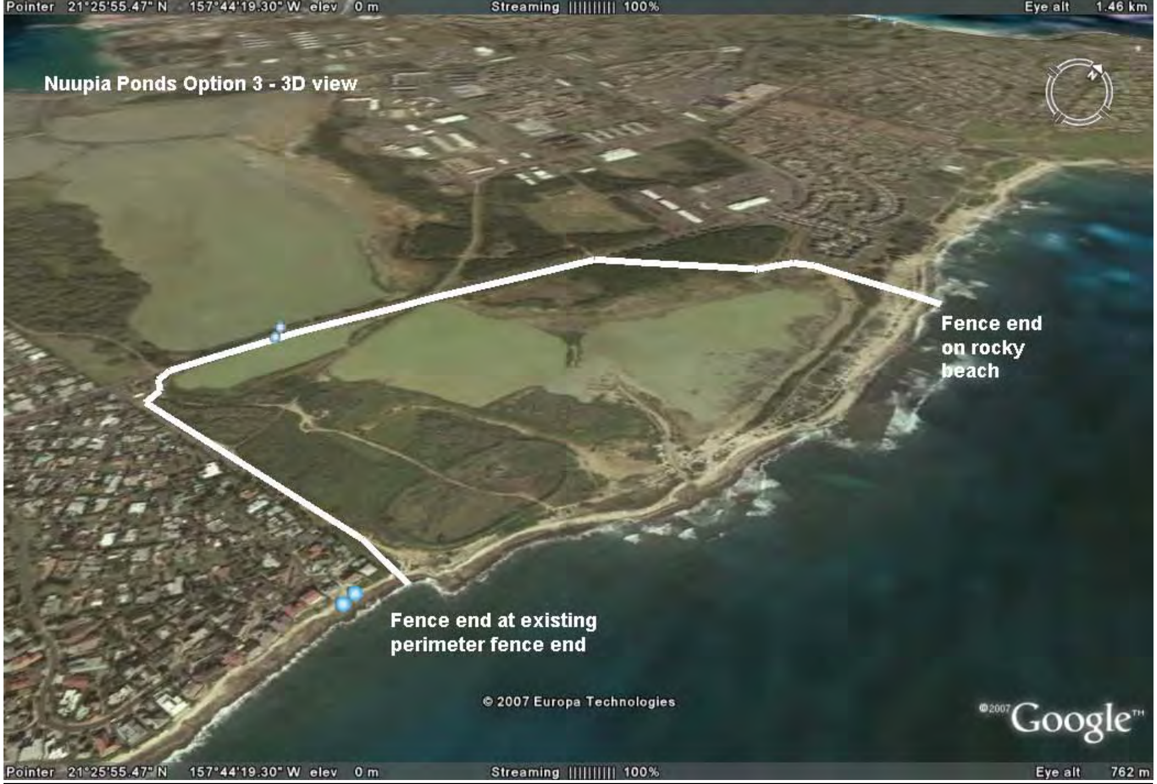
GPS/map measured fence length: 2785 m – marked on map
GPS/map estimated area: 46 ha

Option 2:

GPS/map measured fence length: 3005 m – marked on map
GPS/map estimated area: 50 ha

Option 3:

GPS/map measured fence length: 1980 m – marked on map
GPS/map estimated area: 50 ha



Option 4:

Map measured fence length: 5300 m – marked on map
Map estimated area: >100 ha

Primary fence purpose:
Nuupia Ponds are an important site for native and migratory waterfowl, shorebirds and seabirds. Night heron, koloa hybrids, coots, stilts, moorhen, pacific golden plovers, black noddies, great frigatebirds and a large variety of migratory shorebirds, waterbirds and seabirds all utilize the wetland area. Protection from nest, egg, chick and adult predation by the full range of mammalian pests could be achieved with a pest proof fence.

Fencing feasibility:
A fence surrounding the percolation ditch would be difficult due to the ephemeral channel with the adjacent wetland. This coupled with the narrow fencing corridor adjacent to the parking lot make it very challenging.

Four options exist for fencing the main Nuupia Ponds:

- Option 1: fully encircle the eastern pond area, excluding the wedge-tailed shearwater colony and burial sites
- Option 2: fully encircle the eastern pond area and extend fence ‘wings’ to the sea at the property boundary and sea outlet channel to include the WTSW colony.
- Option 3: fence the eastern pond area with a semi-circular fence that extends to the sea at the property boundary around the back of the pond to the sea along the main beach area. The pond is not fully enclosed by this fence option and poses greater reinvasion risk.
- Option 4: Fully encircle the larger western pond area, using existing road and access platforms where possible. Although this fenceline has not been fully explored, it looks technically feasible on maps.

Fencing costs for any one of these options are unfortunately likely to exceed the fencing budget for this demonstration project, but this does not preclude any of the fence options from being considered and funded from alternative sources. All four fencing options appear to be possible, although Option 3, with open sea ends bears the greatest risk and would be less preferable for pest management than Options 1, 2 or 4.

The fence specification required at Nuupia Ponds must be designed to withstand the extreme coastal environment. Aluminum components would be used to maximize longevity (as has been demonstrated with the existing Nuupia low fence), although this does increase costs by comparison to a non-coastal fence. Heavy duty vehicle access gates would be required to allow amphibious assault vehicles to pass into and out of the fenced area. Fence maintenance costs at this site would be relatively low. Site access for materials, equipment, machinery and staff is excellent. Any Marine Corps assistance with fenceline preparation, construction etc at this site would help to reduce costs.

Site issues:
Sensitive coastal habitat, including shearwater nesting grounds and culturally significant burial sites must be avoided. Corrosion potential is high in this site, meaning a higher specification (and cost) fence is required. Ongoing amphibious assault vehicle training would need to be carefully managed to ensure no damage to the exclusion fence and no

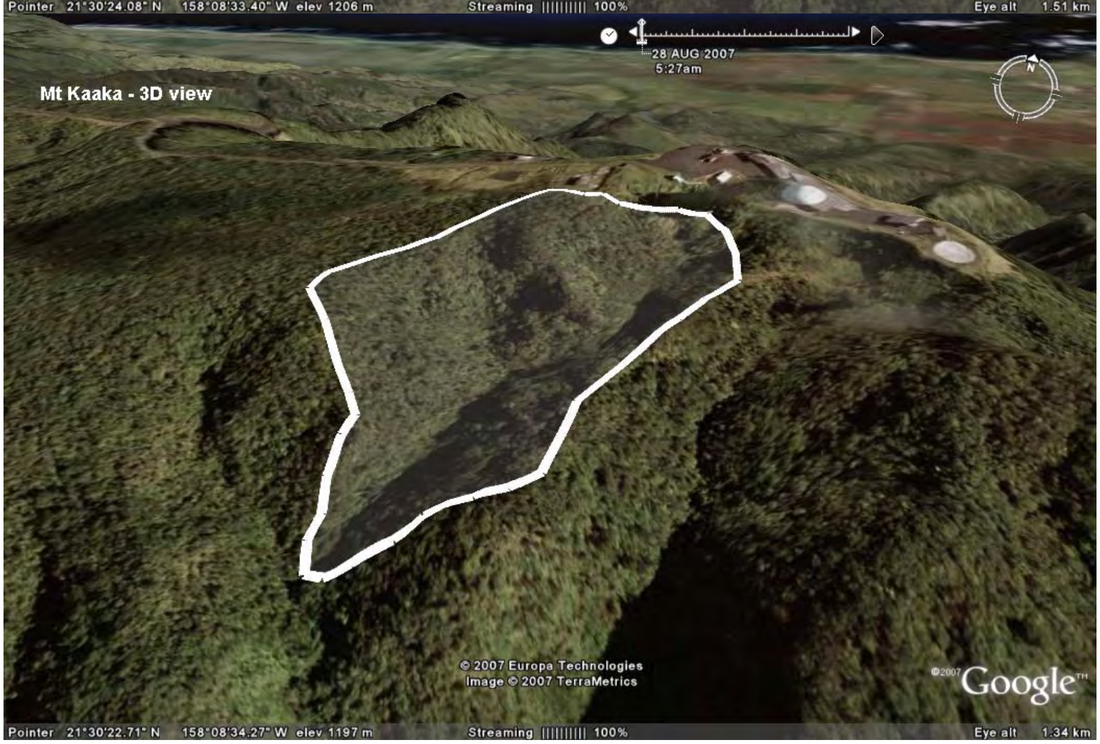
risk of pest animal reinvasion in vehicles or through open gates. Military staff ownership of the project would be required to gain the full benefit of predator exclusion for native species.

Value of fencing:
The value of fencing this site appears to be significant. Removal of mammalian predators would almost certainly see increased productivity from native wetland species. Nuupia Ponds are an important site for native and migratory waterfowl, shorebirds and seabirds. Wetland habitat is severely compromised on Oahu and protection of a site such as this (especially the larger area) would be of great biological value.

Mt. Ka`ala, Oahu

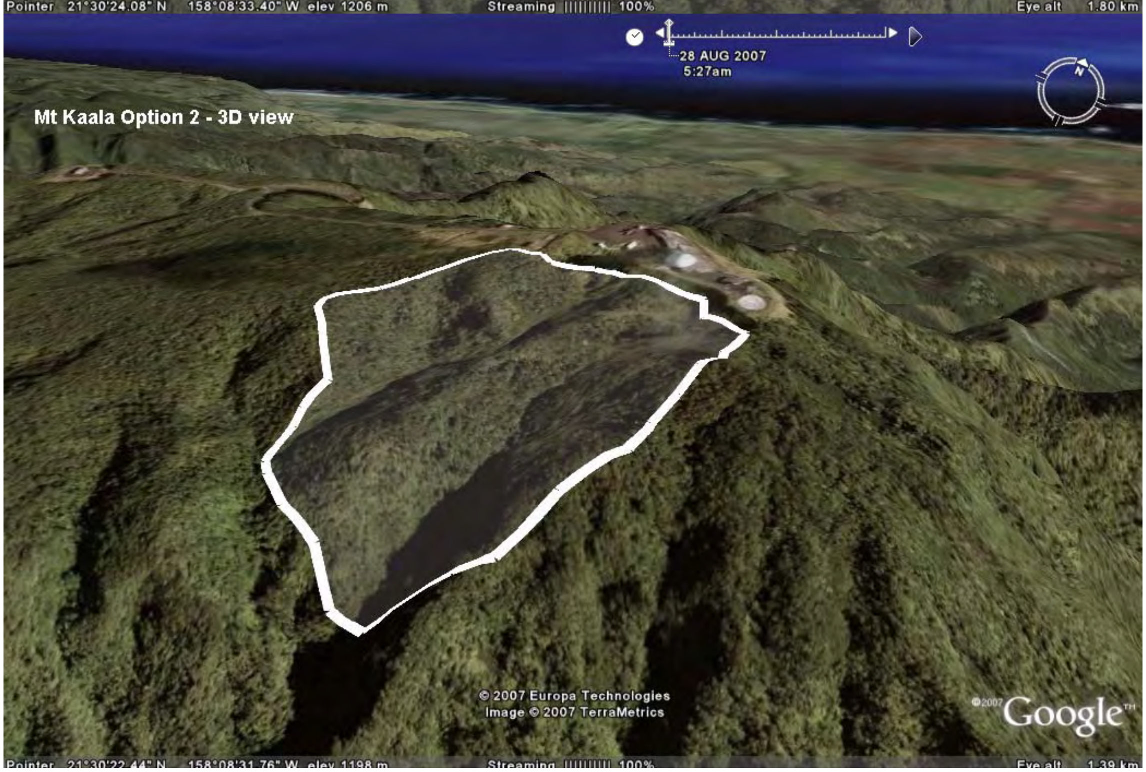
<u>Option 1:</u>

GPS/map measured fence length: 620 m – marked on map
GPS/map estimated area: 2 ha



Option 2:

GPS/map measured fence length: 840 m – marked on map
GPS/map estimated area: ~4 ha



Primary fence purpose:
The site contains a portion of an unusual montane bog habitat that fills the summit crater of Ka`ala, and native forest on adjacent ridges and slopes. There is a single endangered plant in the proposed fence area, *Schiedea trinervis* (13 individuals). Protection of the site from mammalian threats would be valuable.

Fencing feasibility:
An appropriate fenceline was identified, walked and marked with GPS. Exclusion fencing is possible in this site. Two options exist for fencing at Mt Ka'ala:

- Option 1: fully encircle a 2ha site as walked and marked with GPS
- Option 2: fully encircle a 4ha site by extending the same fenceline into the next gulch

It would be difficult to expand the area in other directions due to the presence of very steep slopes (north and southeast) or boggy habitat with very soft soil (west). Serious concerns exist about the feasibility of constructing a fence on the very soft bog substrate. It would not be possible to use any heavy equipment to prepare the site. The depth of the boggy soil is unknown, and it might be necessary to dig deeply to adequately anchor the fence posts, which could cause significant damage to this sensitive habitat.

The proposed fenceline would require the use of earthworks machinery to create a suitable fencing platform. The bottom of the gulch (or gulches) would require pest-proof culvert pipes to allow water out of the site without compromising fence integrity. Access to the site is excellent, with all materials, equipment and staff being able to be driven to the site (daily if necessary).

Site issues:
The site(s) is small, so the area to be protected is small compared to the area to be disturbed in establishing the pest proof fence. The value of this should be considered before decisions to fence or not are made. The site contains relatively few threatened species currently, but is unique and may have value or provide new opportunities for reintroductions. There are significant weed issues at the site which may be exacerbated by the ground disturbance associated with fencing.

Value of fencing:
The value of fencing this site appears to be questionable. Removal of mammalian predators would almost certainly see ecological improvements, but it would be very difficult to demonstrate such changes in such a small area (e.g. changes would probably have to be measured at the invertebrate level or lower). The physical terrain of this site limits the opportunity for site expansion.

A fence here could serve as an example of ecosystem protection. However, this site may be less attractive to the military because there is only a single listed species in the proposed fence area and little management that could provide baseline data to compare with the costs and benefits of predator fencing.

Pohakuloa Training Area *Zanthoxylum hawaiiense*

No specific fenceline was identified or walked at this site although the substrate appeared to be suitable for fencing during the site visit. This site is similar in size, habitat composition, and other factors to the *Solanum* site except for the differences noted in the site visit report.

Appendix 7: Response to Army comments on IC project W912DY-07-2-0003

Predator-proof Fencing for Invasive Species Control in Hawaii: A Comprehensive Prioritization and Implementation Plan to protect native species

Comment 1:

Overall, this report did not accomplish what I thought it would. The estimates are overpriced and based on doing the work Exactly how they do it in New Zealand. I am concerned that they did not adapt their design for Hawaii's remote locations. My understanding is that they can drive to many of their sites and dig big trenches and remove large tracks of forest. It is not acceptable in Hawaii to remove large tracks of native forest since there is so little left. In many instances, it is not feasible to dig a big trench when the only place to run thaw fence line is along a sharp ridge line. It is also not acceptable to ask us to create a road into a remote area that abuts a Natural Area Reserve. This does not pass the common sense test. In addition, why are materials being flown into Hawaii instead of being purchased locally? Did they look into purchasing locally? If so, they should explicitly state that. If they considered other fence options they should also explicitly state that. As it stands, it looks like they just gave estimates for doing their current fencing technology with no changes to account for Hawaii's situation and topography.

Pest proof fencing must be built to very exact specifications to act as an impenetrable barrier to invasive mammals. Thus by design they have to be built exactly as they are in New Zealand. That said, picking sites where the fence lines can be built in already degraded habitat yet encompass high quality forest would result in less take of native forest during construction. Unfortunately, the funding to build demonstration fences is limited and it is difficult to find a place where a 10 hectare fence can protect high quality forest without passing through some of that forest.

The goals of this project were outlined in the original proposal and discussed in detail in the first partner meeting held in Honolulu. These goals are to prioritize potential demonstration sites on DoD lands in Hawaii for predator proof (also called pest proof) fencing. The goal of using demonstration fences was to show the ecological benefit that would be achieved through complete removal of damaging invasive mammals from natural habitats in Hawaii. The goal did not include testing different fencing designs or trying to adapt fences to Hawaiian landscapes. Our feeling is that the specifications developed in New Zealand need to be maintained to keep the fences as effective barriers because we are dealing with many of the same pest species and what keeps the species out in New Zealand can be expected to keep them out in Hawaii.

Comment 2:

In addition, why are materials being flown into Hawaii instead of being purchased locally? Xcluder fence has strict requirements for the materials they use in order to achieve the specifications required to build a fence that will remain pest proof. They have looked globally to find the best price and best quality components. The stainless steel fencing panels are sourced directly from China, providing the highest quality at the best price. These materials are only made in China and are not available in Hawaii. Materials such as fence posts and fasteners may be sourced in Hawaii if they are available.

Perhaps the most significant opportunity for utilizing Hawaii resources is to have Hawaiian companies, using the Hawaiian labor force, build the fences to specification. This, in the long run will provide the most benefit to the Hawaiian economy.

Comment 3:

Why is the estimate for fencing Kaena Point so much less than what the DOD ones turned out to be?

The Kaena Point fence is an open ended peninsula fence, meaning that is a straight line fence that provides a barrier on only one side of the area to be protected. This reduces costs when comparing area protected vs. length of the fence because the fence does not enclose the entire area protected. The cost of a fence a Kaena Point is also reduced because the site allows easy access for large machinery, so most of the heavy work can be done with machine assistance rather than by hand. It is further reduced because the vegetation is sparse and low and does not have to be cleared. And most importantly, the fence at Kaena point is to be built on an existing road line. This road provides an exceptional platform for the fence and requires very little modification. Developing a suitable platform for a pest exclusion fence is a critical, time intensive and expensive part of this technology.

Comment 4 and 5:

The costs in (the report) *do not make this "cost-effective" by any stretch of the imagination! What is the lifespan of this fencing? Are figures on when we would break even going to be included?* Cost effectiveness is addressed in section in the Cost Benefit Analysis section, on page 52 of the report.

The lifespan of the fencing can be generally stated at 20 years, but that is a deceptive number. The real life span of a fence must match the length of time needed to protect the area inside of the fence – until either the threats outside the fence are abated or it is decided that the resources inside are no longer a priority to protect. In order to make a fence last for the duration of the need (i.e. as long as the resource needs protection within the fence) it is typical to incorporate replacement value of the fence every 15 years. This is a conservative estimate and allows for funds to maintain the fence over time essentially making it a permanent fence.

Pest proof fencing involves a large capital investment. There are several ways to measure cost effectiveness of this technology. One way, as shown by the Kaena Point example, is to compare annual expenditures on animal control against the capital investment and maintenance of the fence. However, control activities rarely, if ever, achieve the same degree of biological benefit as a pest proof fence. Ideally the cost benefit is based on the biological benefit of deploying pest proof fencing.

There are several reasons why a cost benefit analysis for the proposed test fences in this report is misleading. First, these fences are relatively small, which increases the cost per area protected. Published analyses state that cost for fencing becomes beneficial for sites around 100-1000 hectares depending in the site, with increasing benefit as the size increases. For the 10 hectare test sites proposed here a cost benefit would be misleading because of their small size.

Furthermore, it is difficult to utilize current control activities to determine cost benefit of fences because the current control activities are not comprehensive. In order to provide a more robust analysis it would require the inclusion of the value of the biodiversity protected. This would require installing the test fences so this benefit could be measured. I think it is important to not underestimate this point. Current technology for control of invasive species is not perfect- there are negative impacts on non targets and there are social issues with the ongoing control of animals and the use of traps and poisons required to control those animals. Combining this with the fact that control rarely reduces invasive species impacts to zero, witness the loss of 30% of the breeding shearwaters at Kaena point to dogs and feral cats even during a control regime, there are large benefits of pest proof fencing that are hard to report as a cost benefit. In the course of this project it was decided that the most we could reasonably achieve is to discuss the cost benefit analysis of these types of projects, present information from other projects and budget to determine this in more detail when testing the technology with demonstration fences.

Comment 6:

We already have fences in many of the locations studied. Why is there no discussion of retrofitting existing fences? Wouldn't that be cheaper and accomplish the same goal and do less harm to the native forest? I think overall, we need more R&D of this technology and how to apply it to Hawaii in remote locations like Kahanahaiki.

The technology has undergone extensive testing in New Zealand. It has also been tested in Hawaii on open lava with mongoose and rodents. There are very specific characteristics that must be met to keep these pests from breaching a fence and those characteristics will be the same in Hawaii as they are in New Zealand. These characteristics include maintaining a fence that has no hole greater than 6 mm in order to keep house mice from passing through it, a minimum height of 2 m to keep feral cats from jumping over the fence and maintaining an open swath of 4 to 5 m wide around the fence to keep animals from using vegetation or other materials as a ramp to cross over the fence.

We did not address retrofitting existing fences in the report because there are no existing fence lines where the proposed test fences would be built. There are some nearby but not close enough to make it worth moving the test fence. Retrofitting is a possibility and some of the fencing being built in Pohakaloa Training Area for ungulates could be retrofitted. This was discussed with personnel in the field but was not discussed in the report because there were not sites where high priority demonstration fences could take advantage of existing fence lines. Additionally, to make retrofitting more effective it would be best if the existing fence line was designed to meet certain specifications including distance between fence posts, ground preparation and other important details.

Comment 7:

There is a possibility that fencing this site would require Explosive Ordinance escort and support which may add a lot to the cost. Was this taken into consideration?

Explosive ordnance was not an issue that was raised by the staff that showed us the site or during the prioritization process. This cost was not budgeted for this site.

Comment 8:

Why were things like the fact that there is an existing fence or that the area occurs in high class native forest not identified as Site Issues? Seems like an area like Nuupia ponds with easy access, flat terrain and non-native vegetation would rank higher because less damage would occur installing the fence.

The site issues used for prioritization were developed in coordination with DoD staff. The technology was described in detail including the requirements for vegetation clearing to keep animals from breaching the fence line. The issue of impact to vegetation was not raised at that time.

The impact of invasive species is severe. Rodents have been described as the single largest negative impact in Hawaiian forests. There are no technologies available that can reduce rodent numbers to zero in Hawaiian forests other than fencing and eradication inside or complete island wide eradication. Control technologies are finally being developed for use in Hawaii but there will remain restrictions on their use. And even where it is used there will be non target, social, access, cost and other issues associated with their use. Land managers in Hawaii will need to make a decision as to whether it is a suitable tradeoff to cut down some native forest in order to protect other parts. Based on our assumptions outlined in the report, the biological benefit to the protected forest will far outweigh the impact of putting in a fence line. The idea of a demonstration fence was proposed to test and hopefully demonstrate this fact to land managers in Hawaii so they have the information to make the difficult decisions presented when addressing invasive species issues.

Comment 9:

It appears that this language is out of place. This fence protects plants not birds.

(We assume this refers to the *Solanum incompletum* site) We describe in detail the theory behind using artificial nests. For this site we recommend using artificial nests to test predation rates because if a full size fence were built it is expected that several of the Hawaiian honeycreepers could flourish in this site in the absence of predation by invasive mammals and due to the high quality habitat that would spring up in the absence of these species as well.

Comment 10, 11, 12:

It is not feasible to get an earth moving machine into Kahanahaiki. It would do too much damage to this high quality native forest and the State would never approve of this. Same comment as above. It is not at all feasible to construct a 4WD road to Kahanahaiki.

It is not realistic to expect removal of 3 to 5 meters of vegetation around the fence line considering this area is next to a State Natural Area Reserve and surrounded by native vegetation.

The options for delivering an earth moving machine to the site and building a road to the site to facilitate fence building were proposed to reduce costs. The fence could be built, as pointed out in the plan, entirely by hand. When discussing this project with the field staff assigned to show the site this issue was discussed and it was decided to develop a plan based on the use of small equipment delivered by helicopter. This equipment would utilize the same pathway required to build the fence and create the necessary gap to keep the fence line from being breached. Thus the use of small earth moving equipment would not cause any additional forest to be disturbed than doing the work by hand.

Paraphrasing the responses in comment 8, land managers in Hawaii have to make a decision in regards to how aggressive they are willing to get to create areas free of invasive mammals. Because invasive mammals are thought to be single most damaging threat to native forests it can be argued that aggressive methods are required. It can also be argued that opening up some forest to be able to radically improve conditions within a large area inside a fence is justified. It is not the place of this report to make that decision, rather it is to provide the information to allow land managers to make those decisions. Building a test fence and monitoring the biological impact will help land managers in those decisions.

Comment 13:

What would the lifespan of this fence be with wooden posts versus metal?

This fence uses a combination of wooden and metal fence posts. Wooden posts are cheaper and provide a more solid fence. However, where posts must be set in rock, metal posts are preferable. While material costs might be slightly lower with all wood posts, construction and maintenance costs would outweigh these savings.