ECOSYSTEM

MANAGEMENT PROGRAM BULLETIN

2018 ISSUE

ON THE COVER **A rainbow illuminates the sky in the waters off the Wai'anae coastline, where the Army's cultural resource program on O'ahu has documented a new petroglyph site.** BACKGROUND **The large, ancient etchings are one of the largest fields of petroglyphs known on the island of O'ahu.**

INTRODUCTION

MOVING FORWARD TOGETHER

The Hawaiian Islands are the most geographically isolated group of islands on Earth. They are also home to more than 500 federally listed threatened and endangered species and countless cultural and archaeological resources.

A number of these unique resources can be found on U.S. Army installations and training areas. From plants and birds, to snails, bats and insects, the Army's natural resource programs on O'ahu and Hawai'i Island manage more than 120 threatened and endangered species. Likewise, the Army's cultural resource programs in Hawai'i manage more than 3,000 significant cultural resources, including historic sites, structures, buildings and artifacts.

The Ecosystem Management Program Bulletin is designed to educate the public and the military community about the unique resources on Army-managed lands and the Army's efforts to conserve them. Our hope is to encourage a collective conservation ethic, foster innovation and inspire and expand opportunities for collaboration and partnership with academia, industry and beyond.

The Army's core mission is to train our Soldiers so they are ready when called, and this mission is directly tied to the environmental stewardship of the resources in our care. Protecting the environment means sustaining the mission and securing the future.

U.S. ARMY GARRISON-HAWAI'I

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Colonel, U.S. Army Commanding

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Director of Public Works

U.S. ARMY

PICHTR

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A NOTE FROM THE EDITORS

The Hawaiian archipelago has long been a hub for discovery. From the earliest voyagers who settled the islands, attributing the first names to taxa found nowhere else, to today's biologists, detecting new species in a world of instant information. Our seeking continues in the fast-paced environment of today.

We continue to uncover a greater picture of the past, as you'll find in the story of petroglyphs on the Wai'anae coast in this issue.

We explore ways to preserve even the most sensitive plant taxa in seed banks for future use.

In our quest for knowledge, we are also reminded that we may not always find what we expect, as the tiny Band-Rumped Storm Petrel showed us in the last few years on Hawai'i Island.

As we look to the future of discovery, we have no doubt that it will be any less captivating than what we're learning today.

EDITORS

Kimberly Welch and Celeste Hanley

Environmental Outreach Specialists

Pacific International Center for High Technology Research

DISTRIBUTION

This magazine is produced on a yearly basis and distributed electronically to more than 2,000 readers.

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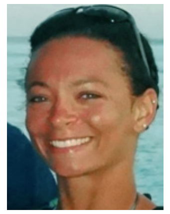
Mouse over the info symbol throughout this issue to find out more information.

CONTRIBUTORS



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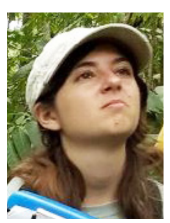

SARA BALMUTH

Sara Balmuth's interest in anthropological archaeology has led her to contributing to field projects in the American Southwest, working at the American Museum of Natural History in New York, and now conducting cultural resources management on O'ahu and in Guam.

Sara is currently an archaeological field technician with International Archaeology, LLC.

NICOLE GALASE

Nicole Galase has worked with endangered species across the Hawaiian archipelago, from Hawai'i Island to Kure Atoll. In addition to her work with the elusive Band-rumped Storm Petrel, she is on the board of the Friends of Hawaiian Islands National Wildlife Refuge, a non-profit organization that connects people with the nature and culture of the Northwestern Hawaiian Islands.

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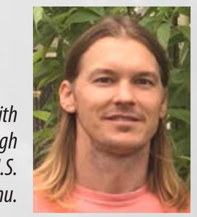

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Dan Adamski has been working with the Army's natural resource program for the past 10 years and currently works with seed laboratory and horticulture professionals in the rare plant program.

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Tiana Lackey was born and raised on Hawai'i Island and has spent the last 15 years contributing to natural resource management and conservation efforts in Hawai'i. She currently writes regulatory and compliance documents to support the Army's natural resource program at Pōhakuloa Training Area.

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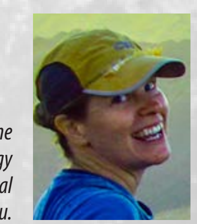

MICHELLE AKAMINE

Michelle Akamine has been working with the Army's natural resource team for over 10 years. A botanist by trade, she is currently exploring a variety of research topics to improve management of rare taxa.

Michelle is a monitoring specialist with the Pacific International Center for High Technology Research, working for the U.S. Army's Natural Resource Program on O'ahu.

ERIKA DITTMAR

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Erika was the project manager for the Hawai'i Vertebrate Introductions and Novel Ecosystems Project, a research effort through the Strategic Environmental Research and Development Program. She now works as a biologist with Pacific Rim Conservation on O'ahu.

ANCIENT ROCK DRAWINGS

UNCOVERED ON THE WAI'ANAE COAST

Local archaeologists race against the changing tides to record data on petroglyphs rarely seen on O'ahu.

Archaeologists from the U.S. Army Garrison-Hawai'i, the Pacific International Center for High Technology Research and the Department of Land and Natural Resources join forces to document over 20 petroglyphs found within beachrock along the leeward coast of O'ahu.

BY DARIENNE DEY, HĀLAULANI DAVAN AND SARA BALMUTH

On a tranquil evening in July 2016, Lonnie Watson and Mark Louviere decided to take a stroll along the shoreline fronting Pililā'au Army Recreation Center, along O'ahu's leeward coast. As the two visitors wandered along the beach, they were admiring the view of the setting sun reflected in the ocean when something unusual caught Watson's eye.

"There was a beam of light," said Watson. "It landed right on one of [the petroglyphs]. I said, 'Look!'"

Watson had caught a glimpse of a large petroglyph, a picture carved in stone by Hawaiians of the distant past.

As Watson and Louviere looked farther along the shore, they saw additional petroglyphs readily visible in the receding tide and fading evening light. Soon afterwards, archaeologists from the U.S. Army Garrison, Hawai'i, the Pacific International Center for High Technology Research and the Department of Land and Natural Resources arrived on the scene and quickly determined that these remarkable images had never previously been documented.

At the time, 16 individual petroglyphs were observed within a stratum of beachrock, which was partially obscured by another younger but similarly-formed sedimentary layer. The sand that normally covered both layers had been naturally cleared away and redeposited offshore. Several weeks later, the sand returned, reburying the petroglyphs. Nearly one year later, in July 2017, ocean conditions once again removed the overlying sand. The same petroglyphs reappeared, however, this time wave action revealed larger sections that were previously covered by young

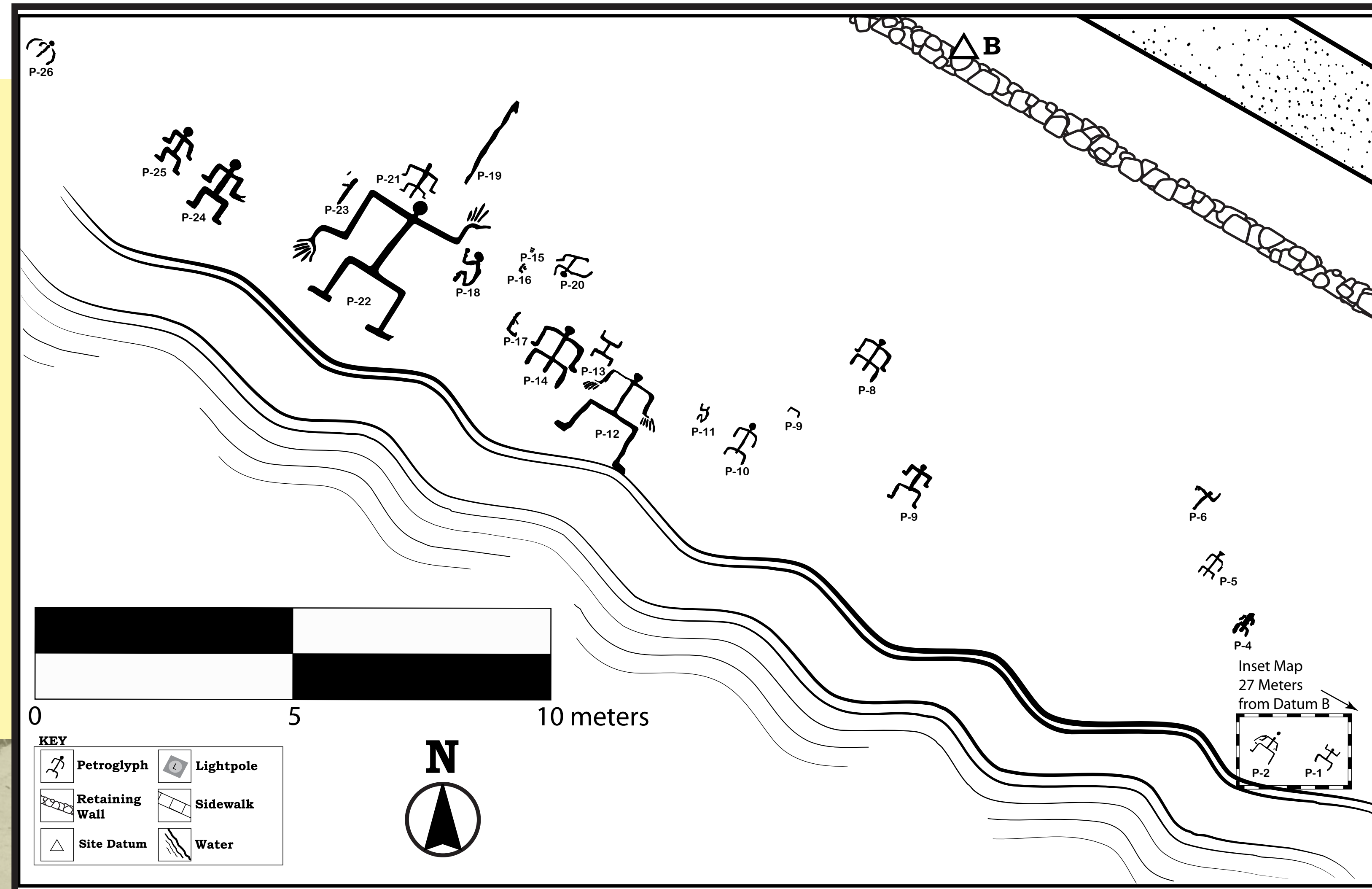
Sunset at Nene'u (also known as Pōka'ī), O'ahu

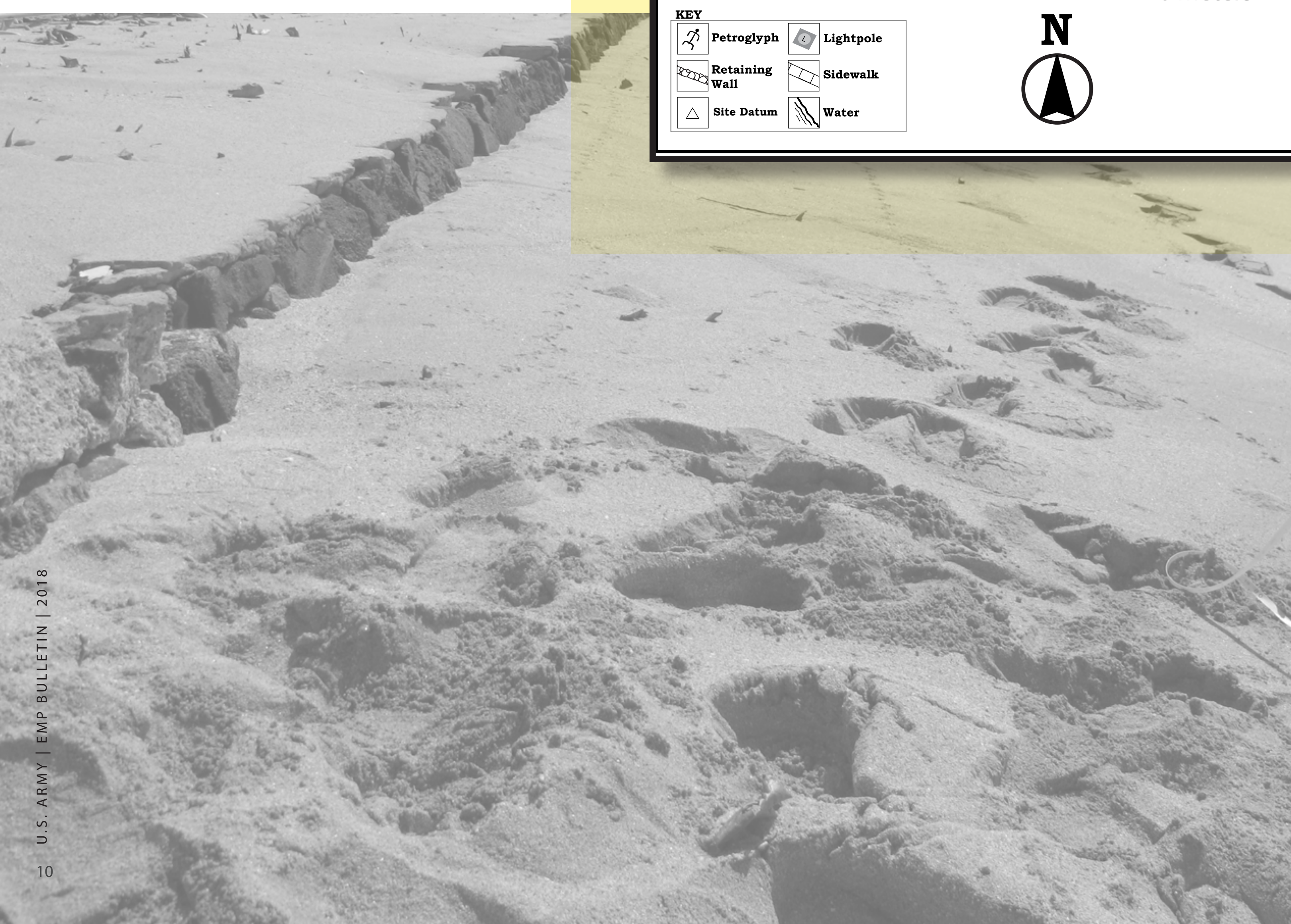
beachrock. Additional individual figures also surfaced, increasing the total to 21 petroglyphs.

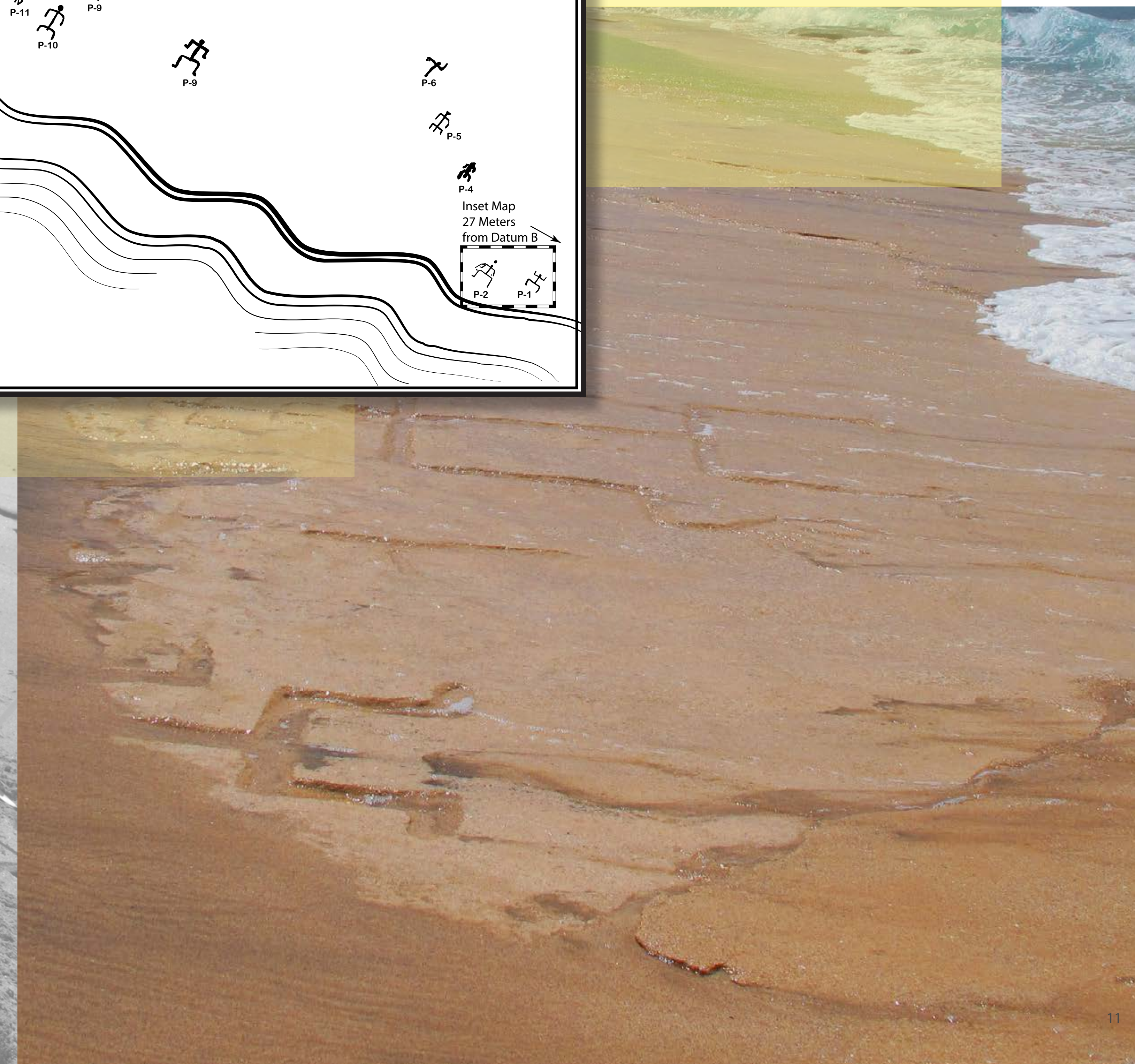
Varying from 15 centimeters to more than one meter in overall length, the majority of the stick figures appear to be anthropomorphic, resembling humans. At least three of the anthropomorphs are depicted in flexed (relatively curled up) positions, and most are oriented with their heads mauka and their feet makai. The exception is one anthropomorph glyph oriented in the opposite direction, sporting an active (i.e., running) pose. Since the petroglyphs seem to share a common style and arrangement with respect to one another, with no two overlapping, the figures likely were carved at or near the same time.

PLACE-BASED INTERPRETATION

Many locals refer to the area where the petroglyphs were found as Pōka'ī. However, according to Glen Kila, a life-long Wai'anae resident, the traditional name for this location







LOWER LEFT **For most of the year, sand completely obscures the petroglyphs within the stretch of beach at Nene'u, O'ahu.** LOWER RIGHT **Summertime ocean conditions are ideal for revealing an array of petroglyphs within lithified sandstone along the same Nene'u coastal strand.** LEFT **A petroglyph field plan view documents the placement of 21 petroglyphs carved into to the coastline.**
MAP BY J. HAAG

is Nene'u. Kila, who has ancestral ties to Nene'u, believes that local knowledge is needed to interpret petroglyph meaning. "Only the descendants of the 'āina (the land), who [know] the relationship of these petroglyphs to the geographical...to the nature of the area, can interpret what these petroglyphs are…[The people of Wai'anae are] very different from those cultures from Maui or from the Big Island when we talk about kupuka'āina."

One possible translation of Kila's term "kupuka'āina" is "offspring [of] the land" and refers to those who possess both physical (and metaphysical) knowledge of a place from firsthand residential experience as well as inherited kuleana (privilege and responsibility) through genealogical ties to their locale.

Over the years, some researchers have speculated that petroglyphs of human figures may represent ancestors, gods, 'aumakua (ancestral guardian spirits) or other concepts related to Hawaiian spirituality. Others take a somewhat more literal view of petroglyphs, believing that they may be portraits or illustrations made for artistic or record-keeping purposes. Still others feel that spirituality and everyday life are not separate or mutually exclusive.

Several possible meanings for Hawaiian petroglyphs have been discussed. Recording travel, ensuring health and longevity, commemorating events and legends, and depicting ancestry and religious stories are all possible reasons for the creation of petroglyphs in the islands.[1]

Stick figures, or anthromorphs, are likely the oldest motifs in Hawaiian sequences,[2] and stick-figure motifs are the most common design found at Nene'u. While

[1] Cox, Halley and Stasack, Edward. (1970). *Hawaiian Petroglyphs*. Bishop Museum Press.

[2] Lee, Georgia and Stasack, Edward (1999). *Spirit of Place: Petroglyphs of Hawai'i*. Easter Island Foundation.

OPPOSITE PAGE **To date, this petroglyph is the largest recorded at Nene'u, measuring over one meter in height.** UPPER LEFT **It takes two archaeologists to get accurate head-to-toe measurements on this same impressive figure.** UPPER RIGHT **A pair of archaeologists works quickly to document the petroglyph field that was revealed in July of 2017 using a variety of tools including a sand snake** (LOWER RIGHT)**, to temporarily prevent sand from filling in the carvings, and tape measures.** LOWER LEFT **Several petroglyphs resembled humans in a curled-up or flexed position, as seen in the figure to the left of the tape measure.**

the archaeological record contains evidence documenting the last several centuries of occupation on the Wai'anae coast, oral traditions suggest that the earliest settlement occurred thousands of years ago.

A HISTORICAL PERSPECTIVE

Material remains of fishing, tool maintenance and other temporary habitation activities have been documented within the vicinity of the petroglyphs. Archaeologists have documented other sites in Nene'u, including Keaupuni heiau (a stone religious structure), which was once located on the northern side of the bay, and Kū'īlioloa heiau, which is situated at Kāne'īlio, the southern peninsular portion of the bay. Though the exact relationship between these heiau and the petroglyphs is not clear, both structures would have been readily visible from the location of the petroglyph field.

Nearly a century of military presence is also evident at the Pililā'au Army Recreation Center. Towards the end of the First World War, President Woodrow Wilson took control of the area via Executive Order. The then-called "Wai'anae Kai Military Reservation" was home to a small community based around the local sugar plantation and railroad station. Most residents were moved out of the reservation to facilitate additional military training exercises at

RIGHT **Recording petroglyphs can be challenging when carvings are partially covered by limu (algae) and ocean water.** ABOVE **A temporary sand fill is a non-invasive technique that can facilitate photo documentation before petroglyphs disappear.**

the onset of World War II. To further assist with the war effort, the local rail system was devoted to transporting railroad equipment, while the beach itself served to simulate combat conditions in which Soldiers could practice landing amphibious crafts.

Despite the heavy traffic of Soldiers, M-4 Sherman tanks and other military craft that traversed the beach, the petroglyphs remained covered and thus undiscovered.

While sea levels change in daily, monthly and annual cycles due to the relative positions of the moon, earth and sun, it was the movement of beach sand that revealed the petroglyphs. Turbulent nalu 'a'ai (waves that swirl and "eat away" loose sand) transported beach sand out to sea for the past two summers. The petroglyph viewing was brief, however, and they are once again covered by sand deposits from the sea.

GEOLOGY MATTERS

Kaupuni Stream, one of the few regularly flowing waterways along the Wai'anae coast, empties into the bay at Nene'u, providing the conditions necessary for beach sand to change into calcareous beach rock. Besides coarse sand fragments, beach rock consists of particles of organic material, such as coral, mollusk shells, and limy foraminifera. One would assume that, since beach rock contains carbon, it might be possible to carbon date the petroglyphs. However, dating the beach rock would reflect the age at which the calcified organisms (whose remains are incorporated into the layer) expired rather than the age of the drawings carved into it. Still, because some of the petroglyphs are partially covered by new layers of beach rock, which must have formed after the drawings were made, geologists could hypothetically infer the minimum age range of the underlying petroglyphs based on how long it took for the new layer to form and cover them.

Unfortunately, beach rock surfaces are highly susceptible to natural weathering, causing drawings to become faint over time. The material also scratches easily, a quality that likely made it a highly attractive medium in which to create new petroglyphs and which makes it all too easy to permanently and irreparably damage preexisting petroglyphs.

At present, the petroglyphs are once again covered by water and sand. In order to help protect these priceless vestiges of Hawai'i's human history, visitors to Nene'u are encouraged to admire the petroglyphs from a distance. The petroglyphs, with their large size, beautiful setting directly on the coastline and mysterious yet familiar depictions of people and objects, allow us a privileged glimpse into the past by showing us what was and still is important to the inhabitants of this 'āina.

ABOVE **Foraminifera are tiny, single-celled organisms that live primarily in deep marine ecosystems but are also found in freshwater and even in damp terrestrial locations. Foraminifera have shells (or tests) made of calcium carbonate and are often used to date strata in palaeontology.**
SIIM SEPP (WWW.SANDATLAS.ORG)

BACKGROUND **As winter swells build, the ocean lays a blanket of sand across the Nene'u petroglyph field. Perhaps next summer will open another chapter of this story.**

FIRST ACTIVE BAND-RUMPED STORM PETREL NEST RECORDED IN HAWAI'I

A VAST PĀHOEHOE LAVA FIELD 40 MILES FROM THE NEAREST COAST AND 2,100 METERS ABOVE SEA LEVEL IS NOT WHERE MOST PEOPLE WOULD LOOK FOR SEABIRDS.

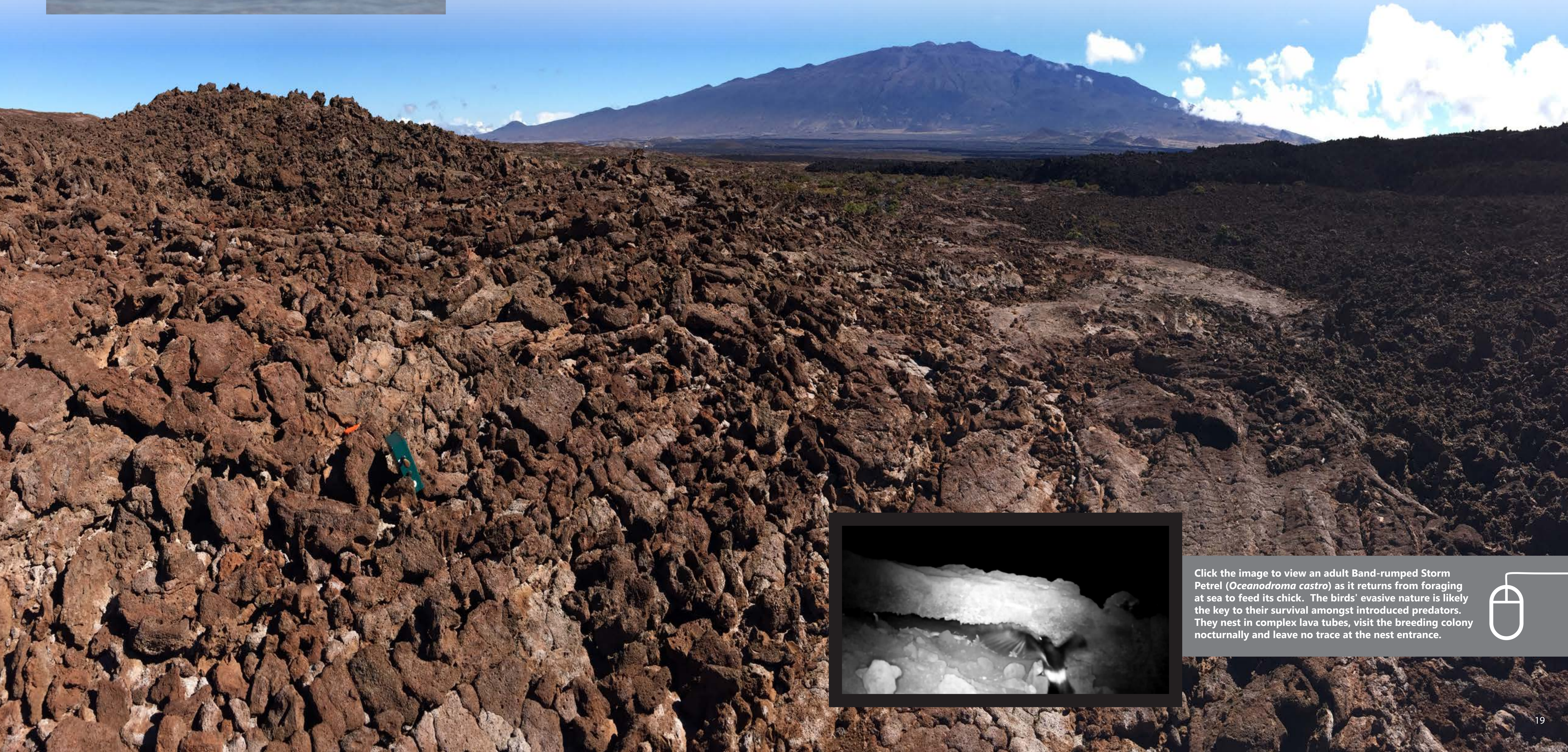
This subalpine tropical dryland forest is a rare, sparsely vegetated ecosystem, dominated by 'a'ā and pāhoehoe lava fields. Despite its barren appearance, this unique habitat, which falls within the Pōhakuloa Training Area (PTA) on Hawai'i Island, is where the Army's natural resource program found the first active Band-rumped Storm Petrel (*Oceanodroma castro*) nest in the Hawaiian Islands.

BY NICOLE GALASE

BACKGROUND **Army natural resource program staff at Pōhakuloa place recording devices (green box in the lava) on remote terrain to capture seabird calls at night.** LEFT **The Band-rumped Storm Petrel (*Oceanodroma castro*) spends most of its life at sea.** PHOTO CAPTURED OFF OF THE COAST OF KONA, HAWAI'I BY ROBIN W. BAIRD/CASCADIA RESEARCH HTTP://WWW.CASCADIARESEARCH.ORG/PROJECTS/HAWAII

"Stormys"—a nickname that birders and researchers have affectionately dubbed the birds—spend their breeding season on remote islands in the subtropical regions of both the Atlantic and Pacific Oceans, including Japan, the Galapagos Islands, Cape Verde, Ascension Island and Madeira, but information is scant about the population that uses Hawai'i as a breeding ground. For decades, evidence of downed birds, carcasses and calls heard on Kaua'i, Lehua Islet, Maui and Hawai'i Island indicated the species' presence, but no active nest locations were confirmed before the Army natural resource team's encounter in 2015.

The Band-rumped Storm Petrel is the smallest seabird in Hawai'i, and at 1.5 ounces, it's about the same weight as a Northern Cardinal (*Cardinalis cardinalis*). Despite their small size, storm petrels are mighty birds, known for weathering fierce storms out at sea where they spend most of their lives. Stormys only return to land to breed in the summer months. When they return, they quickly tuck themselves into small openings in the lava terrain and navigate their way through intricate tunnels in the lava tube system, finally arriving at a living chamber that is safe from introduced predators. While the stormys' cryptic existence on land seems to lend to their survival amongst a landscape of predators, it also makes them a difficult species to study.



Click the image to view an adult Band-rumped Storm Petrel (*Oceanodroma castro*) as it returns from foraging at sea to feed its chick. The birds' evasive nature is likely the key to their survival amongst introduced predators. They nest in complex lava tubes, visit the breeding colony nocturnally and leave no trace at the nest entrance.

A CHANCE ENCOUNTER

Finding Band-rumped Storm Petrels at PTA started off as a coincidental chance encounter. Staff were surveying for a different endangered seabird thought to be present at PTA, the endangered Hawaiian Petrel (*Pterodroma sandwichensis*), with acoustic monitoring devices. Only four Hawaiian Petrel calls were detected in thousands of recorded hours. However, while Hawaiian Petrels appear to merely pass over the installation, staff consistently found another call in the recordings: the Band-rumped Storm Petrel.

SEARCH METHODS

Army natural resource staff used new field techniques to discover as much about stormys as possible. Since researchers previously had little luck in finding active nests, the team at PTA designed a comprehensive and intensive study to find and observe the stormys. Tactics deployed included acoustic data collection, night vision surveys, dog searches and installation of surveillance cameras.

Acoustic monitoring is a passive way to monitor large, difficult-to-reach locations while causing minimal disturbance. This method provides a lot of information, and little effort is needed to implement the technique besides a few kilometers of hiking over rugged lava fields and the analysis of data once it is recorded. Staff used information from the monitoring data to guide subsequent night vision survey locations.

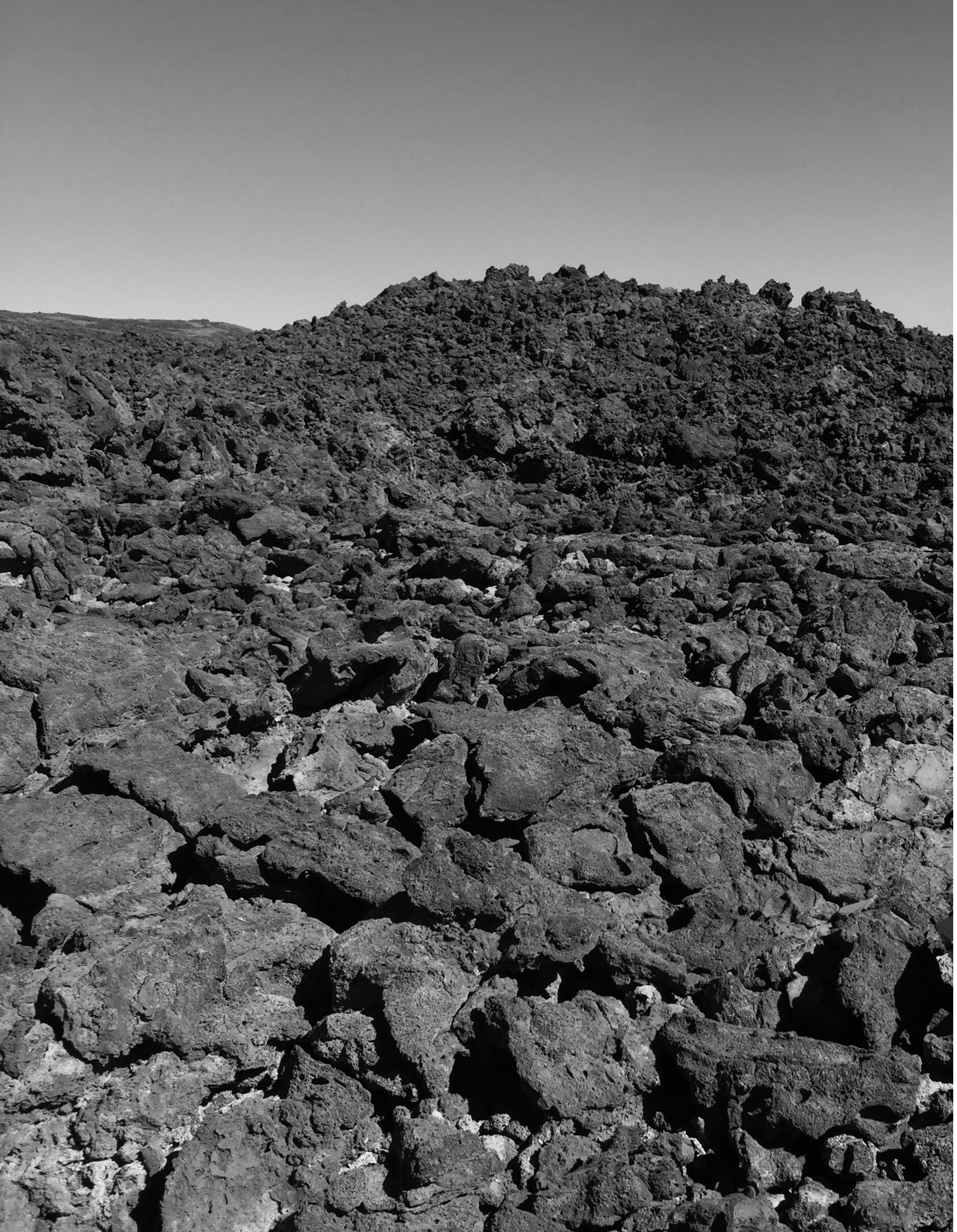
Night vision surveys are where researchers really get tested. Since storm petrels only return to land in the darkness of night, observers have no choice but to brave the cold of the high elevation habitat, harsh winds and—on the unluckiest nights—pelting rain. Even when one submits to these tests, it takes critical thinking, a little help from technology and a lot of sheer luck to be in the right place at the right time to catch conclusive behavior. Staff use near-infrared lamps to light up the terrain and sky, which can only be seen with the help of night vision (a method adopted from the Kaua'i Endangered Seabird Recovery Project). These tools allow the observer to clearly identify stormys from large moths or Hawaiian hoary bats (*Laciurus cinereus semotus*). The possibility of witnessing a stormy land on the ground makes the night work worthwhile.

Despite the aid of night vision technology, even when staff are able to see a bird land, locating the correct passage that leads to the nest chamber is difficult. Enter the detector dog, Makalani, and his handler, Teresa. Observations from night surveys guide where staff take Makalani to sniff out seabirds under the lava's surface. While Makalani's efficacy trials can prove time and again that his sniffer is up to snuff, it is up to the human observer to use the knowledge gleaned from acoustic data and night vision observations to lead him to the best areas to find the stormys. Searches begin as early as possible to take advantage of cooler temperatures, and Makalani does the difficult work of carefully and methodically searching the area. Since Makalani cannot speak, it takes a bit of deductive reasoning to come to conclusions about his findings. Makalani's "point" to indicate seabird activity typically involves him remaining still, with his hind end pointed toward us, followed by a glance over his shoulder to make sure the point is seen. Since the lava tube architecture isn't discernible to those above the surface, there may be many possible nest entrances. With varying wind directions and speeds, the opening to which Makalani directs the handler may just happen to be where the most scent is wafting from, rather than the entrance of the stormy nest.

When Makalani indicates seabird activity at a specific spot, it is still impossible to visibly confirm that the site is indeed a nest.

OPPOSITE PAGE, LEFT **Near-infrared lights illuminate the search area for Band-rumped Storm Petrel (*Oceanodroma castro*) activity during night vision surveys by the Army's natural resource team at Pōhakuloa.** OPPOSITE PAGE, RIGHT **Makalani enjoys a tennis ball reward from handler Teresa Gajate, a contractor for the project, when he finds a scent target in the field.** BACKGROUND **Makalani investigates an opening in the lava tube architecture.**

Nicole Galase (Seabird Project Leader, Center for Environmental Management of Military Lands) sets up a surveillance camera powered by a solar panel to monitor Band-rumped Storm Petrel (*Oceanodroma castro*) activity at a known nest site at Pōhakuloa Training Area.



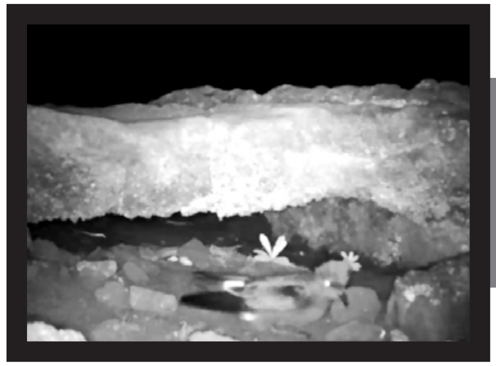
Stormys make their nests deep inside the lava tunnels and leave no trace at the entrance, which means that merely looking into any potential nest openings is unhelpful.

Visibly confirming an active nest requires surveillance cameras at the site, ready to record when triggered by motion. In 2015, staff deployed trail cameras, which only captured a few grainy photos of a stormy in the entrance to a nest. However, these pictures confirmed the first active Band-rumped Storm Petrel nest in Hawai'i. In the following years, staff switched to surveillance cameras with more robust settings and the option to take videos. The new cameras have recorded numerous videos of stormys entering and leaving nests, which provide insight into the typical timing of nest visits and reveal the way that stormys inconspicuously scurry into their nests to avoid danger.

Monitoring and Threat Control

Army natural resource staff confirmed two active nests during the 2017 breeding year. Unfortunately, video cameras recorded a feral cat around one of the stormy nest sites. Staff quickly deployed cat traps, but the cunning cat entered the nest to extract and consume one of the stormys just days before the cat was trapped and removed from the area. More trapping is planned for the coming years to aid survival. However, staff were able to monitor the other nest for a complete breeding season, from the first arrival of the parents and subsequent feeding visits, to the successful fledging of the chick to forage for itself at sea. The information gathered from monitoring this nest will contribute greatly to a better understanding of the species.

These cryptic seabirds are elusive subjects, and we cannot study them unless we can find them. Despite being able to deduce the locations of stormy activity from multiple integrated methods, these two active nests are the first records in Hawai'i. It takes an interdisciplinary team of devoted individuals to deploy the right equipment and conduct surveys. Army natural resource staff will continue to creatively combine various methods of searching and observation to learn more about this endangered species for the scientific community and to ensure a state of coexistence with the natural systems at PTA to maintain the Army's training capacity.



In early October 2017, surveillance cameras captured a chick emerging from its nest for the first time. The chick explores the entrance of the nest and practices beating its wings.

On the night of October 31, 2017, the chick fledges and leaves the nest. This young stormy will now have to forage for food at sea on its own.

Click the images to the left to see what a young Band-rumped Storm Petrel (*Oceanodroma castro*) has been up to outside the confines of the lava tube system.

OPPOSITE PAGE **With ongoing predator control and continued monitoring within the stark lava terrain at Pōhakuloa, Army natural resource staff hope to discover additional Band-rumped Storm Petrel (*Oceanodroma castro*) nests in the future.**

SEEDS in the BANK

SEED BANKS CREATE A SAFE PLACE FOR O'AHU'S PLANT TAXA INSIDE THE ARMY'S SEED STORAGE FACILITY AT SCHOFIELD BARRACKS

BY TIMOTHY CHAMBERS

Human activity has put global biodiversity under siege. Habitat conversion and urbanization, invasive alien species, resource over-exploitation, pollution and disease, and climate change have resulted in at least 25% of the global plant diversity facing the threat of extinction. Hawai'i's diverse and unique ecosystems, with 89% of its native flowering plants found nowhere else in the world, is no exception. In fact, Hawai'i's situation is more ominous. With 10% of its flora already extinct and more than 30% of its flowering plants listed as either endangered or threatened, Hawai'i has become known as the extinction capital of the world.

In order to curb this trend, conservationists must use all tools at their disposal to stabilize and safeguard plant populations faced with extinction. Organizations concerned with biodiversity conservation employ two approaches to plant conservation: *ex situ* and *in situ*. *In situ* means "on-site" and is the conservation of plants within their natural habitats. *In situ* conservation involves protecting those lands that plants occupy and managing threats, such as invasive species, in the field.

Ex situ conservation on the other hand is the conservation of plants "off-site" and is complementary to the *in situ* efforts. Living collections of rare and threatened plants are established at botanic gardens or in laboratories under micropropagation (tissue culture) away from their natural settings. Plants conserved *ex situ* can then be used to repopulate plant species when faced with extinction *in situ*. Another form of *ex situ* conservation, and possibly the most economical, is to stockpile seeds of wild plant species in seed banks.

Saving seeds is not a new concept. Farmers have been saving seeds under favorable conditions for millennia. Today, modern seed banks store seeds under cold and dry conditions to prolong seed viability, preserving them for future use. Conventional seed banking has focused largely on the preservation of domesticated crop varieties and their wild relatives; however, over the last few decades the establishment of seed banks for the purpose of wild plant conservation has become more common. The most notable example of wild plant seed banking is the Millennium Seed Bank at the Royal Botanic Gardens, Kew, in England, which is working to secure 25% of the world's plant diversity in seed collections.

EARLY INVESTMENTS IN SEED STORAGE

Seed banking efforts in Hawai'i began in the early '90s with the establishment of National Tropical Botanical Garden's Hawaiian Seed Bank and Lyon Arboretum's Seed Conservation Laboratory.

ABOVE **This lone fruit was the first observed on a wild, endangered na'u (*Gardenia mannii*) in 15 years. The Army's O'ahu natural resource program collected the fruit in December 2016.** PREVIOUS PAGE **Staff captured an image of one of the tiny seeds from the na'u fruit during germination using a microscope.**

MORE INFO ON THE HISTORY OF THIS SPECIES OF NA'U CAN BE FOUND IN THE TECHNIQUES EDITION OF THE EMP BULLETIN.

ABOVE **Propagule research technician Makanani Akiona, who works for the Army's natural resource program on O'ahu, uses dental tools to sort and count seeds before they head into dessication or germination chambers.** FRUIT AND SEEDS BELOW, FROM LEFT **Hāhā (*Cyanea acuminata*), wiliwili (*Erythrina sandwicensis*), 'a'ali'i (*Dodonea viscosa*), manono (*Kadua* sp.), māmaki (*Pipturus albidus*), ko'oloa (*Abutilon sandwicense*), nīoi (*Eugenia koolauensis*) and *Sanicula mariversa* (no known common name).**

SEED STORAGE BEHAVIOR

In 2007, the Army opened its seed lab to support the conservation of over 50 threatened and endangered plants under Army management, making it the third organization to join the seed storage ranks, followed by the Hawai'i Island Seed Bank in 2008.

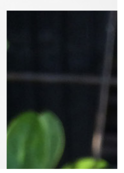
The Army was also one of the founding partners of the Hawai'i Seed Bank Partnership, or Laukahi, and continues to work with 14 other member organizations to advance seed banking efforts in Hawai'i to preserve the diversity of native plant species in support of conservation and restoration.

Prior to the establishment of early seed banking efforts in Hawai'i, little was known about the seed storage behavior of Hawaiian plants. Today we know that not all seeds store in the same way. Researchers have identified three categories of seed storage behavior: orthodox, intermediate and recalcitrant. Orthodox seeds tolerate drying to low moisture contents and store well at frozen temperatures (-18 degrees C). This category is the most common and represents standard seed banking conditions. Recalcitrant seeds do not tolerate drying and as a result cannot be stored under standard seed bank conditions. Researchers are currently working to determine if these seeds can be stored cryogenically (-196 degrees C). Intermediate seed behavior, as the name would suggest, falls somewhere between orthodox and recalcitrant. These seeds generally tolerate drying but are sensitive to negative storage temperatures. These seeds store well in refrigeration (5 degrees C). In contrast to other parts of the world, Hawai'i's flora has a high percentage of seeds that are not orthodox and cannot be stored under standard conditions. As a result, research is ongoing to determine best storage conditions for each species and how long seeds remain viable under these conditions.

Cyrtandra dentata

ORTHODOX

·tolerate drying
·store well frozen
e.g., *Cyrtandra dentata*

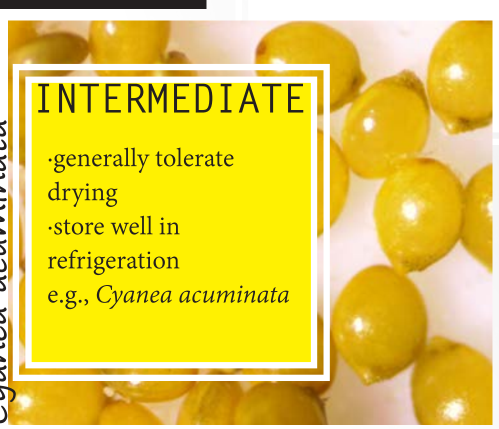


RECALCITRANT

·do not tolerate drying
·unsuitable for seed banking
e.g., *Eugenia koolauensis*

Hawai'i's flora has a high percentage of seeds that are not orthodox and cannot be stored under standard conditions. As a result, research is ongoing to determine best storage conditions for each species and how long seeds remain viable under these conditions. For recalcitrant seeds, like those of the endangered nioi (*Eugenia koolauensis*), research is under way to determine if these seeds can be stored cryogenically (-196 degrees C).

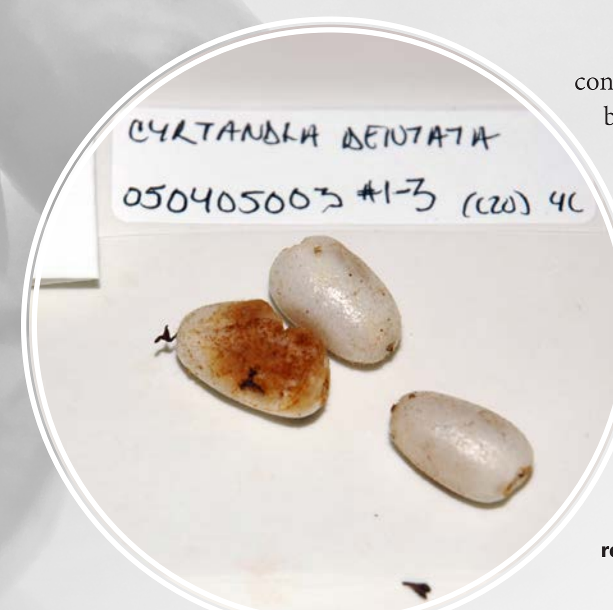
Eugenia koolauensis (fruit and seed)



Cyanea acuminata

INTERMEDIATE

·generally tolerate drying
·store well in refrigeration
e.g., *Cyanea acuminata*



LEFT **Army natural resource staff photograph fruits of endangered plants collected from the wild with a unique ascension number in order to keep track of them throughout their lives.** ABOVE **Temperature and humidity-controlled dessication chambers remove moisture from seeds so that they can be properly stored under refrigerated or freezing conditions.**

ABOVE **Propagule management specialist Tim Chambers with the Army's natural resource program on O'ahu uses a brush to sort tiny spores of palapalai (*Microlepia strigosa*).** BELOW **Once seeds are dried, they are sealed in aluminum packets to enter long-term storage in colder temperatures.** OPPOSITE PAGE **The ripe spores of palapalai are ready for sorting.**

SEED COLLECTIONS

Army natural resource field teams collect seeds from management units in the wild, paying close attention to select mature fruit to ensure the highest seed viability. When the seeds are brought in from the wild to the Army's seed conservation lab, staff give each collection a unique number for identification. Seed lab staff process collections using a variety of tools to separate the seed from the "chaff." Once the seeds are cleaned, staff count or weigh them, depending on their size, to determine the number of seeds in the collection and then pull a small sample to conduct initial germination tests.

The seeds are then plated on growing medium in petri dishes and placed in germination chambers set to replicate day length and day and night temperatures at mid-elevations on O'ahu. Results from these tests help staff predict viability (survival rates) for each collection or can be used to determine the best growing method, if unknown.

Next, staff place the remaining seeds in one of three desiccation chambers for drying. These chambers contain saturated salts which control the relative humidity of the air in the chamber. Seeds are hygroscopic, which means they absorb or release water depending on their surrounding atmosphere. At low relative humidity, seeds will dry by releasing water into the atmosphere. Drying and cooling seeds slows the aging process and improves storage viability through time. Seeds must also be dried to low moisture content in order to prevent damage due to freezing.

VIABILITY AND LONG-TERM STORAGE TESTING

Viability testing is ongoing for collections within the Army's seed conservation lab. Staff test the seeds after six months, one year, two years, and five years in storage, and then at five year intervals after that. The results of these tests not only inform best storage conditions for seeds, but also allow staff to determine how long seeds remain viable in storage. When seed viability falls below an acceptable threshold in the

LEFT **The opened fruits (capsules) of 'ōhi'a reveal tiny, mature seeds. In the face of threats like rapid 'ōhi'a death (*Ceratocystis fimbriata*), a fungus decimating 'ōhi'a (*Metrosideros* spp.) forests on Hawai'i Island, the Army's natural resource program on O'ahu is targeting seed collections from 50 individual trees within each of its management units. The program currently has over three million 'ōhi'a seeds in storage.**

FOR MORE INFORMATION ON RAPID 'ŌHI'A DEATH, VISIT HTTPS://CMS.CTAHR.HAWAII.EDU/ROD/HOME.ASPX.

experiments, it is important to recollect or regenerate that collection in the nursery in order to maintain its conservation value.

Army staff are also working to develop long-term storage solutions for intermediate seeds—those that are sensitive to freezing or short-lived under refrigerated conditions. Staff are hopeful that ultra-low temperatures (-80 degrees C) may be the key to successful long-term storage of these taxa and are currently conducting trials on intermediate seeds within the lab's ultra-low temperature freezer.

In the case of the most challenging group, recalcitrant seeds, until functional cryogenic (-196 degrees C) storage techniques are developed, staff must grow them immediately as they have little tolerance for drying and loose viability quickly under ambient lab conditions.

YIELDING RESULTS

The Army's seed lab has worked with 441 different plant species, and the seed bank contains almost 8.6 million seeds. In addition to securing seeds from over 40 federally listed endangered species and preparing seeds for outplanting to boost endangered plant populations in the wild, the lab is currently increasing the diversity of common native plant species to support ecosystem restoration.

Storing collections of common native species such as 'ōhi'a has also become a tool for protecting rare taxa. Having a genetic safety net, even for common natives, is useful in the event that pathogens (like rapid ōhi'a death) make their way to the island of O'ahu and impact the habitat on which endangered species rely. In addition, securing a diverse community of keystone native species in storage provides another level of protection to the dwindling native habitat on O'ahu, which is already inundated with threats.

For the Army's natural resource program and other seed storage facilities in the State, banking seeds is a worthy and relatively small investment for improving the prospects of the remaining flora that are hanging on to life in the extinction capital of the world.

BACKGROUND **Many seeds in the Army's collections from the wild are germinated and placed in growth chambers. Eventually they will be outplanted into the forest or cultivated within living collections for genetic storage.**

KAHUA

IN THE FACE OF THREATS LIKE FIRE, INVASIVE SPECIES, DROUGHT AND GLOBAL CLIMATE CHANGE, THE ARMY'S NATURAL RESOURCE PROGRAM IS DEVELOPING ANOTHER TOOL TO CONSERVE THE ENDANGERED PLANTS IN ITS CARE.

SCHOFIELD'S NATIVE SEED ORCHARD

For endangered plant conservation, collecting seeds for propagation and storage, along with maintaining living collections of all genetic founders, have been standard practices for mitigating the threats these plants experience in the wild.

In an effort to reduce greenhouse space used for the living collections, as well as reduce field time needed for seed collection, Army natural resource staff developed a new two-acre orchard-like site near a decommissioned landfill, just a short drive down the road from the natural resource baseyard on Schofield Barracks.

ABOVE **Army staff and volunteers planted rows of ko'oko'olau (*Bidens torta*) at the Kahua site. Seeds collected from the 200+ individuals will support habitat restoration in the wild.**

DAN ADAMSKI, RARE PLANT PROGRAM MANAGER FOR THE ARMY'S NATURAL RESOURCE PROGRAM ON O'AHU, TAKES A MOMENT TO BRING US UP TO DATE ON THE SEED ORCHARD APPROACH TO CONSERVATION.

HOW DID YOU COME UP WITH THE IDEA FOR A "SEED ORCHARD"?

We were having a difficult time collecting seeds from field sites due to a number of factors, including low seed set, and timing collections for when the fruit would be ripe. Additionally, the living collection takes up a lot of space in the greenhouse and putting the plants in the ground would allow them to grow bigger and hopefully produce more seed than having them in pots. The idea of the seed orchard came as a potential solution to all of these issues.

...AND THE NAME, KAHUA?

Since it's a new project for us [the Army's natural resource program], we decided to open up the naming of the garden to staff. After collecting suggestions from various team members, "Kahua," a Hawaiian word that can translate to "fruit" or "seed," was the entry that ultimately received the most votes. Ecosystem restoration specialist Julia Lee was the creative contributor.

WHAT ARE THE ADVANTAGES OF THIS SEED ORCHARD APPROACH?

A native seed orchard provides many benefits. Plants can grow much larger since they are rooted in the ground and not restricted by pot size. As these plants grow and mature, staff can easily

ABOVE **Kahua, the Army's new two-acre seed orchard at Schofield Barracks, is fenced to protect the rare plants from damage by feral pigs.**

collect seed that can then be used in field sites or stored in the seed lab. The Kahua site is also more accessible for controlled cross-pollination by hand and helps staff better understand the reproductive biology of some difficult species in the wild, such as kulu'i [*Nototrichium humile*].

WHAT GOES INTO GETTING A SEED ORCHARD STARTED?

The first step was finding a site. Through a series of connections within the U.S. Army Garrison-Hawai'i, we were able to secure the area along the slope of the former Schofield landfill on the northwestern side of the installation. Interestingly enough, our seed lab manager, Tim [Chambers], happens to have previous experience restoring landfills, so the site ended up being a natural match for our team.

Next, holes were dug using augers, and new outplantings were surrounded with weed mat to limit erosion and prevent weeds and grasses from overtaking the area.

Pigs also frequent the area, so we had to build a fence to protect the garden.

Water was the final resource we had to secure. Plants in the wild are susceptible to drought and extreme weather events, so our idea was to provide a sustained water source for the plantings at the site. We built a 400-gallon water catchment upslope from the fence, which supplies an automated irrigation system. The system allows us to spend less time hand watering plants.

HOW MUCH WORK GOES INTO KEEPING KAHUA RUNNING?

We try to construct the area so it will be relatively maintenance-free. This includes building a secure fence, setting up a water catchment and applying weed mat to all outplanted areas.

By taking time to install this infrastructure, we limit our maintenance to checks of the irrigation system and occasional weeding, usually not more than a couple hours each month. As with all of the sites we manage, long-term maintenance must be factored in, and staff time must be balanced between this site and the demands of our rare plant nurseries.

WHAT KINDS OF PLANTS ARE CURRENTLY PLANTED AT KAHUA?

In April, we planted four endangered species at Kahua: ma'o hau hele [*Hibiscus brackenridgei* subsp. *mokuleianus*], ma'aloa [*Neraudia angulata*], kulu'i [*Nototrichium humile*], māhoe [*Alectryon macrococcus* var. *macrococcus*] and nīoi [*Eugenia koolauensis*]. We chose the first three species because the wild populations are located in high risk areas that are very fire-prone. Wild populations of nīoi are currently threatened by an introduced rust (*Puccinia psidii*) that is not possible to control in the forest.

Staff and volunteers also planted over 1,000 native ko'oko'olau [*Bidens torta*] plants and 75 'a'ali'i [*Dodonea viscosa*], which are not endangered, but will be used as a seed source for restoration efforts at various management units in the Wai'anae range.

WHAT CAN WE EXPECT TO FIND AT KAHUA IN THE FUTURE?

Depending on the survival of species currently planted at Kahua, we may consider expanding the boundaries. Currently there are approximately 300 total plants from five endangered species planted at the site. Once these plants begin to flower and fruit, we will collect the propagules for seed storage and for reintroductions of plants into the wild.

IN ADDITION TO MANAGING ENDANGERED PLANTS IN THEIR NATURAL HABITAT, THE KAHUA SITE ALLOWS THE ARMY NATURAL RESOURCE TEAM TO COLLECT AND STORE FRUIT, AS WELL AS MAINTAIN A LIVING COLLECTION IN A FENCED AREA. THE CONTINUED SUCCESS OF THIS SITE WILL ALLOW THESE ENDANGERED SPECIES TO PERSIST FOR FUTURE GENERATIONS.

LEFT **Ma'aloa (*Neraudia angulata*) is one of the endangered species planted within the Kahua seed orchard.** TOP **In the wild, ma'aloa are located on very steep terrain. Ma'aloa fruit** (ABOVE) **will be an easier target for staff to collect from plants within the Kahua site.**

A Strategic Approach

to Improving Habitat for Endangered Nehe at Pōhakuloa Training Area

BY TIANA LACKEY

Nehe (*Melanthera venosa*) is a federally-listed endangered plant in the sunflower family that is endemic to Hawai'i Island.

The species is currently only known to exist on Pu'u Nohona o Hae at Pōhakuloa Training Area (PTA), a 132,200-acre Army installation located in the saddle region between Mauna Kea, Mauna Loa and Hualālai volcanoes. Primary threats to this endangered nehe include loss and degradation of habitat from feral ungulates, wildland fire and invasive weeds.

To help protect the species from the immense threat of feral ungulates and wildland fire, the Army enclosed Pu'u Nohona o Hae with a 6-foot conservation fence and a 60-foot fuelbreak. The pu'u has been ungulate-free since December 2009.

ABOVE **Nehe (*Melanthera venosa*) is one of the species managed by the Army's natural resource program within the Pōhakuloa Training Area.** BACKGROUND **Invasive grasses at Pu'u Nohona o Hae, the only known location of this nehe species, threaten the survival of this endangered member of the Asteraceae family.**

Recent monitoring efforts conducted by the Army's natural resource program at PTA showed that the nehe (*M. venosa*) population was in decline, likely due, in part, to the fact that the pu'u is highly dominated by invasive plants such as fountain grass (*Cenchrus setaceus*). Army staff inferred that plant community structure is important to the survival of this species. Data show that nehe is present in areas with a greater density of native vegetation. Conversely, nehe is absent where invasive species, especially fountain grass, are more abundant.

HABITAT TRANSFORMATION: EASING THE TRANSITION FOR NEHE

Through previous control efforts, the Army natural resource program found that immediate, complete removal of all invasive plants can be detrimental to endangered plant species, perhaps due to decreased plant water availability caused by greater exposure of the soil to evaporative forces such as wind and sun.

Staff thus implemented a gradual approach to invasive plant management on Pu'u Nohona o Hae to minimize detrimental impacts of immediate invasive plant removal while still providing the benefits of decreasing overall competition for resources for nehe. The goal was to remove the fountain grass to promote native community structure, providing favorable habitat and resource availability conditions to allow the nehe population to recover and be self-sustaining.

In January 2016, the Army's natural resource program established a 5-acre weed control area around the nehe population on Pu'u Nohona o Hae. Staff hand cut fountain grass individuals that were within three feet of each nehe location to one foot in height. Throughout the rest of the weed control area, fountain grass individuals were cut down to the ground with line trimmers. Herbicide was carefully applied to all fountain grass within the entire weed control area. After initial implementation was complete, staff returned to maintain the weed control area quarterly.

LEFT Nehe (*Melanthera venosa*) grows on rocky soils within the montane dry shrubland at Pu'u Nohona o Hae.

Feb. 2016

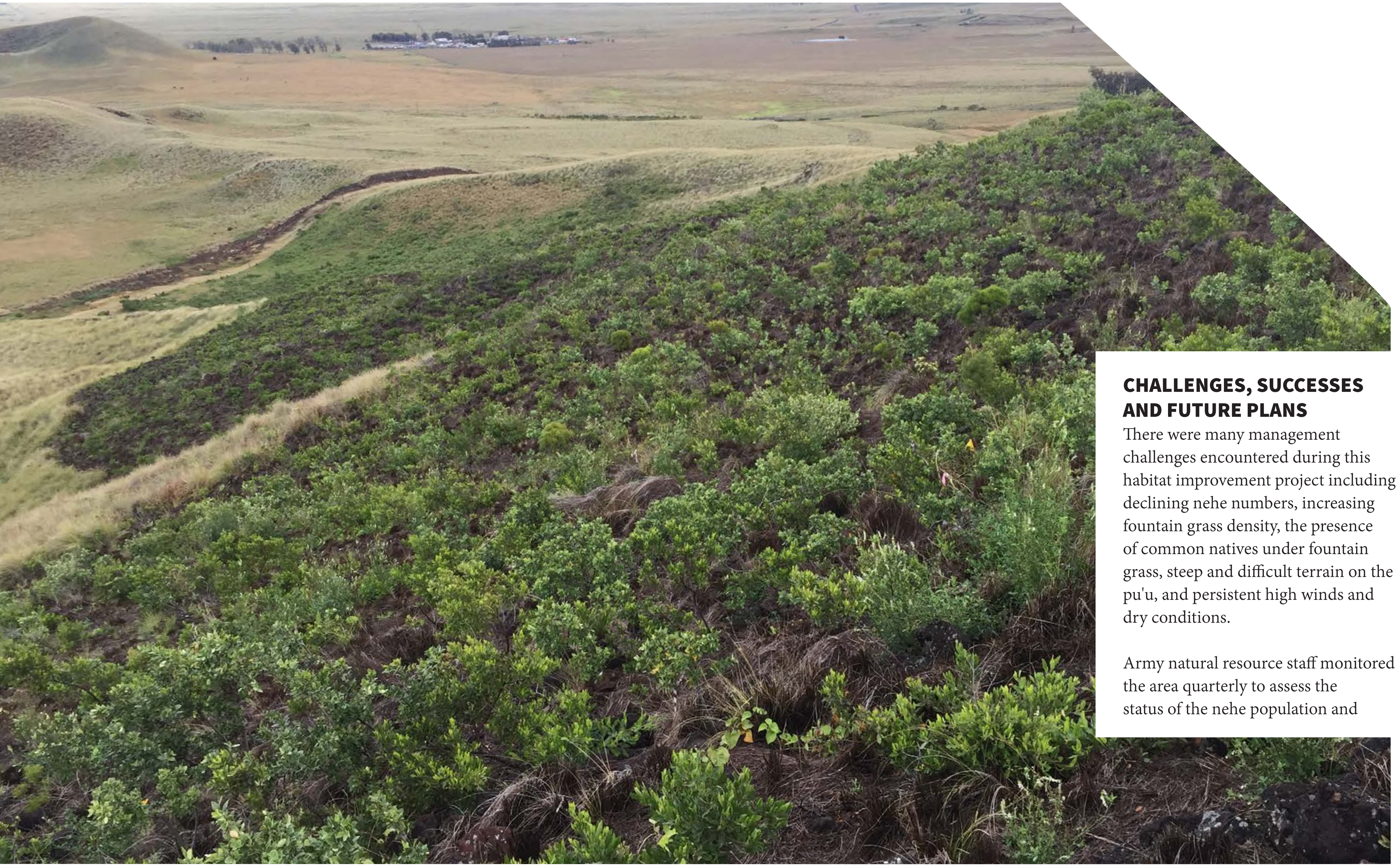
Non-native fountain grass (*Cenchrus setaceus*) dominated the habitat around the nehe (*Melanthera venosa*) at Pu'u Nonoha o Hae.

June 2016

Four months after initial removal, native plants are beginning to receive better access to sunlight, nutrients and water.

Feb. 2017

A year after the initial weeding treatment, native plants begin to grow in height and occupy space where invasive grasses used to reside.



CHALLENGES, SUCCESSES AND FUTURE PLANS

There were many management challenges encountered during this habitat improvement project including declining nehe numbers, increasing fountain grass density, the presence of common natives under fountain grass, steep and difficult terrain on the pu'u, and persistent high winds and dry conditions.

Army natural resource staff monitored the area quarterly to assess the status of the nehe population and surrounding plant community composition. Monitoring results indicate that fountain grass cover within the weed control buffer was reduced to less than one percent of the managed area. The native plant community component at the site showed a significant increase and is currently managed to maintain a 10 to 25 percent cover. The nehe population at the site increased from approximately 100 to 500 individuals. As a result of invasive plant control and beneficial weather conditions, new seedlings were observed! Overall, plant community structure and the associated increases in plant resource availability to nehe plants was shown to be an important factor for this species' growth, regeneration and survival. As a result of these management efforts, the nehe population on Pu'u Nohona o Hae appears to be increasing. Continued monitoring will be needed to confirm these preliminary findings.

LEFT **Reduced competition for resources has benefited the nehe (*Melanthera venosa*) population on Pu'u Nohona o Hae.** ABOVE AND UPPER RIGHT **Nehe seedlings are beginning to germinate in the former grass patches within the weed control site.**

Future goals for the management of the endangered nehe at PTA include further facilitating habitat improvement through outplanting of both common natives and nehe at this site. Additionally, a strategic approach will be applied to other federally-listed plant species for which weed control is implemented. For example, the Army plans to apply the lessons learned from this nehe habitat improvement project to aupaka (*Isodendrion hosakae*), another federally-listed plant species which faces similar threats and management challenges. Future management should incorporate adaptive management approaches, where goals and metrics to assess success are clearly defined.

Exploring Seed Viability

IN UNDISPERSED FRUITS OF ENDANGERED PLANTS

BY MICHELLE AKAMINE

The Army's natural resource program examines how endangered plant seeds fare in the absence of native bird dispersers.

LEFT AND BACKGROUND **Germinating seeds of hāhā (*Cyanea superba* subsp. *superba*) along with fresh and dried-up fruit of 'ōhāwai (*Delissea waianaensis*), collected from endangered lobelioid species managed by the Army's natural resource program.**

There are more than 150 species and subspecies of native Hawaiian lobelioids, a group of plants in the Campanulaceae (bellflower) family, all of which evolved from a single ancestor. Many of these species are rare—or even extinct. The Army manages six endangered lobelioid species, including *Cyanea superba* subsp. *superba*, or hāhā.

BACKGROUND **Endangered hāhā (*Cyanea superba* subsp. *superba*) emerge from the native fern understory at Kahanahāiki within the Mākua Military Reservation.**

Known threats to native lobelioid species include predation of fruits by rats (ingested seeds are either destroyed or dispersed to unfavorable locations), seedling predation by slugs, habitat loss, invasive species, fire and climate change. The Army conducts extensive threat control for endangered lobelioid populations.

INSET ABOVE **Fruit of endangered hāhā (*Cyanea superba* subsp. *superba*) shows signs of rat predation.** INSET BELOW **A rat is caught in the act as it climbs the hāhā to devour the fruit.**

ABOVE **Flowers of the three endangered lobelioid species that the Army is currently testing for seed viability in undispersed fruits include (clockwise from left): *Cyanea superba* subsp. *superba* (hāhā), *Delissea waianaensis* (ʻōhāwai), *Cyanea grimesiana* subsp. *obatae* (hāhā).** OPPOSITE PAGE **Fresh fruit collected from outplanted *Cyanea superba* subsp. *superba* (hāhā).**

Many Hawaiian plants, such as the native lobelioids, depend on birds to disperse their fruits. However, with the disappearance of native fruit-eating birds in O'ahu's forests, staff with the Army's natural resource program have noticed that the ripe fruits on several endangered lobelioid species are rotting or shriveling up on the plants before dropping to the ground. Non-native birds do not appear to be eating the lobelioid fruits.

Each fleshy fruit may have hundreds of seeds, and seeds from fresh fruit generally have excellent viability, or ability to germinate. However, staff have generally observed few seedlings around the plants in the wild.

The Army's natural resource program wanted to know what happens to seed viability when nothing disperses the fruit, and fruits begin to decay or desiccate (dry out). To examine this question, staff experimented with three endangered lobelioids: *Cyanea superba* subsp. *superba*, *Cyanea grimesiana* subsp. *obatae* (both known by the Hawaiian name hāhā), and *Delissea waianaensis* (ʻōhāwai).

ABOVE **Fresh and rotten fruit of the hāhā (*C. superba* subsp. *superba*) and seedlings germinated in the Army's seed conservation lab.**
BELOW **Fresh and desiccated (dried-up) fruit of 'ōhāwai (*Delissea waianaensis*).**

The Army's seed conservation laboratory conducted two types of experiments to test seed viability: one for *C. superba* subsp. *superba* and *D. waianaensis* fruit that have started to rot or shrivel up on the plant, and another to test how quickly seeds from *C. superba* subsp. *superba* and *C. grimesiana* subsp. *obatae* lose viability when fruits begin to decay.

In the first set-up, both fresh and shriveled fruits were collected from plants in the field, and seed viability was compared between these fruit stages.

In the second, fresh ripe fruits were collected from the field, allowed to age in the lab, and seed viability was then tested at different periods of time.

After setting up these treatments, staff found some interesting results on the seeds' viability among the species tested.

CAN FRUIT THAT IS ROTTING ON WILD PLANTS PRODUCE VIABLE SEEDS?

With regards to *C. superba* subsp. *superba* and *D. waianaensis* the answer was different for each species. As expected, fresh fruits from both species had high viability. However, less than half of the *C. superba* subsp. *superba* seeds were viable from fruits that had begun to rot on the plants, whereas nearly all *D. waianaensis* seeds germinated from totally shriveled up fruits.

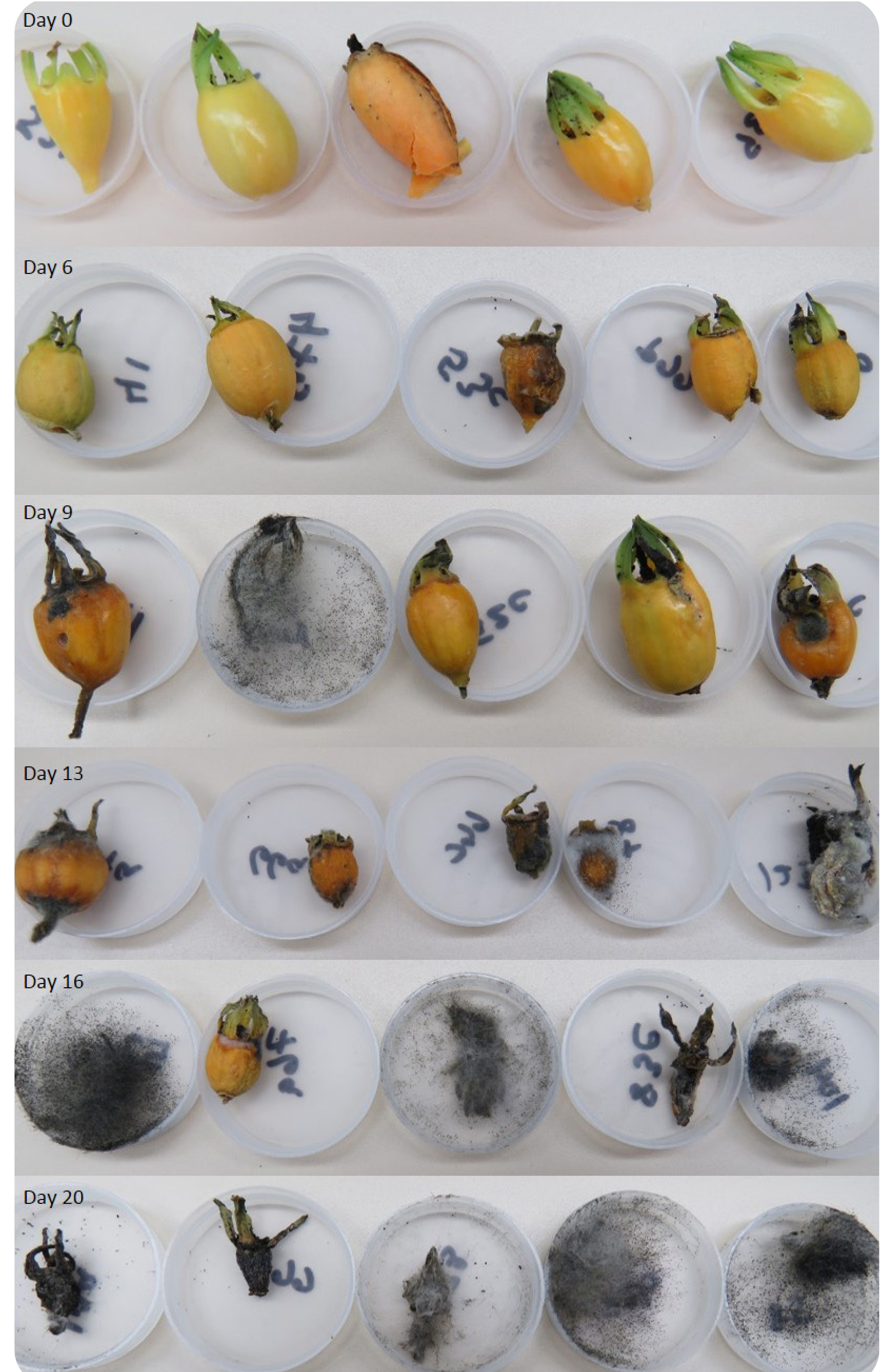
HOW QUICKLY DO SEEDS LOSE VIABILITY AS FRUITS BEGIN TO DECAY/DESICCATE?

For both *C. superba* subsp. *superba* and *C. grimesiana* subsp. *obatae*, seed viability started out excellent, but then declined over time as the fruits aged. Seeds of *C. superba* subsp. *superba* fruits had markedly diminished viability within one week and were completely inviable after two weeks. Around 40 percent of the *C. grimesiana* subsp. *obatae* seeds were viable by three weeks.

The data from the these experiments illuminate the fact that loss of bird dispersers may impact the ability of *C. superba* subsp. *superba* and *C. grimesiana* subsp. *obatae* to survive in the wild. The results point to the likelihood that these species require dispersers, as germination rates were lower for both species when seeds were left in undispersed fruit as compared with seeds from fresh, ripe fruit. Without effective dispersers, long-term self-sustaining populations may not occur. Instead, populations may require ongoing replacement using greenhouse-grown plants or seed sowing as older plants die. Fortunately for *D. waianaensis*, fruits retain high seed viability, and it does not appear to require dispersers.

FURTHER EXPLORATION AND MANAGEMENT IMPLICATIONS

Questions remain on the effects of seed disperser loss on these species as well as other rare Hawaiian lobelioids, especially with respect to seed viability in undispersed fruit. Additional research to pursue includes understanding the length of time untouched fruits remain on plants and seed viability at different periods of time after fruit has naturally fallen to the ground. In addition, forest settings differ from that of the laboratory and could result in different outcomes for viability. Further investigation is warranted in learning about the extent to which non-native dispersers can effectively replace missing native dispersers. If effective *C. superba* subsp. *superba* and *C. grimesiana* subsp. *obatae* dispersers are identified, natural resource managers should consider incorporating or enhancing this interaction at new or existing outplanting sites. Finally, environmental factors that may limit successful seedling germination and survival need further examination.



LEFT ***C. grimesiana* subsp. *obatae* fruit allowed to age for 20 days, shows visible signs of desiccation and molding over time.**

seed dispersal in O'ahu forests

THE importance OF non-native birds

By Erika Dittmar

Historically, O'ahu's forests were home to over 30 native bird species.[1] Each bird evolved to forage on fruit, nectar and/or insects. Many of these birds co-evolved with the native plant species to consume their fleshy fruits and in turn spread their seeds across the landscape, maintaining a diverse forest structure. Today, all of O'ahu's native frugivores have gone extinct or are no longer found in the wild, leaving many plants without their co-evolved dispersers and leaving them vulnerable to co-extinction.[2] This is evident as over 80 of O'ahu's threatened and endangered plant species produce fleshy fruits.[3]

©JULIAN HUME/SMITHSONIAN INSTITUTION

Along with the extinction of native bird species, more than 40 species of non-native birds have been introduced to the island,[4] many of which have established breeding populations. With no native frugivores remaining on the island, the role of introduced birds as seed dispersers merits study. Introduced birds may have many negative impacts to an ecosystem such as competition for resources with native species, spread of disease, predation on native invertebrates, and spread of invasive weeds. However, introduced birds could be dispersing native seeds and thus, be critical to maintaining native plant communities. With the total absence of native frugivores, and studies showing that rats act as seed predators and not dispersers,[5] it is vital to understand the impact introduced bird species may have on native forests as seed dispersers.

OPPOSITE PAGE **A partially eaten 'ōhāwai fruit (*Clermontia kakeana*) at Mānoa Cliffs restoration site on the Ko'olau mountain range.** ABOVE **Extinct O'ahu moa nalo (*Thambetochen xanion*), a type of flightless goose, once roamed O'ahu forests and was likely an important disperser of native seeds. Artist Julian Pender Hume based his conception for this piece on the bones of a three-foot-tall species uncovered in the 'Ewa plain sink holes.**

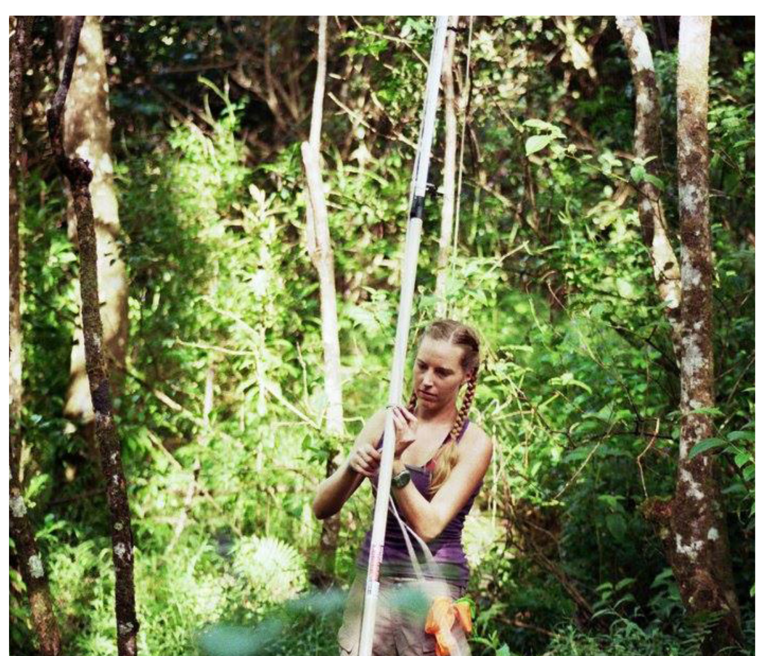
[1]Walther, Michael. (2016). *Extinct Birds of Hawai'i*. Mutual Publishing, LLC; First Edition.

[2]Culliney, Susan, Pejchar, Liba, Switzer, Richard, and Ruiz-Gutierrez, Viviana. (2012). *Seed dispersal by a captive corvid: the role of the 'Alalā (*Corvus hawaiiensis*) in shaping Hawai'i's plant communities*. Ecological Applications. 22: 1718-1832.

[3]State of Hawai'i Division of Forestry and Wildlife. *Threatened and Endangered Plants of Hawai'i.* https://dlnr.hawaii.gov/dofaw/rules/endangered-plants.

[4]Pratt, Douglas, Bruner, Phillip L., and Delwyn, Barrett G. (1987). *A field guide to the birds of Hawai'i and the Tropical Pacific.* Princeton University Press.

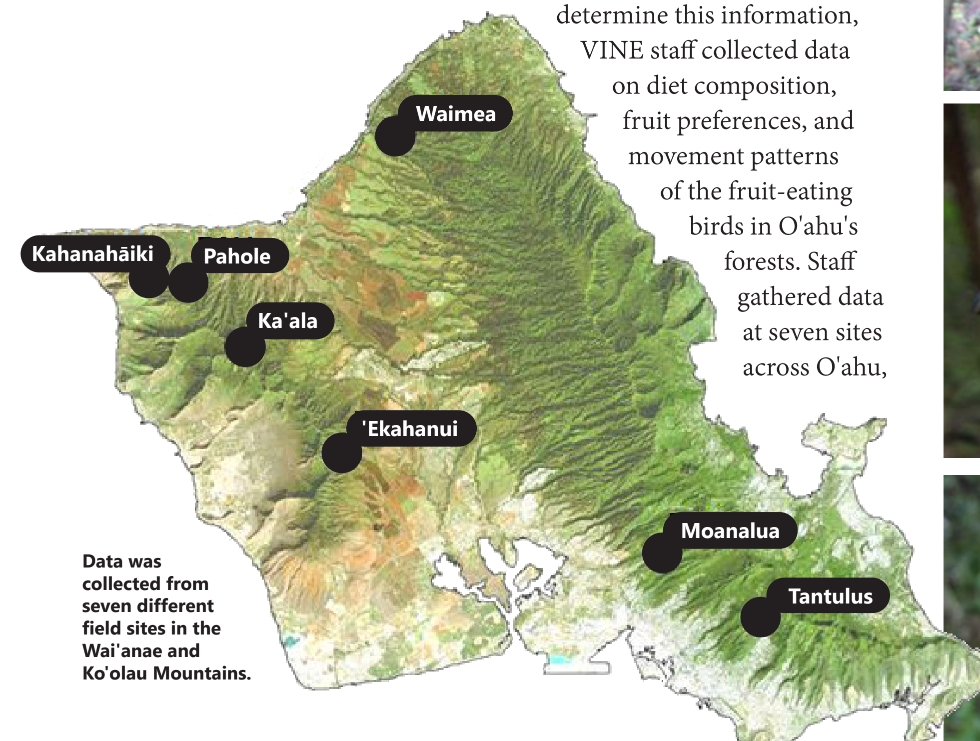
[5]Sheils, Aaron B. and Drake, Donald R. (2011). *Are introduced rats (*Rattus rattus*) both seed predators and dispersers in Hawai'i?* Biological Invasions. 13: 883-984.



TOP AND RIGHT **Fine mesh mist nets are placed at each of the study locations where skilled VINE staff can carefully remove captured birds to collect information on weight, age, sex and health, along with fecal samples.** ABOVE **Once data is recorded, birds such as this Japanese White-eye (*Zosterops japonicus*) are fitted with an identifying leg band before they are safely released back into the wild.**

Hawai'i Vertebrate Introductions and Novel Ecosystems (VINE) Project

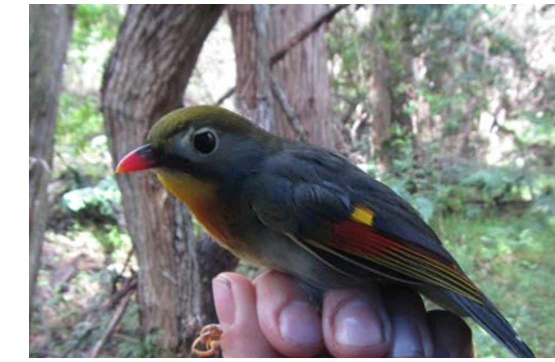
Seed dispersal has many interconnected parts. The Hawai'i Vertebrate Introductions and Novel Ecosystems (VINE) Project focuses mainly on the identification of fruit-eating species and their effectiveness as seed dispersers. To determine this information, VINE staff collected data on diet composition, fruit preferences, and movement patterns of the fruit-eating birds in O'ahu's forests. Staff gathered data at seven sites across O'ahu, including areas managed by the Army's natural resource program, along with State and private lands. These areas vary in rainfall, elevation, and plant community composition, which will allow staff to generalize findings to the whole island.



Data was collected from seven different field sites in the Wai'anae and Ko'olau Mountains.

Identification of Frugivores and Their Diet Compositions

The first piece of the seed dispersal puzzle was to identify which non-native birds are consuming fruits on O'ahu and which types of fruits they are eating. VINE staff collected and examined fecal samples from 17 bird species over the past four years. From this data, four predominant species were found to consume fruits and pass intact seeds: Red-billed Leiothrix (*Leiothrix lutea*), Japanese White-eye (*Zosterops japonicus*), Red-whiskered Bulbul (*Pycnonotus*



FROM TOP **Four predominant species were found to consume fruits and pass intact seeds: Red-billed Leiothrix (*Leiothrix lutea*), Red-whiskered Bulbul (*Pycnonotus jocosus*), Japanese White-eye (*Zosterops japonicus*), and Red-vented Bulbul (*Pycnonotus cafer*).**

jocosus), and Red-vented Bulbul (*Pycnonotus cafer*). These bird species have established thriving populations across the entire island. While it is encouraging to find that some of the introduced bird species are consuming fruits, it is important to note that these frugivores have smaller bodies and mouths relative to some historic native frugivores and thus, cannot consume fruits with large seeds. This means that these birds incompletely compensate for the loss of native fruit-eating birds.

For diet composition, data collection and analysis are ongoing. Thus far, most seeds found in the fecal samples were from non-native fruiting plants, and the prevalence of these plants in the fecal samples seems to be irrespective of the type of forest. Seeds from native plants have also been found in fecal samples collected from birds in forests where native plants are present (see facing page to find out which plants frequently showed up in bird fecal samples). The analysis of diet composition will conclude in 2018, but preliminary results show that birds are mostly consuming and dispersing non-native fruits. However, this may be due to the availability of fruit and not to the birds preferring the fruit of non-native plants. In forests dominated by non-native plant species, understandably birds have no choice but to consume what is available. Combining the data collected from bird diets and fruit preference experiments with detailed vegetation and fruit survey data will allow us to understand what birds are selecting versus what is available to them at each of the sites.

Fruit Preference by Frugivores

Understanding which fruits birds will select to eat, given the fruit available, allows us to determine fruit preference. In order to study fruit preference, wild birds were captured and brought back to an aviary. Once captive birds were comfortably introduced to the aviary, VINE staff conducted experiments during which birds were

A Red-billed Leiothrix chooses non-native shoebutton ardisia fruit (*Ardisia elliptica*) over native pūkiawe (*Leptecophylla tameiameiae*) during a fruit preference aviary trial.

Droppings yield clues to non-native forest bird diet

VINE researchers examined fecal samples from non-native birds in O'ahu forests. Seeds from non-native plants outnumbered those from natives, although this disparity may be due to availability of native fruit, as opposed to fruit preference.

HILO HOLLY, CINNAMON, GUNPOWDER TREE AND MĀMAKI PHOTOS BY FOREST AND KIM STARR

A lapalapa (*Cheirodendron platyphyllum*) canopy emerges from the misty summit of Ka'ala. Seeds from native *Cheirodendron* species were among the many native seeds identified in non-native bird fecal samples.

presented with two types of fruits. Birds were offered a variety of species combinations as well as size and color combinations. With these data we can determine fruit preferences of the bird species based on fruit color, size, and accessibility. The four non-native bird species that were the most important frugivores (Red-billed Leothrix, Red-whiskered Bulbul, Japanese White-eye and Red-vented Bulbul) were offered over 200 combinations of fruits. Preliminary results suggest that the four bird species seem to prefer blue fruits that are small in size. However, accessibility was the most important predictor for fruit choice. Plant species that offer fruits that are easily accessible (i.e., have branches to perch on to reach fruits) as well as those providing small blue fruits may be most likely to be dispersed by birds. Results should further help with management, as allowing preferred fruits to be available on the landscape may increase the chances of birds consuming and dispersing them.

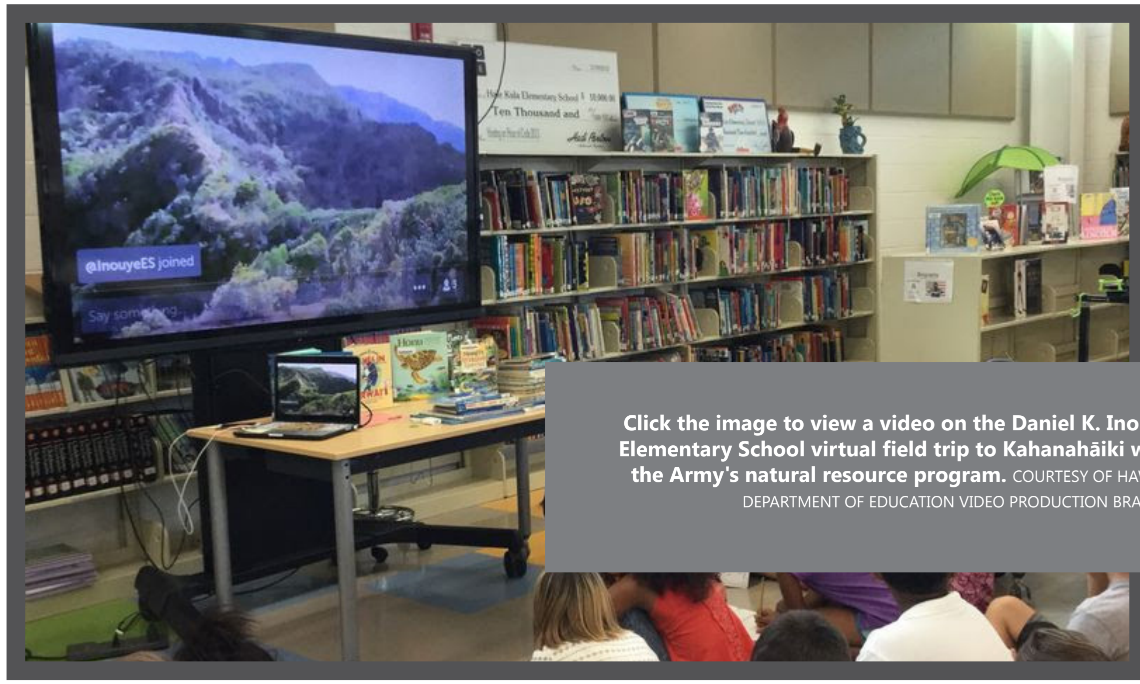
Movement Patterns of Frugivores

Understanding movement patterns of birds is imperative in predicting how far seeds can potentially be dispersed across the landscape. Long distance movements in particular are important for maintaining genetic diversity between populations and expanding plant ranges from natural and outplanted sites. Information on bird movement is collected at two sites using radio telemetry to determine hourly, daily, and seasonal movement patterns. By understanding seasonal variation in bird movement and combining it with plant fruiting phenology and the time it takes for birds to pass seeds, staff will be able to determine which plant species can be dispersed greater distances. Bird movement may also vary based on bird species and age (juveniles versus adults), therefore, staff collected movement data on both age groups for six bird species, including: the Red-whiskered Bulbul, Japanese White-eye, Red-billed Leiothrix, Red-vented Bulbul, Zebra Dove (*Geopelia striata*), and Spotted Dove (*Spilopelia chinensis*). Although data analysis is still underway, there are a few interesting patterns that stand out. Average distance moved in an hour varied by bird species with smaller birds traveling shorter distances. Japanese White-eye and Red-billed Leiothrix traveled about 230 meters per hour, Red-whiskered Bulbuls traveled 305 meters per hour and Red-vented Bulbuls traveled 426 meters per hour. Body size also seems to be a predictor of longer-distance movements. Japanese White-eyes and Red-billed Leiothrix rarely made movements further than 400 meters per hour whereas bulbul species made much more frequent and longer distance movements. Although all four bird species consume fruit, bulbuls have the ability to move seeds further which is crucial for moving seeds away from parent plants, maintaining genetic diversity, and increasing plant species' ranges on the landscape.

Collectively, the information found from this work will be used to understand how lands can be managed to promote the persistence of native forests. Growing and outplanting native species, as well as maintaining restoration sites is both time-intensive and expensive. With our data, conservation agencies can optimize restoration efforts by prioritizing the management of plant species that will not be able to be dispersed by birds and thus, may need to be maintained solely by humans. Additionally, play-back techniques can be used to attract the non-native bird species that are the most effective at dispersing native seeds into areas of conservation concern. Data collected from radio-tracking birds will also be helpful in determining invasive plant eradication boundaries so that introduced plants will not encroach and reestablish in restoration sites. In addition, by understanding how far birds can disperse seeds, managers will be able to establish restoration and outplanting sites to promote patch connectivity, increasing gene flow and forest stability. With a comprehensive understanding of how non-native birds move seeds through the environment and what role they have in these native and invasive forests, we can best protect and promote the growth of native plant species in the continually changing forests of O'ahu.

OPPOSITE PAGE **An adult Red-whiskered Bulbul (*Pycnonotus jocosus*) is fitted with a tiny radio-transmitter (less than three percent of its body weight) at Waimea, to allow researchers to collect information on the bird's home range size and seasonal movements.** RIGHT **A glimpse into the highly native forest of Ka'ala, one of the VINE Project's study sites.**

ARMY NATURAL RESOURCE TEAM TAKES STUDENTS ON A VIRTUAL FIELD TRIP



Click the image to view a video on the Daniel K. Inouye Elementary School virtual field trip to Kahanahāiki with the Army's natural resource program. COURTESY OF HAWAI'I DEPARTMENT OF EDUCATION VIDEO PRODUCTION BRANCH

Daniel K. Inouye Elementary students were treated to a special field trip into the Wai'anae Mountains via social media.

The Army's natural resource team on O'ahu worked with the school's librarian, Michelle Colte, to set up a live Periscope feed from the Wai'anae Mountains where staff and volunteers were planting over 350 native plants. The plants will improve habitat for the endangered species that the Army's natural resource program protects within Mākua Military Reservation.

New Ways to Learn

"Our school has been experimenting with different ways that kids can access information and share their learning," Colte said. "We connected with the Army's natural resource program because of the unique terrain and the location of their project. We are unable to take 125 fourth graders to this area, so Periscope allows our kids to ask the experts questions and to see the plants close up."

Students were able to submit questions to the field experts through the Periscope app, while the experts were working in the forest. Fourth graders are currently learning about native plants and sustainability, which made the experience and opportunity to speak with subject matter experts relevant and engaging.

"Having this technology brings the lesson to life for our students, and they experience what we're learning firsthand. It's hard to get to certain places and be able to do this," shared teacher Jerilynn Schaefer.

Daniel K. Inouye Elementary is located on Schofield Barracks and works with the U.S. Army Garrison-Hawai'i on partnership projects.

E komo mai

NEW BIOLOGISTS JOIN THE ARMY'S O'AHU AND PŌHAKULOA NATURAL RESOURCE PROGRAMS

Dr. Paul Smith began work with the U.S. Army Garrison–Hawai'i as the Directorate of Public Works entomologist. With a PhD in Entomology and an MS in Agricultural Biology, Paul was drawn to the work with the Army's natural resource program on O'ahu and is no stranger to field work. He pursued his Master's at New Mexico State University, where he studied the population dynamics of the desert-dwelling salt cedar leafhopper, spending countless observation hours in the desert. Paul received his PhD from the University of Georgia, where his dissertation focused on insects and public health. Following his formal schooling, Paul served as the integrated pest management and pesticide safety coordinator for the University of Georgia. Later as the division manager for the City of Albuquerque, New Mexico, in their Environmental Health Department, Paul oversaw pest management and vector control programs for the city. In his new role as an Army biologist, Paul's triathlete background has served him well during the challenging hikes and rigorous field work synonymous with natural resource work on O'ahu.

ABOVE **Dr. Paul Smith, biologist for the Army's Natural Resource Program on O'ahu, carries a plant backpack filled with native plants destined for the forest.**

ABOVE **Army biologist Joy Anamizu visits the endangered nehe (*Melanthera venosa*) population at Pu'u Nohona o Hae at Pōhakuloa Training Area on Hawai'i Island.**

Joy Anamizu has experienced the value of sustainability and resource management for most of her life. She spent her childhood in Kahuku, O'ahu, where she helped her family maintain and manage a large ti leaf farm. She went on to receive a BA in Biology from the University of Hawai'i at Hilo and completed her Master's degree at the University of Hawai'i at Mānoa in Bioengineering. As an ecologist with the Army Corps of Engineers, Joy gained experience in the regulatory world—an asset in her biologist position with the Army's natural resource program at Pōhakuloa Training Area. Knowledge gained through her work with the Clean Water Act, Research and Sanctuaries Act permits and wetlands delineations will help guide Joy's work within the management units at Pōhakuloa. In addition, Joy's experience preparing consultation documents for the management of threatened and endangered species on federal land has prepared her well for her work at Pōhakuloa with some of the rarest plants and animals on Hawai'i Island.

Root into your community

HO'OA'A

The U.S. Army Garrison-Hawai'i natural resource program staff leads monthly volunteer service trips to protect rare and endangered plants and animals on Army-managed lands. Each educational trip incorporates hiking and a hands-on opportunity to care for Hawai'i's natural resources through invasive weed control in native habitat and occasional planting activities.

BECOME A VOLUNTEER

JOIN THE VOLUNTEER LISTSERV

Contact OUTREACH@OANRP.COM or 656-7741 to be added to the volunteer database.

ORGANIZE A TRIP

Contact OUTREACH@OANRP.COM to organize a service opportunity for your class, hālau or group.

ABOUT THE U.S. ARMY GARRISON–HAWAI'I

The U.S. Army Garrison-Hawai'i is responsible for the day-to-day operations of Army installations and training areas in Hawai'i. The U.S. Army Garrison-Hawai'i team provides facility management and quality Soldier and military family services for more than 95,000 Soldiers, retirees, civilians and families across 22 military installations and training areas on O'ahu and Hawai'i Island. These installations include O'ahu-based Schofield Barracks, Wheeler Army Airfield, Fort Shafter, Tripler Army Medical Center, and the Island of Hawai'i-based Pōhakuloa Training Area.

The Directorate of Public Works Environmental Division Office at the U.S. Army Garrison-Hawai'i is comprised of two branches: the Compliance Branch and the Conservation Branch, which are dedicated to providing guidance, support and liaison services to those who live, work and train on the installation, while also protecting the environment. The Conservation Branch includes the Army's natural and cultural resource programs, which protect endangered species and cultural resources, respectively, on O'ahu and Hawai'i Island. To learn more about the Army's environmental stewardship mission, visit HTTPS://WWW.GARRISON.HAWAII.ARMY.MIL/SUSTAINABILITY/ENVIRONMENTAL.ASPX.

ABOUT THE PACIFIC INTERNATIONAL CENTER FOR HIGH TECHNOLOGY RESEARCH (PICHTR)

The Pacific International Center for High Technology Research (PICHTR) was established by the 1983 State of Hawai'i Legislature and, originally managed within the University of Hawai'i for administrative purposes, was incorporated in 1985 as an independent Hawai'i-based not-for-profit. Its mission is to accelerate technology commercialization to increase security, safety, and economic opportunities in Hawai'i and the Asia-Pacific region. Its focus is on renewable energy; natural disaster management; agriculture; and ocean, educational and dual-use technology. PICHTR supports the U.S. Army Garrison-Hawai'i Natural Resource Program on O'ahu through a cooperative agreement.