BIOLOGICAL MONITORING

Introduction
Monitoring of biological resources before and after fence construction is crucial for measuring and demonstrating the benefits and effectiveness of predator fencing as a management technique compared with traditional fencing and predator control methods. However, the types and amount of information gathered can vary dramatically depending on the site, budget, and goals, and in some cases there may be insufficient baseline data available to make the desired comparisons. In such cases, the use of simultaneous treatment and control sites located inside and outside areas that have been fenced and from which predators have been excluded can be used to measure the effects of predator fences. In the case of Ka`ena Point, sufficient baseline data already existed for some taxa (seabirds), but was lacking for others (plants and invertebrates) to make these comparisons. Extensive monitoring of a variety of taxa therefore was undertaken prior to fence construction in order to document the effects of the predator proof fence.

To facilitate consistent, repeatable monitoring for a variety of species, staff from the NAR System installed a permanent, geo-referenced, 50-m interval grid oriented on magnetic north throughout the reserve (Figure 5.1), with points marked by rebar with a 10 cm reveal. The rationale for selecting a 50-m grid was to provide an adequate number of replicates within the fenced area (N=73) for ecological comparisons and to have appropriate spacing for rodent bait stations, since 50 m is the average home range size for black rats. Except for Laysan Albatross and intertidal invertebrates, all biological monitoring was done using these grid points.
In seabird nesting areas such as Ka`ena Point, seabirds can act as the dominant species altering vegetation through physical disturbance and marine compound depositions from feces and carcasses, resulting in changes in species composition and habitat structure over time. It is thus important to monitor all aspects of the community to document these changes.

This section covers the protocols that were used to gather baseline data on each taxonomic group. The methods used for each group are presented below, but we anticipate that the before and after results for each group will be written up as stand-alone publications once sufficient ‘after’ data has been collected.

**Seabird Monitoring**

Introduced mammalian predators are one of the most serious threats to seabirds and other native bird species in Hawai`i and on many other islands (Côté and
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, VanderWerf 2009) and have caused or contributed to the extinctions or local extirpation of numerous island-nesting seabird species. Feral cats are also a serious problem for many bird species. Predation on nests by feral cats has been documented in Hawaiian seabirds, including the endangered Hawaiian Petrel (*Pterodroma sandwichensis*) (Simons and Hodges 1998, Hodges and Nagata 2001, USFWS 2005, Lohr et. al. in press).

The effectiveness of predator exclusion on bird populations can be measured by comparing population sizes, survival rates, and reproductive rates. This can be accomplished using temporal comparisons before and after fence construction, and/or simultaneous spatial comparison from inside and outside the fenced area. 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. 2000, Buckland 2006).

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. It may be more feasible to detect changes in other population parameters, such as nesting success. For birds that have been extirpated, simply documenting nesting in the area following predator fencing would demonstrate success.

For the seabird species nesting at Ka`ena Point, the most suitable methods depended on their abundance and how easy they were to detect. For Laysan Albatross (*Phoebastria immutabilis*), which occur in low density but are large and easily visible, a census of nesting birds and regular nest monitoring was conducted. For Wedge-tailed Shearwaters (*Puffinus pacificus*), which occur in high densities and nest in underground burrows, census of nesting burrows was conducted at first, but the monitoring method was switched to a plot-based design.
Laysan Albatross

Laysan Albatross began nesting at Ka`ena Point in 1992 after off-road vehicles were excluded. All chicks hatched at Ka`ena Point were censused and banded with a unique, federal metal band each year by DLNR staff beginning in 1992 when nesting first started. Regular monitoring of adults and chicks began in 2004 for the duration of the breeding season (Nov-Jul). Monitoring consisted of a weekly census of all birds present. Each time an adult was encountered, its location, status (incubating, brooding, or walking), and association with any other adult or chick was noted. Chicks were monitored from hatching (Feb) until fledging (July). Nest number, parent information, hatching date, disease status, and date of either fledging or death were recorded for all chicks. Starting in 2006, each bird was also given a field-readable purple plastic band numbered in white from O001-O999. Chicks that survived to fledging were banded with both a federal metal band and a field-readable plastic band.

Extensive information about the monitoring methods and results, including reproductive success, population size, and survival rates in this colony can be found in Young and VanderWerf (2008), Young et. al. (2009a,b) and VanderWerf and Young (2011). In summary, a population of approximately 365 adults are present on the colony with a maximum of 61 nests initiated in the 2012 breeding season.

Wedge-tailed Shearwaters

Wedge-tailed Shearwaters began nesting in the reserve in 1994, shortly after off-road vehicles were excluded, and a complete census during October or November of active nesting burrows has been conducted almost every year until 2008. Counts consisted of searching visually for burrows and determining whether they were occupied (presence of a chick confirmed visually or by touch), or unoccupied but active (unhatched egg, fresh droppings, feathers, tracks, or digging). Due to the increasingly large numbers of burrows and the impact a census was having on the habitat, a plot-based monitoring technique using the 50-m grid points was begun in 2008 in conjunction with a
determination of what size of plot produced the most accurate results. Each point in the 50-m grid served as the center of a circular plot, and the number of burrows was counted within 4, 5, 6 and 8m radii. Plots with a radius of 8m produced results most similar to the census data likely since they represent a large total proportion of the area surveyed. From 2009 onwards, the plot design was used exclusively to monitor Wedge-tailed Shearwater reproduction.

Other Seabirds
Bulwer’s Petrels nest on several islets off O`ahu but are currently not known to nest at Ka`ena Point. This species was searched for at Ka`ena by imitating its barking call at night in rocky areas preferred by this species for nesting and waiting for a response. Other nocturnal Procellariformes were monitored by listening during the dusk hours at the appropriate times of year to detect their presence. Prior to fence construction, no other seabirds were detected nesting aside from those described above.

Red-tailed Tropicbirds nest at one other location on Oahau and also on Manana Island off the eastern coast of Oahau (VanderWerf and Young, 2007). Up to seven adult Red-tailed Tropicbirds have been observed simultaneously courting at Ka`ena Point, but no nests have been observed. Individuals of this species may colonize Ka`ena Point naturally because there are colonists close by.

Invertebrate Monitoring
Invertebrates are a relatively inconspicuous but extremely important components of native ecosystems. Native invertebrate communities provide integral ecological services, including pollination and nutrient cycling, without which most Hawaiian plant species could not exist (Howarth and Mull 1992; Mitchell et. al. 2005). Changes in abundance, diversity, and species composition of the invertebrate fauna at a site may help to indicate improved ecosystem functioning. Extensive coastal strand habitat is exceedingly rare in Hawaii. Several rare invertebrate species can still be found at Ka`ena Point. A
noteworthy example is a native yellow-faced bee, *Hylaeus longiceps*, which is currently being considered for federal protection (Magnacca 2007).

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 previously unknown at the site (Watts 2007).

There are approximately three vegetation habitat types at Kaʻena Point—coastal strand, naio shrubland, and invasive grasses. Invertebrate monitoring was done at three grid points in each habitat type at Kaʻena Point. Exact points were chosen using a random number generator to produce three selections in each habitat type in Microsoft Excel. Points D6, D7 and E7 (see Figure 5.1) were located in coastal strand sites; C7, D9 and G12 in naio shrubland, and D11, D13 and E12 were in invasive grassland. Vegetation beating, sweep netting and litter sampling were completed once at each point. In addition, one pitfall trap, one yellow pan trap and one yellow sticky card were laid out at each point (nine total) for three days.

Invertebrate specimens will be identified to species where possible. Invertebrate abundance will be measured as a total number of individuals and/or biomass captured per trapping interval / collection effort. Abundance of invertebrates in different feeding guilds (herbivores, detritivores, nectarivores, predators, parasitoids, etc.) will be examined to look for shifts in ecosystem functioning before and after predator removal. This baseline of species diversity and abundance will help determine whether predator exclusion affects invertebrate diversity, and if native species in particular will increase in abundance.

*Pit-fall Traps*

For ground-dwelling species, pit fall traps are an effective passive sampling method (Spence and Niemela 1994). To install pit fall traps, a shallow hole is
dug in the ground and a small cup or bowl filled with a killing agent or preservative is placed inside. The lip of the container is positioned to be even with the surrounding ground, and, as a result, crawling invertebrates inadvertently fall into the container and cannot escape. Ka`ena Point pit fall traps were baited with propylene glycol (anti-freeze), and deployed for three days. Following trap collection, specimens were transferred into 70% ethanol for storage.

**Yellow Pan Traps**

Many insects are attracted to the color yellow, a trait which is often used to facilitate their collection (Neuenschwander, 1982). A yellow pan trap is a quick and easy way to catch specific types of invertebrates. A shallow yellow pan or bowl is either placed on the ground or into a small hole in this case so that its rim is level with the ground. The bowl is then filled with water, and several drops of detergent are added to break the surface tension. Insects that are attracted to yellow (ex. flies, wasps, and beetles) will fall in and drown. The traps will also collect invertebrates not attracted to yellow, intercepting them in the same manner as the pit-fall traps. Following collection of the pan traps, specimens were transferred to 70% ethanol for storage.

**Yellow Sticky Cards**

Sticky cards traps are used to collect the adult stages of flying insects (e.g., flies, gnats, shoreflies, leaf miners, winged aphids). A single Trece Incorporated Pherocon AM trap (without lure) was placed at each of the sampling points and left for three days. Sticky cards consist of 8.5” x 11” yellow card-stock, folded in two, coated with a thin veneer of a sticky paste. At each point, a trap was hung from vegetation, 0-2m from the ground, where it was visible to flying insects. Sticky cards were collected, wrapped in plastic wrap, and placed in a freezer for long-term storage.

**Vegetation Beating and Sweep Netting**
Vegetation beating and sweep netting are some of the most effective approaches for collecting a broad assortment of invertebrates from vegetation. To survey woody shrubs or trees, a tarp or “beat sheet” is laid under the vegetation targeted for sampling. The vegetation is then shaken by hand, or “beaten” with a sweep net handle, to dislodge invertebrates present on the foliage. Specimens were then collected by hand or with an aspirator. Since herbaceous vegetation, grasses and some shrubs do not ordinarily lend themselves to beating, they are better sampled through the use of sweep nets. Canvas insect nets were swung across vegetation, knocking off and capturing invertebrates present on the foliage. Those specimens were also collected by hand or with an aspirator. Fifteen beats and fifteen sweeps were completed at each sampling point at Ka`ena Point.

**Ant monitoring**

Due to particular concern over the potential impacts ants may have on the ecosystem after the removal of rats, an ant monitoring protocol was established. Four replicates per habitat type (12 points total) were set up inside the reserve and 12 outside the reserve for control and experimental purposes. Ant bait (spam, peanut butter, and honey) was placed on an index card for up to two hours and then the card removed to inventory the ants. In addition, a transect design was used that bisects the preserve so that all habitat types would be surveyed, and a comparable transect was selected outside the reserve. Eleven index cards baited with peanut butter, honey, and spam were placed at 50-m intervals along the "E" transect (see Figure 5.1). Sampling was conducted twice, once each in the spring and summer.

**Vegetation monitoring**

The effects on native plants from browsing, trampling, gnawing and seed destruction by predators is ubiquitous and can be very serious in many areas of Hawai`i (Scowcroft and Giffin, 1983; Tomich 1986, Hess et. al. 1999). Monitoring of plant populations is important to gauge the effectiveness of
predator fencing and eradication at many sites. Plant monitoring should not be limited to endangered species; changes to more common plant species that form the bulk of native habitats should also be monitored.

At Ka`ena Point, an overall inventory was done as well as a transect design that monitored percent cover, species assemblages and soil types over time to document potential changes at each grid point as a result of predator removal and associated ecosystem shifts. Each vegetation plot consisted of a 16m baseline transect, oriented from E-W, and centered on a grid point; along each baseline transect, five 16m transects oriented N-S were established at 4-m intervals producing a 16 x 16 m grid centered on the 16-m-diameter circles of the shearwater plots.

![Figure 5.4- example of transect design](image)

At every meter along the 5 N-S transects, all species intercepted by a vertical rod were counted using the point-intercept method (Mueller-Dombois and Ellenberg 1974), and the data were converted to absolute percent cover (which cannot exceed 100% for any single species, but may do so for all species combined). Substrate type (rock, sand, volcanic soil) was also recorded at all 85 point-intercept points. Data were collected at 52 of the 73 grid points; points outside the fence line, in unvegetated parts of the intertidal zone, directly on main trails, and on graded gravel slopes were omitted.
Observational data
Monitoring of plants for survival, amount of gnawing, browsing, seed predation, and other damage caused by predators is one important method of monitoring for the presence of predators, particularly at sites where baseline data on status of endangered plants is available for comparison. Natural recruitment of wild plants should also be observed and measured. At Ka`ena Point, observational data was collected on Ohai (*Sesbania tomentosa*), and coastal sandalwood (*Santalum ellipticum*), both of which are frequently targeted by rats for their fruits, and are good indicators of rodent presence.

Soil Sampling
In seabird nesting areas, seabird can act as the keystone species by altering vegetation through physical disturbance and marine compound depositions in the soil from their guano. Due to these disturbances and nutrient inputs, plant and invertebrate communities can change over time which alters habitat structure and as a result, it is important to monitor all aspects of the community to document these changes. To ensure that any changes that were associated with marine compound deposition in the soil could be quantified, soil sampling was conducted.

A push corer was used to extract ~250ml of soil samples at each grid point from the surface up to a depth of 15 cm. Samples will be sent to Agricultural Diagnostic Services at UH and have total N, P, C, pH, and salinity measured. The sampling will be repeated at least two years after predator removal to document changes in soil composition that are potentially associated with changes in seabird densities.