

A TEACHER'S GUIDE TO

NĒNĒ

HAWAII'S ENDANGERED STATE BIRD



Prepared by the State of Hawai'i
Department of Land and Natural Resources
Division of Forestry and Wildlife

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HAWAI'I STATE SCIENCE CONTENT STANDARDS

The unifying theme of this Teacher's Guide is that the Nēnē is a Hawaiian endemic species that is adapted to live in a native Hawaiian environment without predators. Native waterfowl have certain environmental needs that may be hard to find in modern Hawai'i, and this makes survival difficult. This booklet provides information and activities that meet the following benchmark content standards for developmentally appropriate content, knowledge and skills at grade levels 4-5.

HOW HUMANS THINK WHILE UNDERSTANDING THE NATURAL WORLD

Doing Scientific Inquiry

- Conduct simple investigations to answer questions about how animals behave in their environment (section III)
- Collect and organize data for analysis (section III)

Habits of Mind

- Identify patterns of change (section IV and V)
- Scale and model: measure population sizes and model growth rates (section V)

WHAT WE KNOW ABOUT THE WORLD AROUND US

Historical Perspectives

- Knowledge is acquired through scientific investigation (sections III and IV)
- Examine and explain why there is a need to conserve natural resources (section I, III and VI)

ORGANISMS AND DEVELOPMENT

Unity and Diversity

- Different organisms need specific environmental conditions to survive (sections II and III)
- Relationship between structure and function in living things (section II and IV)

Interdependence

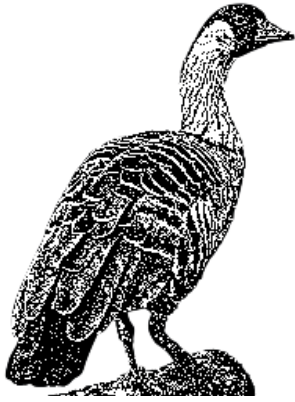
- Plant and animal interdependence (section III, IV, and VI)
- Organisms respond to a constantly changing environment (section II, IV)

Cycle of Matter and Energy Flow

- How animals' food can be traced back to plants (section VI)
- How energy is needed for organisms to stay alive and grow (section III)

Biological Evolution

- Compare fossils to one another and to living organisms, explain their similarities and differences (section IV)
- Certain organisms are more likely to survive than others in the same environment (section IV)



A TEACHER'S GUIDE TO NĒNĒ HAWAII'S ENDANGERED STATE BIRD

The story of Nēnē is a classic example of the challenges of rescuing a species from the brink of extinction. Breeding Nēnē in captivity and releasing them into the wild saved the species at a time when so few individuals remained in the wild that it was certain to disappear forever. Today after 40 years of reintroduction, wild Nēnē still struggle to survive, due mainly to introduced predators and loss of feeding habitat. The continuing "endangered" status of

the Nēnē has taught us that captive propagation alone is not enough to restore a species if appropriate habitat cannot be guaranteed upon release.

The Nēnē (*Branta sandvicensis*) is found only in Hawai`i, and is among the most isolated, sedentary and threatened of waterfowl. It has been the State Bird since Hawai`i became a state in 1959. At that time it was so critically endangered that wildlife experts in Hawai`i sought this designation in order to secure federal funds to help save it.

The Nēnē was once widely distributed throughout the islands in a broad range of habitats. They seem to have occupied lowland grasslands and open forest. Today they live only on Hawai`i island, Maui, Moloka`i and Kaua`i in limited locations.

Nēnē populations began declining when Polynesians began arriving 1200 years ago, and inadvertently introduced the Polynesian rat. It is believed that rats quickly populated the islands and severely altered lowland habitats, abruptly changing the food sources for many native birds and insects. Later human colonization further altered native habitat for agricultural crops and Nēnē were used for food. Westerners brought guns and the Nēnē was almost hunted to extinction until hunting was banned in 1907. A trade in salted Nēnē meat with sailing ships existed in the 1800s. By 1949 a population that was once estimated at 25,000 in the mid 1800's had been reduced to a mere 30 birds living in the uplands of the Big Island.

Fortunately Nēnē were saved by a considerable international effort by wildlife biologists in Hawai`i and England. A small flock of captive Nēnē had been maintained on the Big Island since 1918. In 1949, a pair from this flock were loaned to the Wildfowl Trust in Slimbridge, England and a pair to the Territory of Hawai`i for propagation in captivity. These and subsequent adult breeding pairs were maintained in cages and their year-old offspring were released to the wild on Maui and Hawai`i. Since 1960 more than 2,300 young have been raised and released on four islands. Still, there are only about 1300 Nēnē in the wild after nearly 40 years of intensive captive breeding and release. Population sizes in August 2003 were estimated to be 325 on Maui and Moloka`i, 350 on Hawai`i Island, and 620 on Kaua`i.

Nēnē are uniquely adapted to life on land. They evolved from Canada geese (*Branta canadensis*) that by chance settled in Hawai`i a half million years ago. Canada geese are dependent on bodies of fresh water to feed and escape predators. However, the ancestors of the Nēnē no longer needed to take to the water to escape predators because there were no land-dwelling mammals or reptiles in the ancient, pre-human Hawaiian environment. As a result the Nēnē has evolved anatomical changes from its Canadian ancestor that befit a more terrestrial lifestyle.

Hawks, owls and an extinct eagle were the only natural predators of Nēnē prior to human arrival. Humans introduced carnivorous mammals such as mongooses, rats, cats, dogs, and pigs that eat eggs or kill goslings or adult Nēnē. Ground-dwelling Nēnē have no effec-

tive defense against these predators, and goslings are especially vulnerable. Automotive traffic is a new danger. Adult Nēnē are often hit by cars in places where people feed them along the roadside. People can help by driving carefully in areas populated by Nēnē and by not feeding them so they will not be attracted to areas with people and their vehicles.



Don't Feed The Nene!

Nēnē are also challenged to find enough nutritious food in modern Hawai`i, especially for goslings that need high protein forage. Managed grasslands with young shoots, herbs, shrubs and ferns are best for Nēnē but these areas are declining on most islands. Introduced mammalian browsers such as goats, sheep, deer, pigs and cows also eat native shrubs critical for good Nēnē nutrition, and they spread the seeds of less nutritious introduced plants in their droppings.

The struggle of Nēnē to survive in the wild illustrates how important it is to preserve habitat for native Hawaiian species. Kaua`i is the only island where mongoose were never introduced and where lowland grassland habitats are still widely available. When it became apparent that a small flock of Nēnē inhabiting lowland pasture on Kaua`i were flourishing without human intervention, the focus of Nēnē management on all islands changed from release of captive bred animals to habitat management. Those on the other islands still require active management to maintain their populations. This includes controlling feral dogs and cats, fencing out pigs and goats from Nēnē habitat, restoring nutritious native plants that Nēnē need for food, and trapping mongoose and rats, especially in Nēnē nursery areas.

SUGGESTED READING FOR STUDENTS:

“Nēnē” by Marion Coste. University of Hawaii Press, 1993.

ADDITIONAL RESOURCES:

Nene O` Moloka`i. www.aloha.net/~nene/

The Nene – the Hawaiian Goose. Hawai`i Nature Focus, Nature Studies for Children. www.kilaueapoint.com/education/naturefocus/hnf14/

Avian Web, All about Birds. www.avianweb.com/geese.htm

All About Birds. www.kidzone.ws/animals/birds3.htm

Canada Goose. www.kidzone.ws/animals/birds/canada-goose.htm

Hawai`i's State Bird - The Nene. www.birdinghawaii.co.uk/XNene2.htm

Hawai`i Volcanoes National Park, Nene Website. www.nps.gov/havo/resource/nene.htm

Honolulu Zoo. www.honolulu zoo.org

The Hawaiian Goose. Janet Kear and A. J. Berger, 1980. The Wildfowl Trust.

Hawaiian Goose (Nēnē). Paul C. Banko, Jeffrey M. Black, and Winston E. Banko. In “The Birds of North America”, no. 434, 1999

NĒNĒ AND THEIR CLOSEST RELATIVE THE CANADA GOOSE

OBJECTIVE: Explain the relationship between structure and function in living things. Students will learn that Nēnē are related to Canada geese, and Nēnē anatomy is adapted to living on land. Students will also learn words describing waterfowl anatomy and behavior.

BACKGROUND FOR TEACHERS: DNA analysis shows that Nēnē (*Branta sandvicensis*) and Canada geese (*Branta canadensis*) have a common ancestor that arrived in Hawai'i 500,000 years ago and eventually evolved into a new species. Nēnē adaptations to the unique conditions in Hawai'i can be understood by comparing the anatomy and life habits of these two species.

Canada geese are found all over Canada and the northern US. They have many natural predators, like hawks, owls, wolves, bear, foxes, weasels and cats, which they escape by flying or by staying on the water. To protect their goslings they nest near the water or in marshes. They graze on grasses and sometimes feed on aquatic plants using their long neck to reach into the water. In contrast, Nēnē evolved in Hawai'i where there were no terrestrial predators before human arrivals (although there were aerial predators such as hawks and owls). Nēnē were not dependent on bodies of water for protection, and this allowed them to feed on a wider variety of grasses, sedges and shrubs in more different kinds of habitats.

Nēnē anatomy has diverged from their Canadian ancestors to make life on land easier. Nēnē legs are relatively long and about 25% bulkier than in other geese. The foot has reduced webbing, long flexible toes, large nails and protective pads that facilitate climbing, walking and running on rugged ground. Nēnē walk with little waddle or sway like other aquatic geese because their legs are located more forward on the body. With reduced webbing, Nēnē do not swim as strongly as Canada geese, but they do enjoy swimming when water is available. Like other waterfowl, Nēnē goslings will dive underwater if pursued by predators. The furrowed pattern of neck feathers that appears to be striped is one of the most obvious features of Nēnē. The stripes help camouflage females sitting on a nest under a shrub.

Nēnē are capable of inter-island flight, but they do not migrate over long distances like Canada geese. Nēnē wings are reduced about 16% in size compared to their Canadian cousins, and the flight muscles in the breast are smaller.

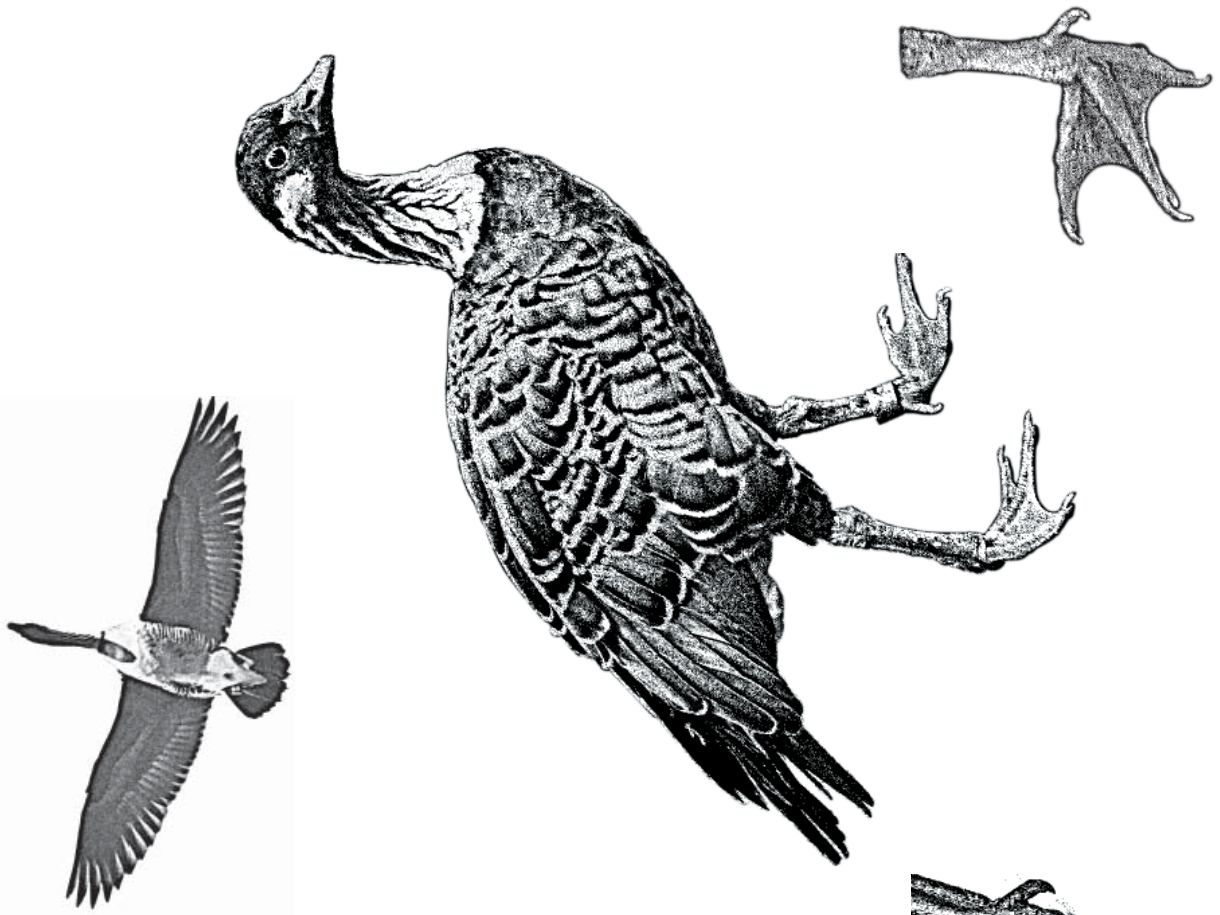
ACTIVITIES

Introduce students to Nēnē and Canada geese, their home ranges and land-use habits. Distribute copies of the drawing and text on the following pages. To compare and contrast the two species, draw a venn diagram to discuss the similarities (e.g., fly, swim, avoid predators, plant-eaters, close relatives) and the differences as described above. Afterwards the students can fill in the blanks with the vocabulary words at the bottom of the text page.

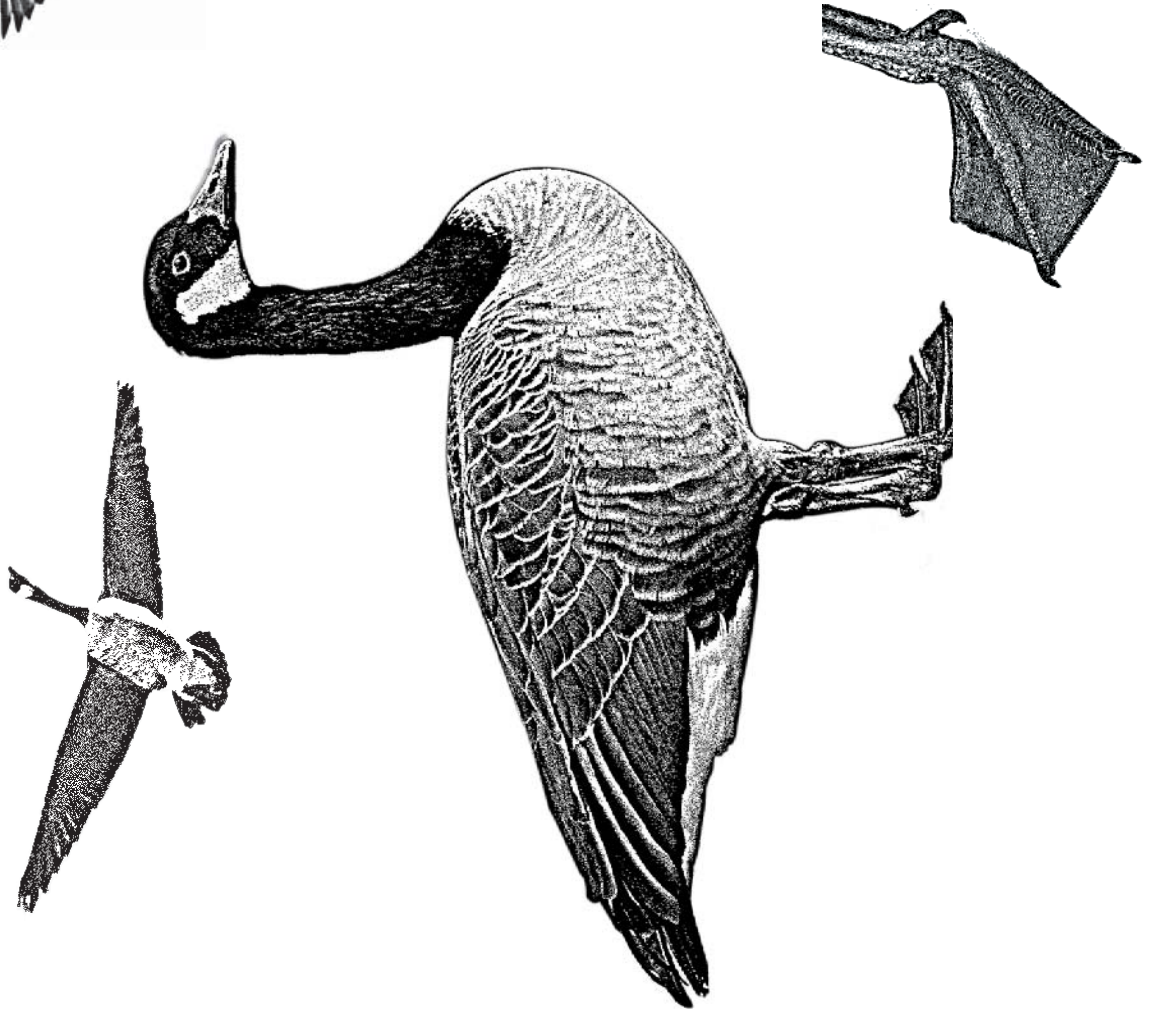
1. By photocopying the drawings in an enlarged format, students can color in the drawings or draw in appropriate backgrounds that reflect the different lifestyles of each species. Ask students to do Internet or library research on predators of each species and draw those into the picture.

2. Have students walk forward while bent over at the waist. The center of gravity is ahead of the feet. Now compare it to walking upright. The center of gravity is over the feet. Explain that waterfowl walk more easily when their legs are forward on their body, but they swim better when the legs are back on the body, much like a propeller on a boat. For most ducks and geese body posture is a tradeoff between walking well and swimming well, and their build depends on where they spend most of their time.

Nene



Canada Goose



COMPARE AND CONTRAST THE NĒNĒ WITH ITS CLOSEST RELATIVE, THE CANADA GOOSE

CANADA GOOSE Lives all over North America	NĒNĒ Lives only in Hawai'i
<p>Canada geese have a body built for swimming. On land they are a little awkward and they _____ when they walk.</p>	<p>NĒnĒ have a body built for living on land. They are very good 'walkers' thanks to their _____ posture.</p>
<p>Canada geese go in the water to escape from predators like foxes and weasels. They have _____ feet for strong swimming.</p>	<p>NĒnĒ evolved with no land predators so they never needed to swim in the water to escape. Their feet and legs have 3 adaptations for walking over rough ground. These are _____ and _____.</p>
<p>Canada geese fly long distances south for the winter and back north for the summer. This is called _____. To do it Canada geese need long _____.</p>	<p>NĒnĒ never leave Hawai'i. They only fly short distances. Over time their wings and _____ in the breast have become smaller than Canada geese.</p>
<p>Canada geese nest in marshes or near water to stay safe from _____.</p>	<p>NĒnĒ nest on land under bushes. The neck color might help as _____ to hide them from predators such as owls or hawks.</p>
<p>wings reduced webbing thick legs</p>	<p>flight muscles waddle predators</p> <p>long toes camouflage</p>

NĒNĒ BEHAVIOR

OBJECTIVE: Explain the relationship between behavior and its function. Students will learn that scientific inquiry can answer questions about how Nēnē use their environment. Students will become familiar with animal behavior and its function, and have the opportunity to observe and quantify behaviors.

BACKGROUND FOR TEACHERS. Nēnē are very social birds and family life is important to their survival. High adult and gosling mortality is the main factor in the failure of wild populations to become self-sustaining. Wildlife managers study Nēnē behavior to learn the causes of mortality and how to increase their survival rate. They need to know how Nēnē use their environment, such as where Nēnē go to find food in different seasons and their nutritional requirements at different life stages. They need to know how they raise their goslings and what habitat characteristics increase their success.

Breeding Nēnē adults choose their partners when they are 1-2 years old, and pairs usually stay together for life. Nēnē breed from August to April, but most goslings hatch in January and February. In Hawai'i, winter is a good time to hatch young goslings because there is more fresh vegetative growth due to higher rainfall. However, in years when food is scarce females may not even be able to lay eggs.

The breeding season starts in the fall with the adult pair returning to the area where the female hatched, then beginning to defend a small feeding and nesting territory from other Nēnē. This is a good time of year to observe Nēnē aggressive behavior even among captive Nēnē! In January females construct a nest on the ground, concealed under low shrubs, by digging out a hole then lining it with leaves and feathers for warmth. One – six eggs are laid and the female incubates them for 30 days while her nearby mate stands guard vigilantly, often on an elevated area. He chases away anybody who comes near the nest, including other Nēnē, predators or humans. The female sometimes rises to roll the eggs over using her bill so they will incubate evenly. She will leave the nest and eggs about 4 times per day for about an hour while she feeds or naps nearby, covering the eggs with down and feathers so they will stay warm.

Goslings. Usually only 1-4 youngsters hatch. Very young goslings can often be seen nestling on top of the mother's back or under her wing to keep warm. They also wander around nearby for their first few days. Within several days of hatching Nēnē parents lead their goslings to good foraging areas, teaching them where to find food (but Nēnē parents do not feed their young). Because young goslings and the molting adults cannot fly in the post-hatching period, they all must hike to where the food plants are best or they run the risk of starvation. One parent walks on each side of the youngsters at all times, always vigilant for predators such as rats, mongoose, cats, dogs and pigs. Goslings react to danger by hiding under a parent and give a repeated peep distress call if they do not find cover. In modern Hawai'i it is a struggle for parents to protect them, and most goslings do not survive. Those that do survive fledge at about 12 weeks when they are then able to fly with their parents to different locations on the island to find the best food. Families stay together for about a year, then in October the parents begin the nesting cycle again, and the younger Nēnē are on their own.

Feeding. Wild Nēnē spend over 40% of their time during the day feeding. They graze on grasses and browse on the nutritious tender parts of plants like young leaves and shoots, seeds, fruits and flowers. They are known to eat at least 75 different native and introduced plant species by biting or pulling the edible parts with their bill or stripping seeds from the stem. A problem for Nēnē is that much of their historical lowland habitat has been lost to agriculture, urbanization, and alien plants. Goslings in particular need food plants that are high in protein, and starvation has been a key reason for poor gosling survival. The coloring pages in the back of this folder are examples of eight native plants that are good, nutritious foods that Nēnē prefer.

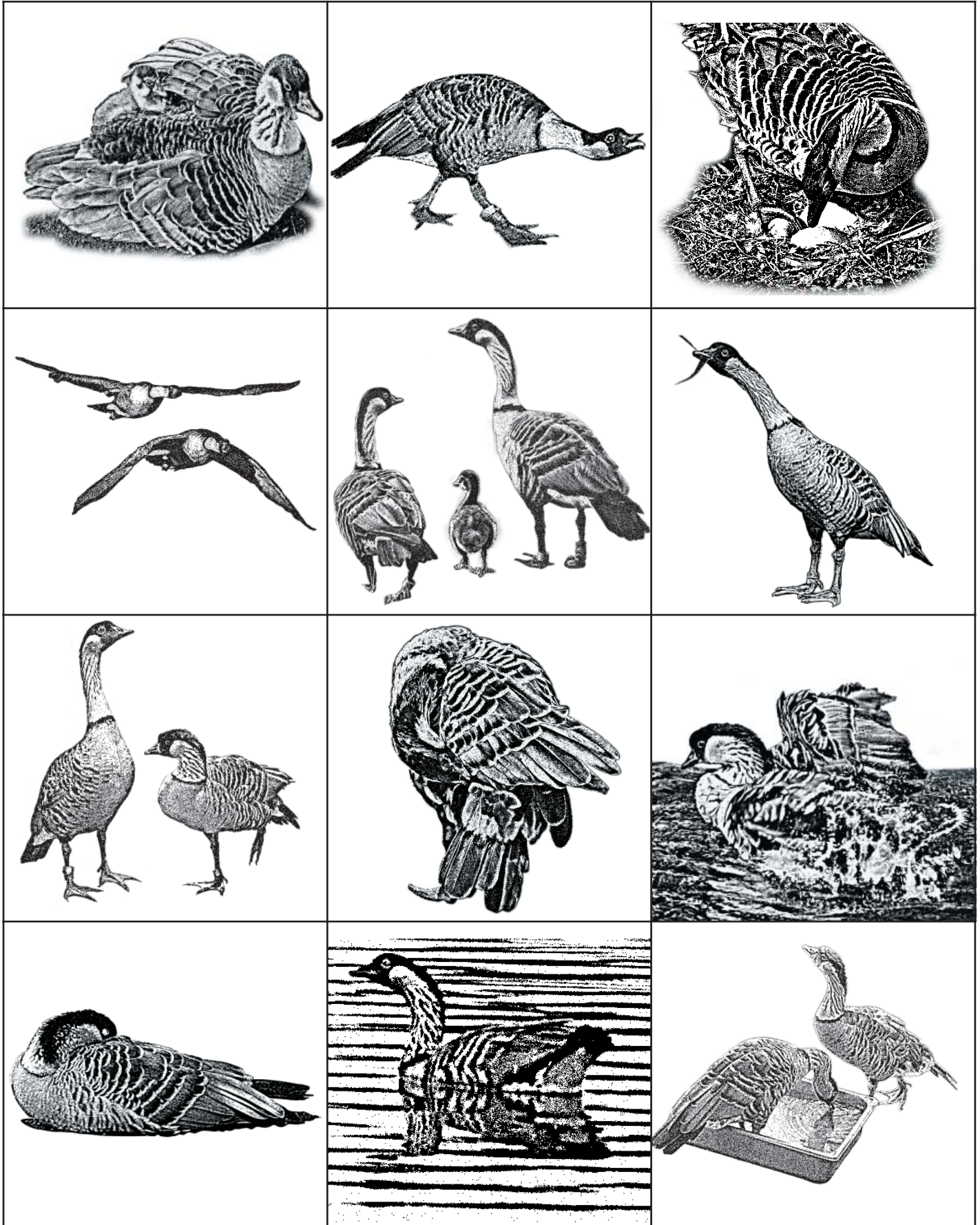
ACTIVITIES

In these exercises students learn about 12 basic behaviors of Nēnē (and other waterfowl). On the next page are 12 photographs with a space at the bottom for students to write in the names of the behaviors as they learn them. On the back of this page the name and description of each behavior and its function are provided in squares. These two pages can be used in a variety of ways to teach recognition of these behaviors. Teachers should discuss what the behavior indicates about how Nēnē use their habitat.

1. Photocopy the behavior page for each student. Then, read off the descriptions and functions of the behaviors and teach the class the name for each behavior. Have them find it on their Nēnē behavior sheet and write the name in the space provided.
2. Flash cards. Two-sided photocopies of the behavior photographs and the following page of text squares can be distributed to students to cut out and make flash cards. They can be used to recognize the behavior as they learn its name and its purpose.
3. Play Nēnē Behavior Bingo. First pass out copies of the behavior pictures. Have students make bingo boards by cutting out the squares and pasting or gluing 9 of them in a different order on a piece of cardboard to make a 3 x 3 board. You can use the boards as is or cover them with clear contact paper to make them stronger and reusable with grease pencils. Play bingo in the classroom by calling out behaviors. The first person to mark 3 pictures in a row across, down or diagonally is a winner. You can vary the game a little by making the requirements different each time or by taking students outside to observe real waterfowl (below).
4. Zoo visit or wildlife hike. If possible, take students on a hike to a wetlands area that has ducks and/or geese, or to the Honolulu Zoo where Nēnē are on display. Have them take their Nēnē behavior page or bingo board, and whenever they spot one of the behaviors have them mark it off. It's a fun way to learn to observe while becoming familiar with how waterfowl behave. These basic behaviors also apply to ducks and other geese. (Goslings or ducklings will only be present in the spring months.)
5. Quantify Nēnē behavior. Discuss with students some of the questions they have about Nene. Make a list of questions that students have about Nēnē behavior. Then discuss which ones they can answer by watching Nēnē at the Zoo. Some questions students can ask are: When do Nēnē eat? When do they rest? Are males more aggressive than females? Are some pairs more aggressive than other pairs? (*Males at the Zoo have metal bands on the right leg and females on the left leg. From September-May pairs stay close together so it will be easy to identify which birds are paired*).

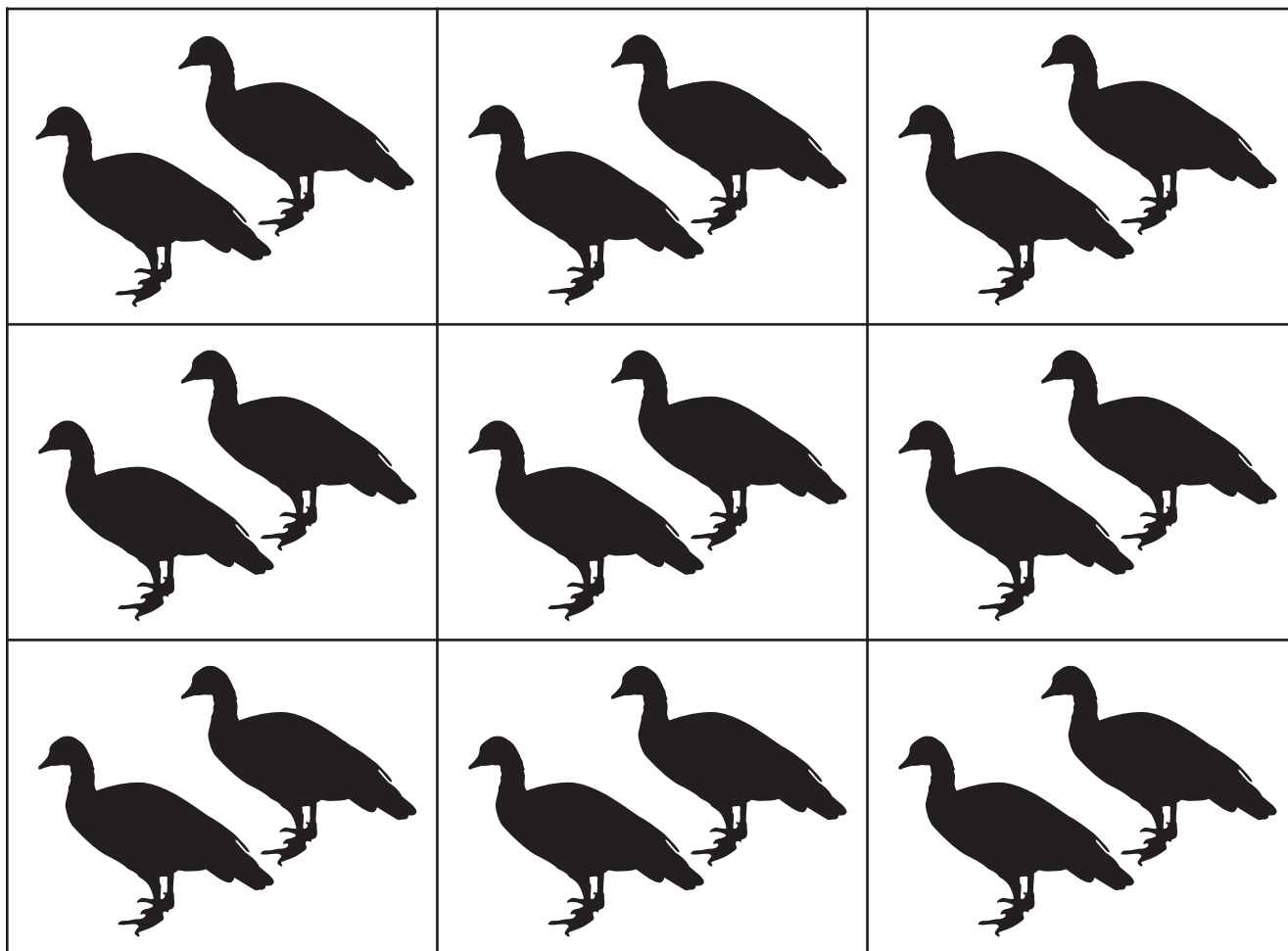
On page 14 is a simple observation spreadsheet with the most basic Nēnē behaviors. Copy this for students so they can answer these questions by watching Nēnē at the Zoo. They should conduct 2 periods of observation and compare the data collected in each. Have them observe one individual, a pair, or the entire group for a given length of time (5-10 minutes), then at a later time have them re-observe the same birds. For example, students could ask the question "When do Nēnē eat?" or "When do Nēnē sleep?" They could observe for 10 minutes in the morning, noting the time of the observation. Every time they see one of the behaviors on the spreadsheet they should make a tick mark in the first column. Then come back an hour later, noting the time, and re-observe the same birds, this time making tick marks in the second column. At which time did more feeding occur? More sleeping? More bathing? What other behaviors differed in frequency between the two observation periods?

BEHAVIOR BINGO



<p style="text-align: center;">INCUBATION</p> <p>Female sits on 1-6 eggs for 30 days until they hatch. Sometimes she gets up and rolls over the eggs with her bill.</p> <p style="text-align: center;">WHY?</p> <p>Keeps the eggs warm so they will develop. Rolling keeps the eggs equally warm on all sides.</p>	<p style="text-align: center;">FORWARD THREAT</p> <p>Nēnē put their head to the ground and vibrate their neck feathers as they charge at an enemy.</p> <p style="text-align: center;">WHY?</p> <p>Warns other Nēnē and predators that they will attack.</p>	<p style="text-align: center;">BROODING</p> <p>Newly hatched chicks nestle under mother's wings.</p> <p style="text-align: center;">WHY?</p> <p>Keeps young goslings warm.</p>
<p style="text-align: center;">FEEDING</p> <p>Nēnē bite, tear, pluck or strip vegetation with their beak.</p> <p style="text-align: center;">WHY?</p> <p>To eat tender parts of plants that are especially nutritious.</p>	<p style="text-align: center;">DEFEND GOSLINGS</p> <p>Both parents stay alert and chase away anyone or anything that comes near their goslings.</p> <p style="text-align: center;">WHY?</p> <p>Protects goslings from predators while they are growing and learning to find food.</p>	<p style="text-align: center;">FLYING</p> <p>Nēnē mostly stay on the ground but sometimes they take to the air, making a honking call as they go.</p> <p style="text-align: center;">WHY?</p> <p>Move to areas where food is better or where they are safe from predators.</p>
<p style="text-align: center;">BATHING</p> <p>Nēnē splash water into their feathers and shake. They also dunk their head.</p> <p style="text-align: center;">WHY?</p> <p>Removes dust and dirt from the feathers. Also keeps them cool.</p>	<p style="text-align: center;">PREENING</p> <p>The beak is used to spread oil from a gland at base of tail into the feathers</p> <p style="text-align: center;">WHY?</p> <p>Keeps feathers water repellent and in good condition.</p>	<p style="text-align: center;">ALERT OR RELAXED</p> <p>Nēnē stretch up their head, neck and body to pay attention to possible danger. When relaxed, the head is held much closer to the body.</p> <p style="text-align: center;">WHY?</p> <p>Stretching up helps Nēnē to see farther and hear more.</p>
<p style="text-align: center;">DRINKING</p> <p>Nēnē take water into their mouth then raise their head up to let it flow down their throat.</p> <p style="text-align: center;">WHY?</p> <p>Nēnē mostly get water from their food, but they also drink when they find freshwater.</p>	<p style="text-align: center;">SWIMMING</p> <p>Like other waterfowl, Nēnē love to float and paddle on the water when it is available.</p> <p style="text-align: center;">WHY?</p> <p>Nēnē feed on land so they rarely encounter pools of water.</p>	<p style="text-align: center;">SLEEPING</p> <p>Like most birds, Nēnē tuck their head under their wing when they sleep.</p> <p style="text-align: center;">WHY?</p> <p>Tucking the head saves energy by keeping heat in the body.</p>

NĒNĒ PAIR SILHOUETTES



Behavior:	1 st observation period	2 nd observation period
Feed		
Drink		
Bathe		
Swim		
Sleep		
Forward threat		

GIANT EXTINCT WATERFOWL OF HAWAI'I

OBJECTIVE: Compare fossils to living and extinct organisms. Students will learn to examine paleontological evidence for the evolution of life. They will also learn that adaptations to certain lifestyles can lead to extinction when the environment changes.

BACKGROUND FOR TEACHERS: A diverse assemblage of large, flightless waterfowl once lived all over the Hawaiian Islands. Scientists know about these extinct prehistoric birds from bones they find in lava tubes, sinkholes, sand dunes and crater beds. Paleontologists have found bones of at least 11 species of large “waterfowl” (geese and ducks) that were living in the islands when humans first arrived 1200 years ago. Now all are extinct.

Birds are the only vertebrate animals (except for the Hawaiian hoary bat) that colonized the isolated Hawaiian Islands. There were never any mammals or reptiles to prey on the birds that became established. Ground feeders like geese, ducks, ibis and rails that settled in the islands did not need to take flight for survival so they gradually lost their ability to fly. Some evolved greater size and weight, with larger feet and bizarre tooth-like beak structures specialized for browsing on forest plants. Flightlessness has evolved on many isolated oceanic islands. Unfortunately flightless birds are the first to go extinct when humans settle on islands because they are mostly defenseless against introduced predators and hunting by humans.

The line-up of birds on page 10 shows this fascinating and strange group of waterfowl that used to exist in Hawai'i along with the Nēnē. These oversized, extinct fowl are the ‘dinosaurs’ of Hawai'i, so to speak, because they were like nothing that exists today. The drawing is by Julian Hume for the Smithsonian Institution, and it is a fanciful rendering of what these giant waterfowl might have looked like based on skeletons that have been found.

Three of the “fowl” pictured on page 10 are ‘true geese:’ the Nēnē (far left), a large species from Maui that could probably fly a little (2nd from left), and the Hawai'i giant flightless goose (far right). All are descended from the same ancestor as today's Canada geese. Only the Nēnē has survived, probably because it retained the ability to fly and was adaptable in its foraging preferences.

The other four fowl in the middle of the drawing on page 10 look like geese, but according to DNA analysis, are descended from a duck. They have been named ‘Moa Nalo,’ which means “vanished fowl”, to distinguish them from ancient ‘true geese’. Moa Nalo bones are found only on the older islands from Kaua'i to Maui. Their jaws sport bony, tooth-like projections, or in one case, a very broad, flat jaw similar to a tortoise. All have greatly reduced wings and were unable to fly. Moa Nalo probably fed on leafy forest plants, which is a very unusual diet for a bird. Scientists think that Moa Nalo filled the same ecological niche in Hawaiian forests as mammalian grazers and browsers like deer and goats in continental forests.

ACTIVITIES

Teachers should distribute photocopies of pages 10 and 11 to students and discuss the contents with them. Talking points include:

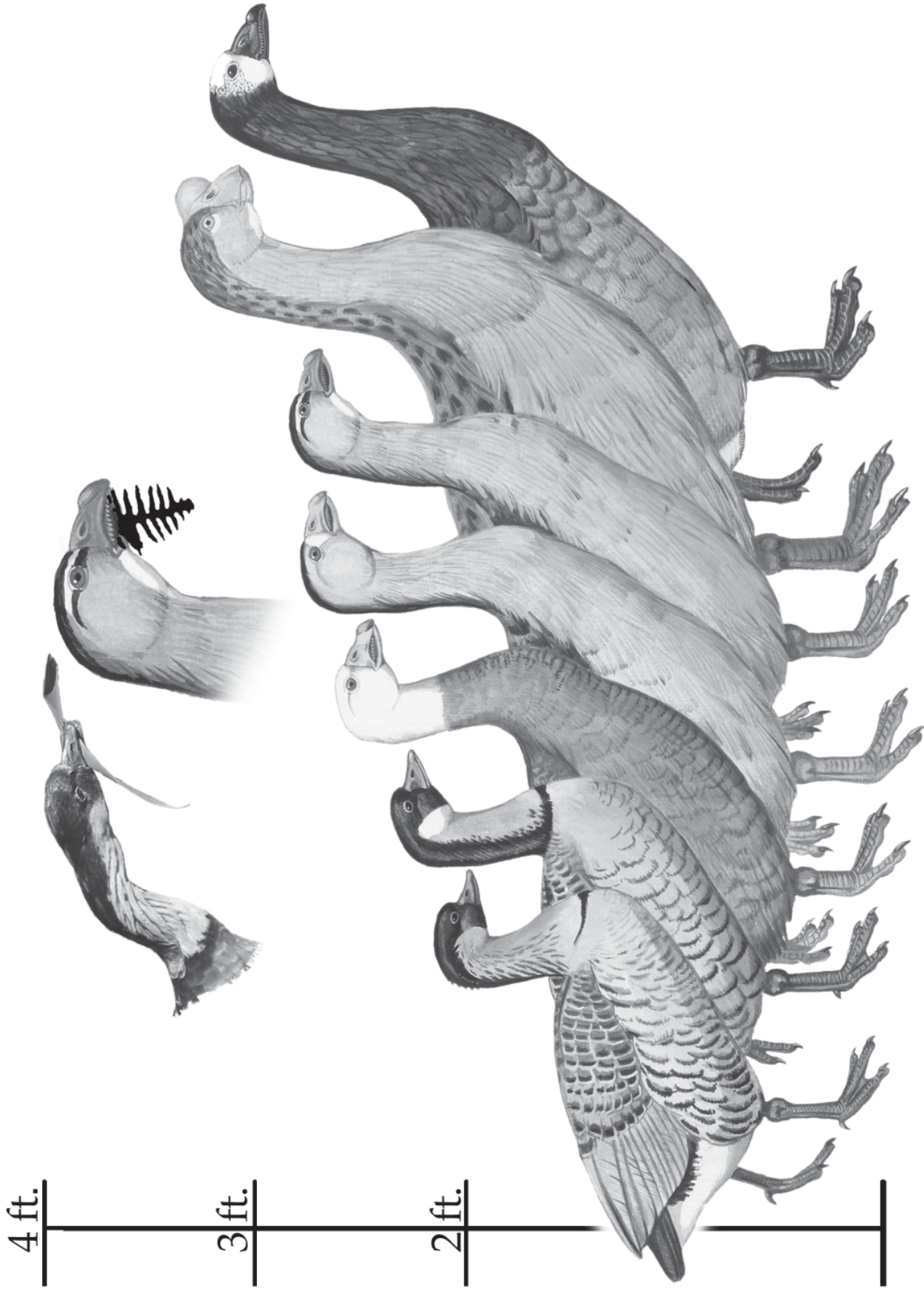
1. There are seven large native waterfowl (geese and ducks) whose bones have been found in lava tubes and caves. Six of these are extinct, but one is still living. Which one do you think it is? Only one of these birds could fly well. Which one? Why do you think it survived and the others went extinct after humans arrived in the islands?

ACTIVITIES CONTINUED

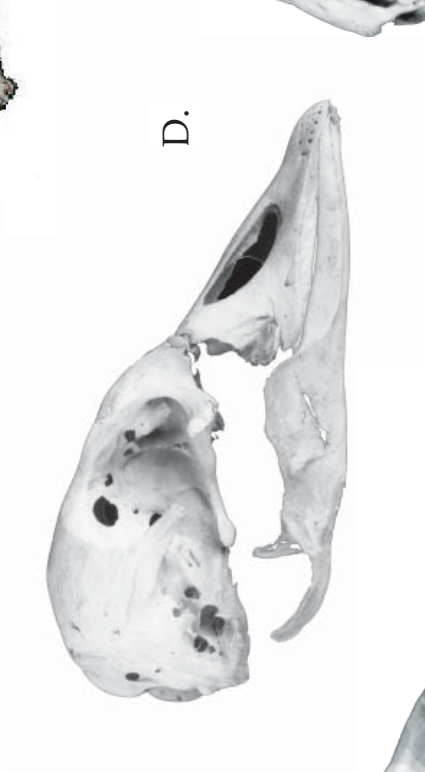
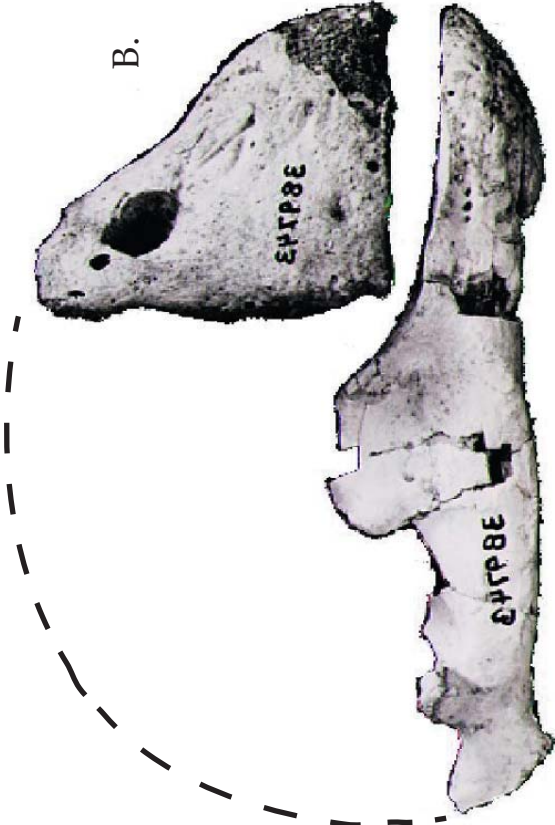
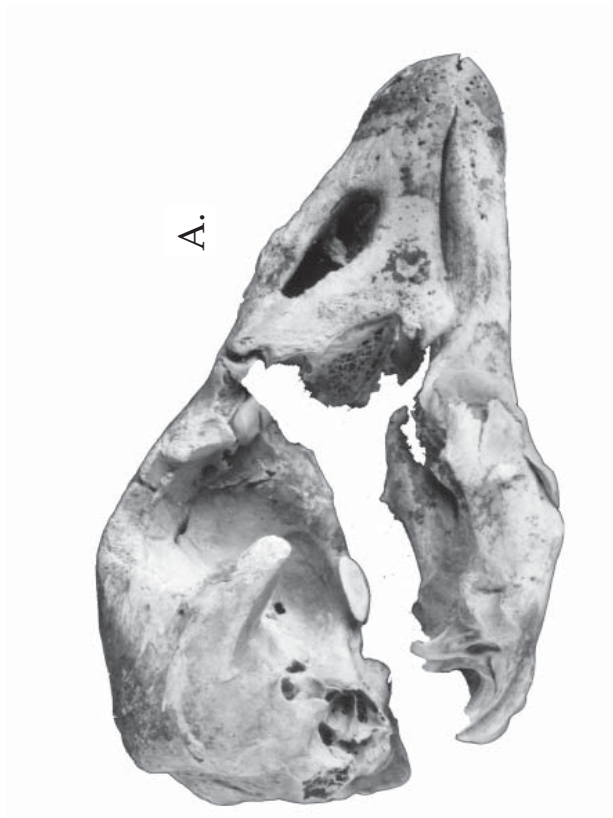
2. There are two kinds of waterfowl in the drawing on page 10. By comparing the bills and the shape of the heads can you tell which ones are true geese and which are Moa Nalo?
3. All these fowl, except two were completely flightless and lived only on land, but two of them probably spent some time in the water and could fly a little. Can you tell which ones by looking at their feet? (Hint: on page 10, Nēnē and Nēnē Nui – first two on the left, have a bit of webbing between their toes.) Look at how the eyes are more above the bill for these two birds compared to the Moa Nalo. Do you think this makes a difference in how the bird can see? Why do you think this is? (Answer: birds that could fly would need to be able to see over their bill, but the terrestrial birds do not).
4. On page 11 are photographs of five of the skulls that the artist used to draw the birds. Only the bones of ancient animals are preserved in caves and sinkholes. Feathers and skin degrade over time, so there is no way of knowing what these birds looked like on the outside. Scientists can tell by looking at the bones the shape and size of the bird, and what it probably ate by looking at the bill and neck. They can also tell where soft tissues were attached to the bones (such as the fleshy knob that might have been on the forehead of the Tortoise-jawed Moa Nalo of Kaua'i). Ask students if they can you find the nostril on each skull? Can they tell about where the eye socket was in the skull? (the larger, darkened area in the upper middle of the skulls). Ask students to match the skulls on page 11 with the birds on page 10 by writing the letter of the skull above the appropriate bird. Only one skull (E) is shown for the Moa Nalo in positions 3, 4 and 5 because differences between these three "toothed" Moa Nalo are so subtle that their skulls are hard to distinguish.
6. Compare the skull of the Nēnē (C) to the Moa Nalo skull (E), and to the drawings of the heads at the top of page 10. What differences can you see in the structure of the bills? Do you think they ate different foods? Moa Nalo probably bit into leafy plants with their tooth-like bill and pulled with their strong neck muscles, but Nēnē eat softer plants like grasses and berries that they grasp with their bill and tug from the plant.
7. Have students draw a picture of what an ancient Hawaiian forest might have looked like with giant flightless waterfowl living in it.

KEY TO PAINTING OF ANCIENT HAWAIIAN WATERFOWL (PG. 10), AND SKULLS (PG. 11).

L-R P. 10	COMMON NAME	SCIENTIFIC NAME	WHERE IT LIVED	SKULL P.11
1st	Nene	<i>Branta sandvicensis</i>	all islands	C
2nd	'Nene Nui' or 'Forest Nene'	<i>Branta hylobatisdes</i> (hylobatisdes = forest walking)	Maui (probably also O'ahu, Kaua'i)	D
3rd	Clumsy Moa Nalo	<i>Ptaiochen pau</i> (ptai = stumble. Named for propensity to fall into holes.)	upland Maui	E
4th	Comb-toothed Moa Nalo	<i>Thambetochen xanion</i>	O'ahu	E
5th	Maui Nui Moa Nalo	<i>Thambetochen chauliodous</i>	Maui, Moloka'i and Lana'i	E
6th	Tortoise-jawed Moa Nalo	<i>Chelychelynechen quassas</i>	Kaua'i only	B
7th	Giant Hawai'i Goose	none yet given	Big Island only	A



Courtesy of Smithsonian Institution



DON'T PUT ALL YOUR EGGS IN ONE BASKET

(adapted with permission from the Alaska Native Knowledge Network)

OBJECTIVE: Students simulate a population of nesting Nēnē and analyze the population growth. Students will learn that animal populations grow through births. They will also observe the relationship between the size of a population and the number of young that hatch each year.









BACKGROUND FOR TEACHERS: This activity introduces students to a population of Nēnē as it changes in size through hatching of young. Students will observe the capacity of small and large populations to grow, or fail to grow, and use their math skills to observe this relationship. A consequence of the birth rate of a population is the ability of the population to build up from small numbers. As long as a population is relatively large, animals that die are replaced each year when young are born and grow up. Wildlife managers are concerned about small populations of wildlife because they may be in danger of going extinct. If populations are small or have declined to low numbers, people may need to make efforts to help the population grow or recover.

PROCEDURE: Materials for this activity include small paper plates (one per student), photocopies of Nēnē Pair Silhouettes, dry leaves, feathers or cotton batting, beans, poster paper, glue or tape.

1. Pass out the paper plates, and make the leaves, feathers or cotton batting and beans available to the students. Tell the students that they will each be making a Nēnē nest by gluing grass and down or batting on the plate.
2. After the students have made the nests, give each student a photocopy of the Nēnē pair silhouettes and have them cut out pairs of Nēnē.
3. Tell the students that each pair of Nēnē will produce 5 eggs each year (in actuality they produce about 4 per year). Have each student place five beans in their nest.
4. Create a large graph on poster paper with two columns. Label the left-hand column "Pairs of Nēnē ", and the right-hand column "Number of Eggs" (see illustration). Explain that a Nēnē population will have a certain number of pairs. You might have to introduce the term "population" to your class.
5. Begin filling in the chart. Start with "one pair of Nēnē." Ask a student to bring up a Nēnē pair silhouette. The Nēnē can be taped or glued to your chart. Move to "two pairs of Nēnē." Again ask students to bring the pairs up. Continue until the population has 20 pairs.
6. Explain to the students that the number of eggs laid by each pair varies; for the purpose of this activity, however, each Nēnē pair will lay five eggs. Begin with "one pair of Nēnē" and draw a nest (circle) and fill it with five eggs. Ask the class to count the number of eggs in the egg column and write that number down. Continue this process for the increasing number of pairs (older students can do this by multiplication).
7. Compare the number of eggs laid by the largest population with those of smaller populations. Ask students to think of things that could happen to adult Nēnē so there would suddenly be fewer in a population (they could be eaten by mongoose, cats or dogs, be run over by cars, or starve to death because there was too little food). Which population would recover quickest if each population lost 10 adult Nēnē? Cross out 5 Nēnē pair from each population and their 5 nests. Recount the number of eggs in the egg column and compare the remaining number of pairs with the remaining number of eggs. The smallest populations would become extinct, and other small populations would take a long time to recover because there would

be fewer eggs each year compared to the larger populations. The largest population would have the greatest chance to recover quickly. What is the minimum population size needed to recover from the loss of 10 adults?

8. Explain that people are concerned about small populations of wildlife because they may be in danger of going extinct.

	Pairs of Nēnē		Number of Egg
1 Pair of Nēnē		5 Eggs	
2 Pair of Nēnē		10 Eggs	
3 Pair of Nēnē		15 Eggs	
4 Pair of Nēnē		20 Eggs	

EXTENSION: Explain to the students that female Nēnē do not always lay the same number of eggs. Each student should choose a number of beans, between 1 and 6, to place in their nest. Hide the nests around the room or on the school grounds and then have the students conduct a nest search and count the total number of eggs. Older students can calculate the average clutch size (number of eggs per nest) by adding up the numbers in each nest and dividing the total by the number of nests. The exercise can be repeated with one of the students designated “mongoose” who removes the beans from the nests he/she finds. The class can then recount and compare the number of eggs remaining in the population with and without predation.

FOR ADVANCED STUDENTS: You can continue discussing gosling mortality by adding a third column to the chart labeled “Goslings Fledged”. Explain that once the eggs hatch the young goslings are vulnerable to predators because they cannot fly. Their parents must constantly protect them. Then explain that ‘fledging’ means ‘being able to fly’ and that this takes about 12 weeks for Nēnē goslings. With this information the subject of reproductive rate of Nēnē in Hawai‘i can be approached. It is possibly the lowest of all geese. Discuss the following points with students and illustrate the effects on the number of eggs or the number of goslings surviving from those eggs:

- Not all Nēnē pairs lay eggs each year. Sometimes only half of all pairs on Maui and Hawai‘i Island nest, due to insufficient nutrition for females to produce eggs.
- Not all eggs hatch. Some are infertile and some are eaten by predators such as mongoose. Usually half of all eggs fail to hatch
- On Maui and the Big Island there may not be enough nutritious food for goslings and there are many predators. Only about 1 in 7 goslings survive to fledging age. Students should be able to see that certain minimum sizes of populations have to exist, and adults must successfully fledge young for many years if the Nēnē population is going to be stable or to grow under the conditions on Maui and the Big Island. This is why people need to help Nēnē, by controlling predators, restoring nutritious plants for Nēnē to eat, and releasing captive reared youngsters in the wild when they are older than 1 year old and more likely to survive.

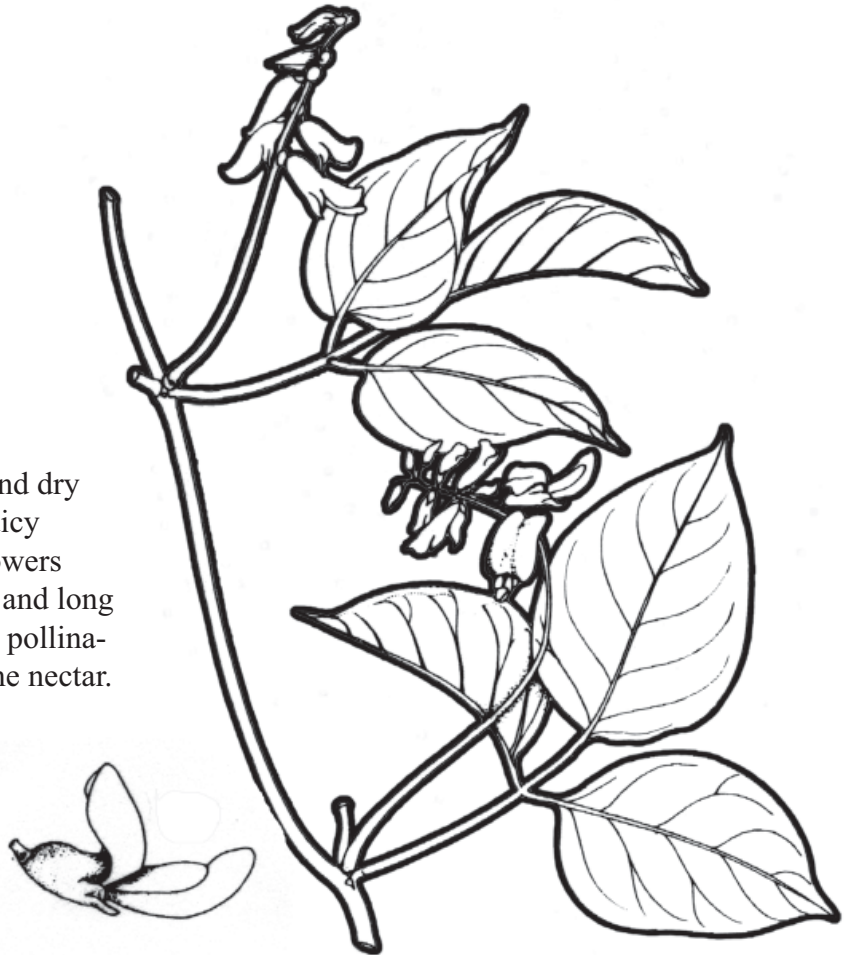
COLORING BOOK

DELICIOUS-NUTRITIOUS PLANTS FOR NĒNĒ

MANY NENE GOSLINGS DO NOT SURVIVE LONGER THAN ONE YEAR. SCIENTISTS THINK THIS IS DUE TO POOR NUTRITION FROM “JUNK-FOOD” PLANTS - *PLANTS THAT ARE OFTEN CONSIDERED WEEDS IN HAWAII*. ON THE NEXT PAGES ARE SOME OF THE PROTEIN-RICH NATIVE PLANTS THAT ARE GOOD FOR NENE GOSLING GROWTH. WILDLIFE MANAGERS ARE TRYING TO PLANT NATIVE SPECIES LIKE THESE IN NENE HABITAT TO HELP THEIR POPULATION GROW.

‘ĀWIKIWIKI
(*Canavalia galeata*)

‘Āwikipiki is a vine of the lowland dry forest. Nēnē munch on its soft juicy leaves, It has beautiful purple flowers with different shades of lavender and long white lines. The colors may help pollinators, like insects and birds, find the nectar.

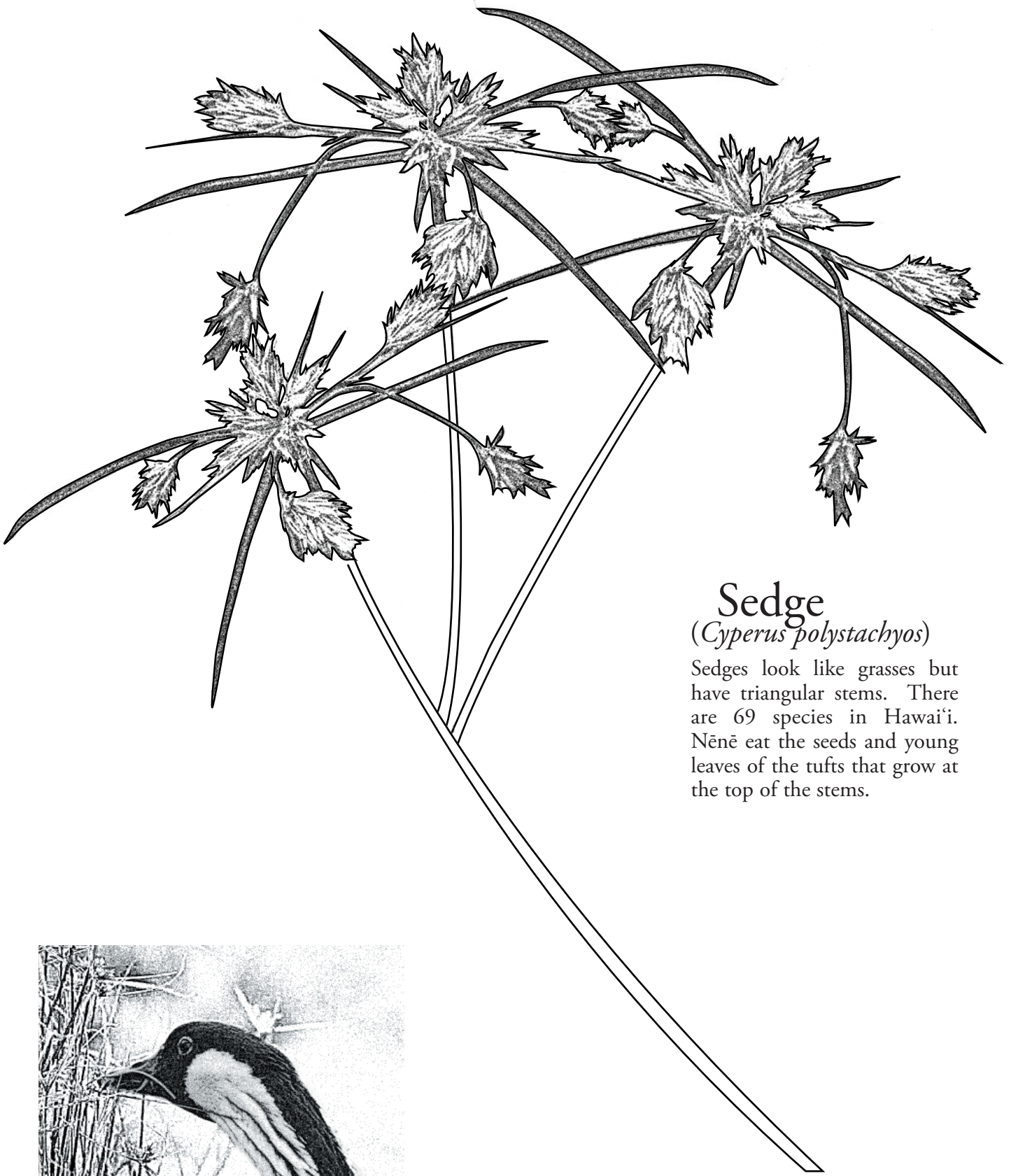




KO'OKO'OLAU
(*Bidens hawaiiensis*)

Ko'oko'olau is a native Hawaiian plant in the daisy family. The leaves and flowers are the choice parts of the plant for Nēnē. The seeds are very unusual. Their shape is twisted so they can spring away and roll down the mountain away from the mother plant.





Sedge (*Cyperus polystachyos*)

Sedges look like grasses but have triangular stems. There are 69 species in Hawai'i. Nēnē eat the seeds and young leaves of the tufts that grow at the top of the stems.





‘ŌHELO
(*Vaccinium reticulatum*)

‘Ohelo has delicious berries for Nēnē and humans. It is related to cranberries, blueberries, and huckleberries. In the old days ‘ohelo was sacred to Pele. People would first offer a gift to Pele of some fruit and then they could eat some ‘ohelo themselves.



PŌPOLO (*Solanum americanum*)

Popolo is a shrub with shiny black fruit. These are ono to eat, for people and Nēnē. This was a highly used medicine in old Hawai'i. Popolo is in the same family as many edible plants like tomato, potato and eggplant. Nēnē also eat the leaves of this plant.





PILI (*Heteropogon contortus*)

Pili is a grass that is found on many islands of Polynesia. When it is young and tender the leaves are a favorite food of Nēnē. They also eat the seeds on the grass heads by stripping them sideways through their bill. When pili matures it is hard and tough. Ancient Hawaiians used it to thatch their hale (houses).

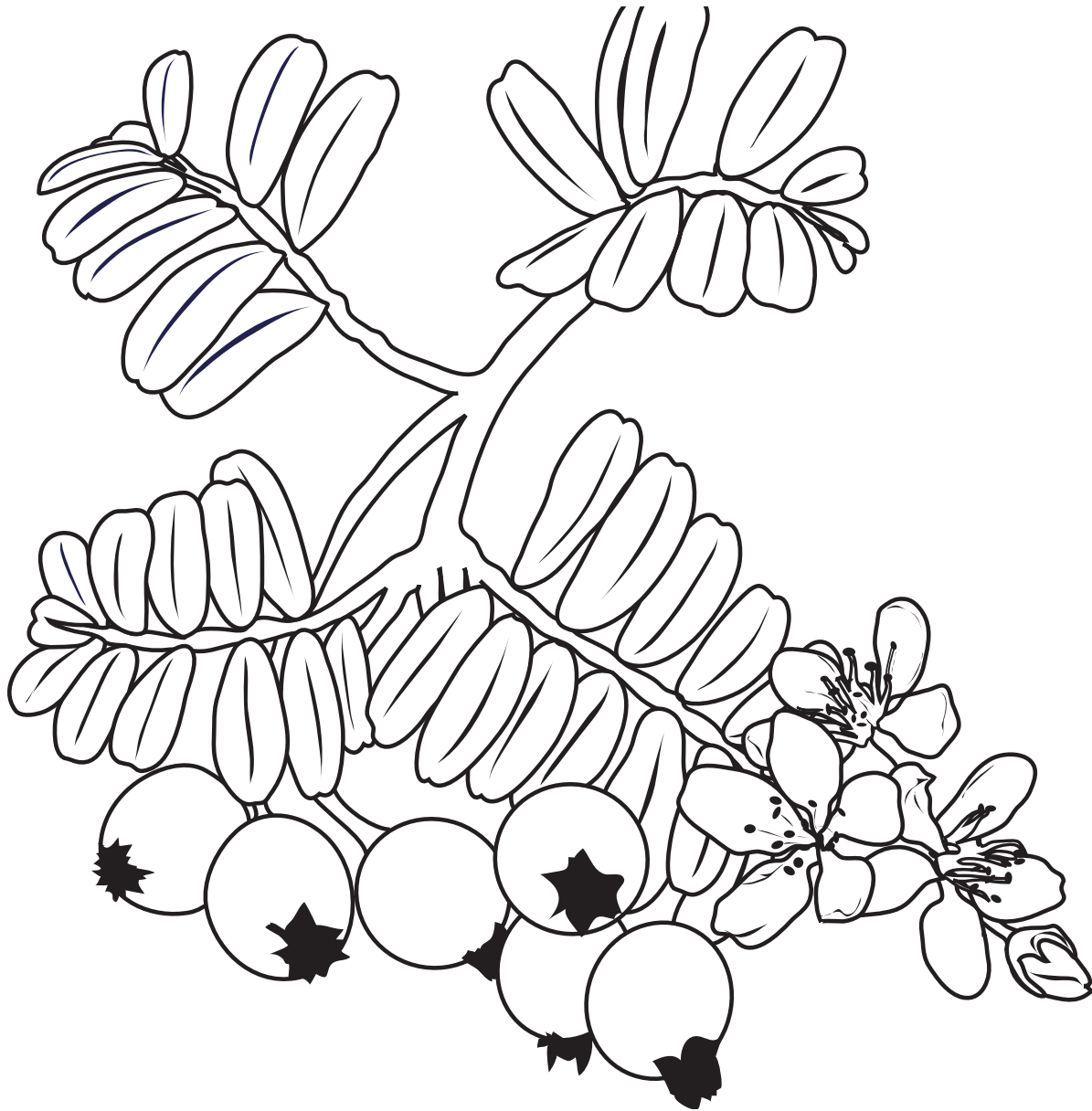




PŪKIAWE
(*Styphelia tameiameia*)



Pūkiawe is a shrub or small tree that grows in dry forests. It has short stubby leaves and small white flowers. The fruit can be white, red, and sometimes mottled pink and white. Nēnē sometimes nip on the new leaves of pūkiawe, but the berries are their favorite part of the plant. Pūkiawe berries are added to beautiful haku lei, and in days of old the wood was burned for ceremonial purposes.



'ŪLEI (*Osteomeles anthyllidifolia*)

'Ulei is a tough, shrubby plant with fine glossy leaves. It is in the rose family and has clusters of white fragrant flowers. The flowers form white berries and is perfect food for Nēnē and other birds. Nēnē are also good for the 'ulei plant. The berries contain small seeds that are not digested by the Nēnē and after a while they pass out in its feces. The seeds then grow into new 'ulei plants. So the Nēnē gets a delicious treat to eat, and the 'ulei plant “hops a ride” to a new spot.



Glossary

CAPTIVE BREEDING: the encouragement of reproduction among animals (particularly endangered ones) in a protected, captive setting for conservation purposes.

CAPTIVITY: the maintenance of animals in enclosures of some kind, not in the free, wild state.

CLUTCH: a group of animals that hatch from one nest of eggs at the same time.

ENDANGERED: animals or plants that survive in such low numbers that they could become extinct in a few years unless something is done to help populations increase.

EXTINCT: no longer exists.

FLEDGE: the point at which a young bird has grown enough feathers to begin to fly.

INCUBATION: providing warmth to eggs so they will grow and hatch.

MIGRATE: to move from one region or climate to another for feeding or breeding.

NUTRITIOUS: describes food that contains things important for growth and good health.

POPULATION: the number of a kind of animal that lives in a place.

SEDGE: a type of plant that is similar to grass but with a solid stem and tuft on top.

TERRESTRIAL: living mostly on land (instead of in the water or in the air).

TERRITORY: the home range of an animal that is defended against other members of the same species.

WATERFOWL: a general name for geese and ducks.

CREDITS

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Written by Kathy Carlstead, Ph.D, Honolulu Zoo Society.

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Skulls from: mtDNA from fossils reveals a radiation of Hawaiian geese recently derived from the Canada goose (*Branta canadensis*), Ellen E. Paxinos, Helen F. James, Storrs L. Olson, Michael D. Sorenson, Jennifer Jackson, and Robert C. Fleischer. *Proceedings of the National Academy of Sciences*, February 5, 2002, vol 99(3): pages 1399-1404.

Ko'oko'olau & 'Āwikiwiki drawings from the *Manual of Flowering Plants of Hawai'i*, Revised Edition, Volume 1, by Warren L. Wagner, Derral R. Herbst, S. H. Sohmer. Illustrations by Yevonn Wilson-Ramsey. University of Hawai'i Press and Bishop Museum Press, 1999.

Front cover courtesy of Honolulu Zoo. Other photographs courtesy of Jack Jeffrey, Forest & Kim Starr (USGS),etc.

Nene Food Plants



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