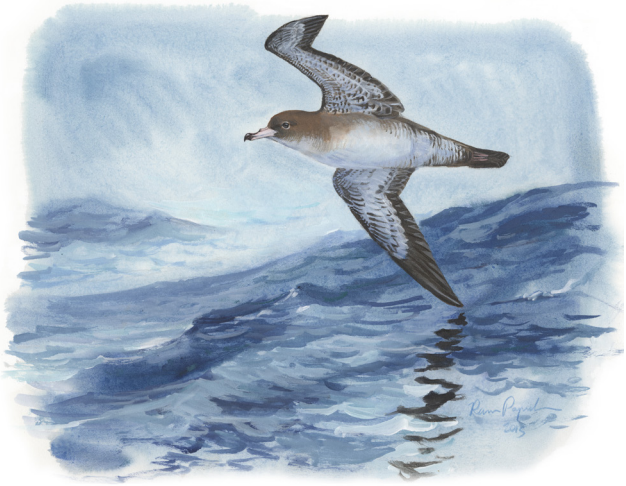
INVASIVE SPECIES AND SEABIRDS

MIDDLE SCHOOL CURRICULUM



Seabird Youth Network

Seabird Youth Network

AUK ECOLOGICAL CONSULTING

COASTAL CONSERVATION

Aleut Community of St. Paul Island
Tribal Government
Ecosystem Conservation Office

ISLAND CONSERVATION
Preventing Extinctions

NATIONAL FISH AND WILDLIFE FOUNDATION
NFWF

NORTAC

oikonos

St. Paul
St. George
Pribilof School District

Ram Papish

St. George Island
INSTITUTE

ST. GEORGE TRADITIONAL COUNCIL

THALASSA

U.S. FISH & WILDLIFE SERVICE

U.S. DEPARTMENT OF THE INTERIOR
U.S. Fish and Wildlife Service
NATIONAL WILDLIFE REFUGE SYSTEM

Auk Ecological Consulting	Coastal Conservation	Ecosystem Conservation Office Aleut Community of St. Paul Island		Island Conservation	National Fish and Wildlife Foundation	NORTAC	Oikonos
Pribilof School District	Ram Papish	St. George Island Institute	St. George Traditional Council	Seabird Youth Network	Thalassa	U.S. Fish & Wildlife Service National Wildlife Refuge System	

The Invasive Species and Seabirds middle school curriculum was developed by the Seabird Youth Network and multiple partners in response to a need for more community outreach and education regarding invasive species and seabirds on the Pribilof Islands, Alaska and the Juan Fernandez Islands, Chile. The curriculum was designed with rural schools in mind, where teachers may come from outside the community and have little or no understanding of the local ecosystem. Curricula summary information is provided in PowerPoints to help teachers from varying backgrounds understand the biology of seabirds, history of invasive species, and need for biosecurity plans. PowerPoints can be used as teaching aids or substituted for a text book. All five lessons in this curriculum are designed to complement the Seabird Youth Network's Seabird curriculum. Lessons are targeted for 6th to 8th grade. Labs can be taught at a higher level with the Extend and Explore options.

The Seabird Youth Network website (http://seabirdyouth.org/seabird-activities/) has large group games and activities that reinforce the concepts presented in Lesson 1-4.

Funding for the curriculum was provided by National Fish and Wildlife Foundation.

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INTRODUCTION

INVASIVE SPECIES AND SEABIRDS

INVASIVE SPECIES

For thousands of years, species have moved around the world colonizing new areas. When an introduced species outcompetes native species and alters the native food web it is considered invasive. Invasive species decrease biodiversity, put endangered and threatened species at risk, and displace native plants and animals. According to the International Union for Conservation of Nature (IUCN), invasive alien species are the second most significant threat to biodiversity after habitat loss. On islands they are the primary threat to biodiversity. In their new ecosystems, invasive species become predators, competitors, parasites, hybridizers, and diseases of our native and domesticated plants and animals. The U.S. Department of State estimates the cost of invasive species to the United States alone is in the tens of billions of dollars annually.

SEABIRDS

A seabird is a bird that spends most of its life at sea. Despite huge variations among different species, seabirds share similar characteristics. They are all adapted for a life at sea and they all must come to land to lay their eggs and raise their chicks. Most seabirds gather in large colonies along marine shorelines to breed and raise their young.

Introduced species, such as rats and cats, have been responsible for almost half of all bird extinctions in the last five centuries. Invasive species can have huge effects on seabirds, and this problem is even more pronounced on isolated islands where species have evolved without predators and have little protection. Seabirds are threatened by a range of alien species including rats, cats, mongoose, and snakes.

BIOSECURITY

In the context of invasive species, biosecurity refers to the implementation of actions to reduce the risk of invasive species introduction to a particular area (e.g., island) and how to respond to a confirmed invasive species incursion. A biosecurity plan provides the public and land managers with detailed guidelines and information that can be used to implement these actions and identifies pathways of invasion with strategies for preventing or reducing the probability of new introductions/reinvasions.

CURRICULUM FRAMEWORK

The curriculum consists of five lessons. The lessons are designed to reinforce and expand the lesson themes, and provide hands-on opportunities for students to investigate and integrate the information they have learned.

THIS CURRICULUM ACCOMPLISHES THE FOLLOWING OBJECTIVES:

- Increase understanding of the relationship between invasive species and seabirds.
- Develop awareness and importance of biosecurity plans for islands and invasive species.
- Increase the awareness of the need for more community involvement when dealing with invasive species detection, prevention, and eradication.

WHAT ARE ASSESSMENT METHODS?

Assessment methods vary with each lab; any of these methods can be given a point value. Methods include:

- Pre and Post Assessment
- Verbal presentations
- Research summaries

HOW MUCH TIME DO I NEED?

Each lesson can be completed in 1-2 class periods of 55 minutes each.

ACKNOWLEDGMENTS

Funding for the curriculum was provided by the National Fish and Wildlife Foundation, with in-kind services provided by the Pribilof School District, Ecosystem Conservation Office Aleut Community of St. Paul (ECO), Alaska Maritime National Wildlife Refuge, St. George Traditional Council, St. George Institute, and the Seabird Youth Network.

Information on St. Paul Island rat prevention was provided by St. Paul Island Ecosystem Conservation Office.

Original artwork was created by Ram Papish.

Lessons were developed by Pam Goddard and Lauri Sadorus at Thalassa, Tonia Kushin (Pribilof School District), and Ann Harding (Auk Ecological Consulting). Background information for Lessons 2-5 was provided by Chris Gill (Coastal Conservation). Peter Hodum (Oikonos) provided information on the Juan Fernandez Islands.

Please send any comments or inquiries to:

Ann Harding
Seabird Youth Network
a.m.a.harding@gmail.com
www.seabirdyouth.org
or

Pam Goddard
Thalassa
p.goddard@thalassa-education.com

CURRICULUM OVERVIEW

INVASIVE SPECIES AND SEABIRDS

Subject Area(s): Life Science	**Grade Levels:** Middle School	**Teaching Time** 55 minutes per lesson

Lesson Topics:	seabirds, invasive species, biosecurity, stewardship
Learning Objectives:	Students will learn about invasive species, seabirds, and the consequences of their interactions.

Key words:	invasive species, introduced species, endemic species, seabirds, biodiversity, ecosystem, biosecurity, stewardship
Focus Question	• Why are seabirds so vulnerable to invasive species? • How do invasive species alter island ecosystems? • What community based programs have successfully eradicated or prevented invasive species?

ACTIVITIES		STATE STANDARDS	NEXT GENERATION SCIENCE STANDARDS		
		AK	MS-LS2 Ecosystems	Minutes	Grades
LESSON ONE	Seabirds	SC2;SC3.2;SE1	LS2.A: Interdependent Relationships in Ecosystems LS2.B: Cycle of Matter and Energy Transfer in Ecosystems	55	6-8
LESSON TWO	Invasive Species and Biodiversity	SC2;SC3.2;SE1	LS2.B ; LS2.D: Biodiversity and Humans	55	6-8
LESSON THREE	Invasive Species: Consequences	SC2;SC3.2;SE1	LS2.B; LS2.D	55	6-8
LESSON FOUR	Stewardship and Biosecurity	SC2;SC3.2;SE1	LS2.D	55	6-8
LESSON FIVE	Case Studies		ETS1.B: Developing Possible Solutions	55	6-8

The Seabird Youth Network website (http://seabirdyouth.org/seabird-activities/) has large group games and activities that reinforce the concepts presented in Lesson 1-4.

See Appendix II for detailed information on educational standards.

LESSON ONE SEABIRD BASICS

OBJECTIVES

Students will be able to describe seabird life history and colony structure.

Students will research a seabird and create a fact sheet.

BACKGROUND

A seabird is a bird that spends most of its life at sea. All seabirds must come to land to lay their eggs and raise their chicks. Most seabirds gather in large colonies along marine shorelines to breed and raise their young. The Pribilof Islands in Alaska support an estimated 2.8 million breeding seabirds each year. Seabirds species on the Pribilof Islands include Common Murres, Thick-billed Murres, Red-legged Kittiwakes, Black-legged Kittiwakes, Horned Puffins, Tufted Puffins, Lest Auklets, Parakeet Auklets, and Crested Auklets.

Seabirds are important part of the marine food web in Alaska. Primary prey includes forage fish, such as sand lance and juvenile pollock. Guano (feces, poop) produced by the birds provides critical nutrients (nitrogen and carbon) for terrestrial plants. The birds also provide food for the native Arctic fox (native on the Pribilof Islands).

Lesson 1 introduces seabird life history and breeding strategy. For more information on seabird biology please see the Seabird Curriculum hosted on the Seabird Youth Network (www.seabirdyouth.org).

Large group activities are also provided on the Seabird Youth Network website (www.seabirdyouth.org/seabird-activities/)

SEABIRD BASICS

Diet
Seabirds eat primarily fish, squid, and zooplankton.

Long-lived
Most seabirds live a long time (between 20-60 years!)

Few chicks
In general, seabirds also have fewer chicks (1-3) than other species of land birds, and often don't start breeding until later on in life (2-10 yrs old).

Mates
Most seabirds mate for life.

Hard-working parents
Parent seabirds spend a lot of time and effort rearing their chick.

For example, parents of some of the larger albatross species feed their chick at the colony until they are 10 months old.

Living for a long time and having fewer chicks per year has likely evolved because of their unpredictable marine conditions, challenges of finding food at sea, and the relative lack of predation compared to land-birds.

SEABIRD GROUPS

The five main groups of seabirds (seaducks, loons, grebes, and phalaropes are sometimes also included as seabirds) are:

- **Penguins.** All are highly adapted to underwater travel, but cannot fly. Except for the Galapagos Penguin, they all live in the Southern Hemisphere (but not all live where it is very cold).
- **Alcids.** This group of species (family Alcidae) both fly and swim with their wings. They live only in the Northern Hemisphere. The Great Auk is now extinct. Species of alcids include the puffins, murres, and auklets.
- **Tubenoses.** All tubenose species (Order Procellariformes) have their nostrils enclosed in tubes. They include the albatross, fulmar, petrels, shearwaters, and prions.
- **Other seabirds.** This order (Pelecaniformes) includes the gannets, pelicans, boobies, tropic birds, cormorant, and frigate birds.
- **Gull-like birds.** The skuas, jaegers, gulls, kittiwakes and terns (family Laridae).

SEABIRD DISTRIBUTION

Seabirds can be found worldwide, from the tropics to both polar-regions. We all know that penguins live in the snowy Antarctic, but did you also know they live in Australia and South Africa?

LESSON ONE SEABIRD BASICS

MATERIALS

Worksheets listed below.

Internet access.

Bird identification book if available.

RESOURCES

Seabird Youth Network Activities
http://seabirdyouth.org/seabird-activities/

Alaska Fish and Wildlife News
http://www.adfg.alaska.gov/index.cfm?adfg=wildlifenews.view_article&articles_id=328

Alaska Department of Fish and Game: Birds
http://www.adfg.alaska.gov/index.cfm?adfg=animals.listbirds

Alaska Maritime National Wildlife Refuge
http://www.fws.gov/refuge/alaska_maritime/

http://www.fws.gov/refuge/Alaska_Maritime/wildlife_and_habitat/birds.html

Alaska Seabird Information Series
http://www.fws.gov/alaska/mbsp/mbm/seabirds/species.htm

Marine Ornithology
http://www.marineornithology.org/

USGS Alaska Science Center
http://alaska.usgs.gov/science/biology/seabirds_foragefish/index.php

The Cornell Lab, All About Bird Biology
http://biology.allaboutbirds.org/#home-page-top

Looking for Seabirds: Journal from an Alaskan Voyage. 2004. Sophie Webb. ISBN-10: 0618212353

My Season With Penguins: An Antarctic Journal. 2000. Sophie Webb. ISBN-10: 0395922917

Seabirds of the World: The Complete Reference. 1997. Jim Ednicott and David Tipling. ISBN-10: 0811702391

Seabirds: An Identification Guide. 1996. Peter Harrison. ISBN-10: 0691015511

Biology of Marine Birds. E. A. Schreiber, and Joanna Burger (Editors). 2001. ISBN-10: 0849398827

PROCEDURES

LAB 1.1 SEABIRDS OF THE PRIBILOF ISLANDS

Use the Internet or PowerPoint 1 to create a list of the seabirds of the Pribilof Islands or an island near you.

LAB 1.2 SEABIRD FACT SHEET

After showing the PowerPoint presentation for Lesson 1, ask the students to complete Lab 1.1 Seabird Fact Sheet for each seabird that nests on the Pribilofs or an island near you. See Appendix III for examples of seabird fact sheets.

LAB 1.3 SEABIRD NESTING MAZE

Figure out all of the ways Rat can reach the nesting birds, chicks, and eggs on the Pribilof Islands.

LAB 1.4 SEABIRD NESTING WORKSHEET

Identify the birds on the maze provided. Discuss nesting habitat and bird vulnerability.

EXTEND AND EXPLORE

- Seabird colony structure: using the fact sheets from Lab 1.2 and the maze provided in Lab 1.3 create a seabird rookery in your classroom. Be creative, use bookshelves as cliffs or cabinets as burrows.
- Seabird vulnerability: research and discuss how vulnerable each species is to predation.

Student Name: _____

Date: _____

Classifications: Gull-like bird, Penguin, Alcid, Other seabird, Tubenose

Species Name	Classification

LESSON ONE LAB 1.1 SEABIRDS OF PRIBILOFS - TEACHER KEY

Student Name: _____

Date: _____

Classifications: Gull-like bird, Penguin, Alcid, Other seabird, Tubenose

Species Name	Classification
Horned Puffin	Alcid
Tufted Puffin	Alcid
Crested Auklet	Alcid
Parakeet Auklet	Alcid
Red-legged Kittiwake	Gull-like bird
Black-legged Kittiwake	Gull-like bird
Red-faced Cormorant	Other seabird
Common Murre	Alcid
Thick-billed Murre	Alcid
Northern Fulmar	Tubenose

Student Name: _____ Date: _____

Seabird Fact Sheet

COMMON NAME	SCIENTIFIC NAME

GLOBAL CONSERVATION STATUS	LOCAL CONSERVATION STATUS

BREEDING TIME	# EGGS PRODUCED	INCUBATION	DAYS TO FLEDGE

TYPE OF NEST	FEEDING BEHAVIOR	DIET

IMAGES

LESSON ONE | LAB 1.2 SEABIRD FACT SHEET PAGE 2

Student Name: _____ Date: _____

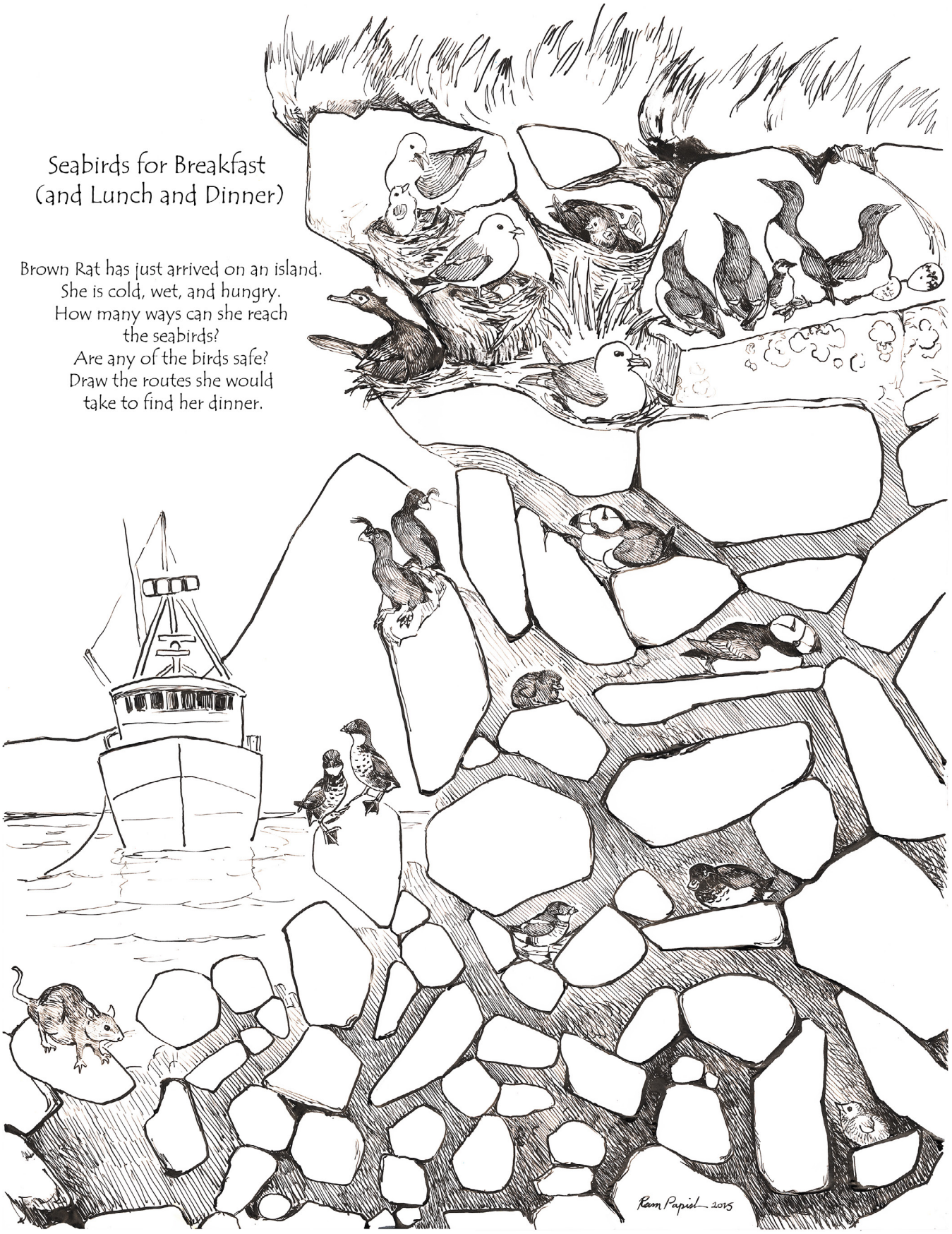
DESCRIPTION

DISTRIBUTION

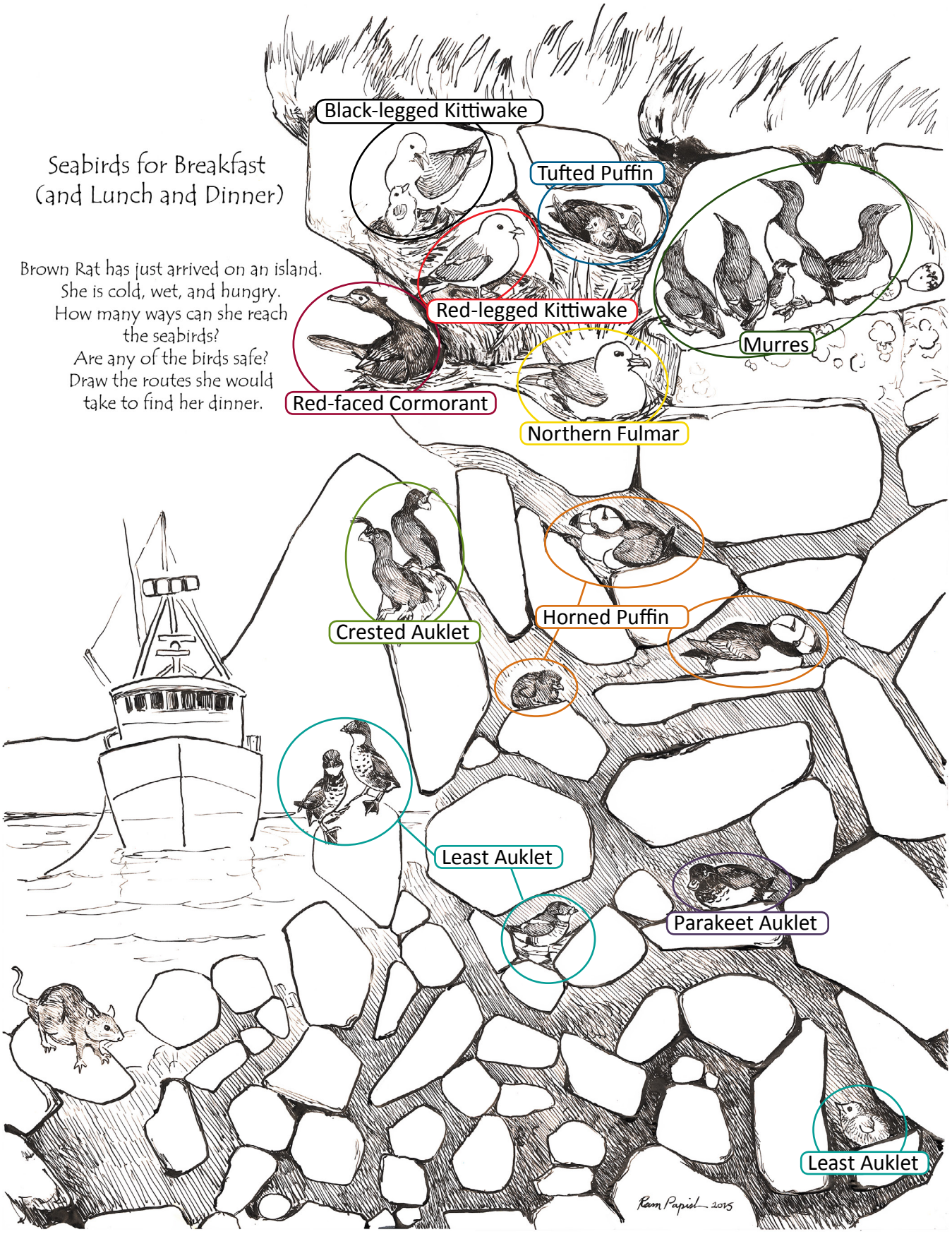
CONSERVATION CONCERNS

CULTURAL USE

COOL FACT


Seabirds for Breakfast
(and Lunch and Dinner)
Brown Rat has just arrived on an island.
She is cold, wet, and hungry.
How many ways can she reach
the seabirds?
Are any of the birds safe?
Draw the routes she would
take to find her dinner.
Ram Papish 2015

LESSON ONE LAB 1.3 SEABIRD MAZE - TEACHER KEY



LAB 1.4 SEABIRD NESTING WORKSHEET

Student Name: _____ Date: _____

Instructions: Based on the information gathered for the Seabird Fact Sheets and the Seabird Nesting Maze, assign one of the nesting habitats from the list below to each species in the table.
Extra Credit: Find and label the corresponding bird on the seabird maze.

ROCK CREVICE, TREE, CLIFF, SANDY BEACH, BURROW, FOREST

Species	Main Breeding Habitat
Horned Puffin	
Tufted Puffin	
Crested Auklet	
Parakeet Auklet	
Least Auklet	
Red-Legged Kittiwake	
Black-Legged Kittiwake	
Red Face Cormorant	
Common Murre	
Thick-billed Murre	
Northern Fulmar	

LESSON ONE LAB 1.4 BREEDING HABITAT - TEACHER KEY

Student Name: _____ Date: _____

Instructions: Based on the information gathered for the Seabird Fact Sheets and the Seabird Nesting Maze, assign one of the nesting habitats from the list below to each species in the table.
Extra Credit: Find and label the corresponding bird on the seabird maze.

ROCK CREVICE, TREE, CLIFF, SANDY BEACH, BURROW, FOREST

Species	Main Breeding Habitat
Horned Puffin	Rock crevice
Tufted Puffin	Burrow
Crested Auklet	Rock crevice
Parakeet Auklet	Rock crevice
Least Auklet	Rock crevice
Red-legged Kittiwake	Cliff
Black-legged Kittiwake	Cliff
Red-faced Cormorant	Cliff
Common Murre	Cliff
Thick-billed Murre	Cliff
Northern Fulmar	Cliff

OBJECTIVE

Students will investigate invasive species and their impacts on biodiversity.

TIME REQUIRED

55 minutes

BACKGROUND

INVASIVE SPECIES

An introduced species, also called an alien or exotic species, is any species that is not native, or original, to an ecosystem. An introduced species that significantly modifies or disrupts an ecosystem and poses a threat to the environment, human health, or the economy is called an invasive species or invasive alien species in that ecosystem.

A species may be considered native in one place, but introduced and/or invasive in another, nearby location. For instance, northern pike (*Esox lucius*)are native to most of Alaska, but where they have been introduced in the waterways of south-central Alaska, they are an invasive species because they are preying on populations of trout and salmon, causing a threat both to the environment and to the economy.

Several key characteristics make an introduced species more likely to become invasive:

- they have few natural predators, disease, or parasites to keep their numbers in balance in the new ecosystem;
- they reproduce quickly and often;
- they can adapt to many habitat conditions;
- they are able to migrate (and therefore spread) easily;
- they are generalists, i.e., they can eat a variety of foods and live in a variety of habitats; and
- they often defend themselves well or are particularly aggressive predators.

Introduction of invasives

Species are restricted to a natural range by their characteristics and those of the environment around them. Physical barriers such as high elevations, desert regions, or expanses of water prevent movement of the species into new areas. Invasive species have overcome those barriers to invade new habitats; human activities are the most common way that invasive species are transported to new habitats. Some examples include escaped (or released) pets (e.g., red-legged frog [*Rana aurora*]); boats that either sail from one port to another (e.g., Norway and black rats [*Rattus norvegicus*, *Rattus rattus*]) or are used in one lake and then moved to another lake (e.g., zebra mussels [*Dreissena polymorph*a], Eurasian water-milfoil [*Myriophyllum spicatum*]); movement of animals for sport hunting/fishing or for farming ventures (e.g., northern pike, arctic fox [*Vulpes lagopus*]); or intentional introduction because a person likes the species (e.g., European Starling [*Sturnus vulgaris*]). Many intentional introductions are the result of economic motivations, such as the introduction of Arctic foxes to the Aleutian Islands to bolster the fur farming industry in the 18th century. In this and many other cases, the ecological consequences of introducing an invasive species were not considered first, resulting in often devastating effects on the native ecosystem.

Introduced, non-invasive species

Not all species that are introduced are considered invasive. Plant and animal species that have been domesticated by humans, or are under the control of humans, and introduced species that are more beneficial than they are harmful are not considered invasive. As an example, many of the plants and animals that we consume for food are not native. Domestic chickens originated in India but are now raised for eggs and meat around the world; European honeybees (*Apis melifera*) have been introduced around the world to pollinate fruit trees and other agricultural crops; and potatoes, tomatoes, and peppers (sweet and hot) all originated in South America. Despite having been introduced around the world; these species are not considered invasive because their economic benefits (food production, food security) outweigh any negative effects (e.g., honey bees may out-compete native bees for pollen). However, domesticated plants that spread and animals that become feral may be considered invasive if they begin to negatively impact the environment and economy where

they are located. Feral goats are a problem on a number of islands around the world, where they overgraze areas leading to loss of biodiversity and increased soil erosion.

Some species have an overall negative effect on the environment or the economy in a location, but are not considered invasive because they are native species. Canada geese (*Branta canadensis*) are native to most of North America and most populations migrate annually, though there are also non-migratory populations throughout much of the United States, where they are often found grazing in parks and on lawns and golf courses. They are often considered to be a pest and may have a negative impact where they are found, but they are a native species, and thus not considered an invasive.

Islands and invasives

Invasive species may drive native species to extinction or localized extirpation via predation or competition for resources (e.g., food, habitat). This in turn can have a cascading effect on entire ecosystems. Island species and ecosystems are especially vulnerable and the introduction of a new species usually has a dramatic negative impact. Often, island species (and particularly endemic species) have evolved in an environment without any threat from non-native predators and thus have not developed defense mechanisms to respond to the threat of predation. Similarly, invasive species may out-compete native species for local resources. Currently, 75% of all threatened bird species found on oceanic islands are experiencing population declines that are attributed to predation or competition for resources by invasive species. Invasive predators, especially rats, represent the greatest threat to native island species. However, the impacts of habitat modification by herbivores such as goats and feral pigs and reduced fitness resulting from invasive micro-organisms (e.g., disease caused by microparasites) are also significant. There are many examples in which these threats, alone or combined, have caused extremely rapid declines and even extinctions.

Impacts

There are also indirect impacts caused by invasive species; the removal or reduction of one species can change how the food web functions, upsetting the balance of the ecosystem. For example, the Aleutian Islands are considered to be one of the most productive seabird breeding areas in North America with more than 10 million seabirds of 26 species breeding on the archipelago. Until three centuries ago the islands were free of predatory land mammals. In the years that followed, Arctic foxes were introduced intentionally for fur farming, and rats were introduced unintentionally. Both foxes and rats preyed on burrow and ground nesting seabirds, eating eggs, nestlings, and adult birds, decimating local populations. Only species that nested on unreachable cliff faces escaped predation.

On islands with mammalian predators, the populations of seabirds are much lower than they are on islands that have remained predator-free. With the reduction in seabirds comes a reduction in the productivity of the entire ecosystem because nesting seabirds transfer a great quantity of nutrients from the ocean to the islands in the form of guano. The guano fertilizes the islands, providing nutrients to support a diverse grassland habitat, which in turn provides food and shelter for herbivores such as slugs and the native species that prey upon them (e.g., spiders and land birds).

The elimination of seabird colonies by non-native arctic foxes and rats interrupted the transfer of nutrients from ocean to island, resulting in reduced soil nutrients, which in turn led to a shift in plant communities from a grass, sedge, and large forbe dominated community to a less diverse dwarf-shrub tundra vegetation community. Changes to the vegetation community consequently lead to a reduction in native herbivore and predator abundance and diversity. The introduction of a non-native mammalian predator can thus cause indirect impacts to an entire island ecosystem.

BIODIVERSITY

Biodiversity is the variety of life that is found on Earth. We can talk about the biodiversity of Earth as a whole, the biodiversity of a specific region of Earth, such as a continent, country, or town, or even the biodiversity of a space as small as your backyard. Often, we want to compare the

biodiversity of one location to another. One way to do this is to determine the species richness of a place by counting the number of species that are present. All kinds of life are included in this count: plants, animals, fungi, bacteria. Tropical rainforests tend to have many more species than arctic regions; we say that rainforests have greater species richness than arctic regions (tropical rainforests are thought to be the oldest biome on Earth and thus it is not surprising that they contain the most species, because they have had the most time for their inhabitants to diversify). It can be difficult to accurately determine the species richness of a place, especially if we include bacterial species, which are hard to count, so we often look only at the more obvious species, measuring biodiversity by counting, for instance, the number of bird species or the number of plant species.

The number of species isn't the only thing that contributes to biodiversity. Genetic variation, that is differences in the physical features of individuals within a species due to small differences in their DNA, increases the diversity of a population, both within a single species and within a group of species.

Groups of species form a wide variety of ecological communities, this depends partly on their habitat– natural environment in which a species or group of species lives. Habitat features include the physical features—soil, temperature range (climate), light availability, and weather (moisture)—as well as the availability of food and the presence of predators. A habitat can be said to be more diverse when it contains more ecological communities. For instance, a place with a forested area and open grassland has more diversity than just the grassland alone. Similarly, a backyard with a lawn, a few trees, and some garden beds has more diversity than one that is just a grassy lawn.

In an ecological community, species evolve (evolution) to coexist with one another. Every species has a role to play; these roles are interconnected and can be described using a food web. In a typical food web, plants fill the role of primary producer or autotroph, producing organic matter from inorganic substances (sunlight, water, carbon dioxide, minerals). These plant species are consumed by herbivores, animals that eat only plant matter. Herbivores are in turn consumed by primary predators (animals that eat herbivores), which are in turn consumed by secondary predators (animals that eat other predators). Throughout this cycle, plants and animals die, and their bodies are consumed by detritivores, animals (especially invertebrates), fungi, and bacteria that breakdown plant and animal matter and release the nutrients back into the soil where it can be used again by primary producers. Together, herbivores, predators, and detritivores are referred to as heterotrophs because they must obtain their energy from organic sources.

BIODIVERSITY ON ISLANDS – A SPECIAL CASE

Throughout the world, islands are unique examples of biodiversity. Geographical size, habitat features and distance from the mainland result in ecosystems that may be vastly different from the nearest mainland ecosystems. The isolation of islands results in the evolution of a large number of endemic species (a species that is only found in a defined geographic location, such as an island, nation, country or other defined zone, or habitat type). For example, over 90% of the native species found on the Hawaiian Islands are endemic, and the island of Madagascar, off the east coast of Africa, is home to more than 8,000 endemic species. Endemic species have become specially adapted to the habitat features that make their island home unique.

Most islands lack predators and in the absence of substantial predation pressure, many species have gradually lost anti-predator defenses (over the course of thousands of years) since they can cost energy and time that might otherwise be used for growth, foraging, mating, and reproduction. This can lead to the development of unique characteristics such as flightlessness in birds, loss of defense behaviors (e.g., the instinct to hide in the presence of a potential predator) and/or defensive mechanisms (e.g., thorns on plants), ground nesting behavior in some bird species, and gigantism or dwarfism (unusually large or small body size).

LESSON TWO INVASIVE SPECIES AND BIODIVERSITY

Endemic island species are particularly susceptible to changes to the habitat and ecosystem where they live. While island life presents unique opportunities for adaptation, it also imposes constraints: population sizes are often small, and genetic diversity is low due to isolation and the small population size. Because many species are less able to disperse, they tend to be concentrated in smaller areas. These characteristics and strategies work fine when there are no changes to the island, but island species are increasingly at risk as the human population increases and there are fewer places that are left pristine. Island species are less able to react to changes to their ecosystem, and many have become rare, threatened, or even extinct as habitats are destroyed by development and/or new species are introduced that either compete for food or prey on susceptible island species. One of the biggest threats to island biodiversity is invasive species.

MATERIALS

Worksheets 2.1, 2.2, 2.3, 2.4

Internet access

Appendix IV and V

PROCEDURES

LAB 2.1. INVASIVE SPECIES

Ask students or groups of students to research an invasive species and complete the worksheet. Please note, students are asked to research an animal not a plant. This curriculum only addresses invasive animals.

LAB 2.2. INVASIVE SPECIES SUMMARY

As a class summarize the information on the invasives species each group researched.

LAB 2.3 INVASIVE SPECIES FOOD WEB

Based on the information gathered in Lessons 1 and 2, complete the food web worksheet.

LAB 2.4 CROSSWORD PUZZLE

Test the students knowledge with the crossword puzzle.

DISCUSSION

How has an invasive species changed the biodiversity of your local ecosystem?

How do invasive species alter food webs? What are the consequences?

EXPLORE AND EXTEND

Discuss humans as invasive species.

RESOURCES

Alaska Department of Fish and Game
http://www.adfg.alaska.gov/index.cfm?adfg=wildlifenews.view_article&articles_id=145

Alaska Sea Grant Marine Advisory Program
http://seagrant.uaf.edu/map/conservation/rats/index.html

National Geographic: Rat Reproduction
http://video.nationalgeographic.com/video/rat_indian_reproduction

Science

Science Warriors: The Battle Against Invasive Species. 2008. Sneed B. Collard III. ISBN-10: 0618756361

What Can We Do About Invasive Species. 2010. Amelia von Zumbsch (ed.). IISBN-13: 978-1435824874

LESSON TWO LAB 2.1 INVASIVE SPECIES WORKSHEET

Student Name: _____

Date: _____

Research an invasive animal species.

Species Name: _____

Country of origin: _____

Method of introduction: _____

Consequences of introduction: _____

Life history of introduced species (How long does it live?, How many offspring does it have? How often does it have offspring?, What does it eat?, Where does it live?)_____

LESSON TWO LAB 2.2 INVASIVE SPECIES SUMMARY

As a class, summarize the invasive species information gathered.

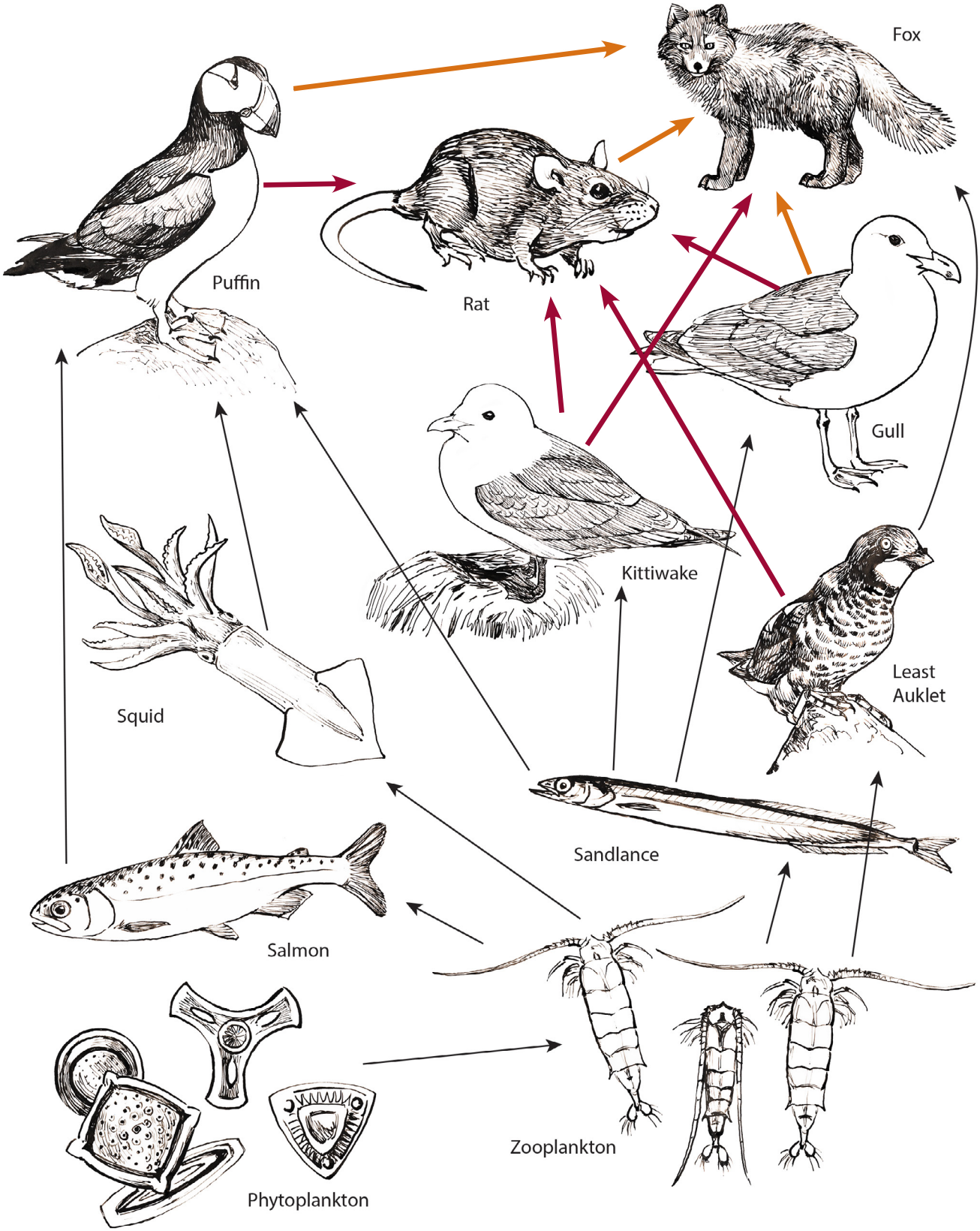
Species Name	Country of Origin	Method of Introduction	Consequences

LAB 2.3 ALASKA INVASIVE SPECIES FOOD WEB

Label each species and draw arrows showing the transfer of energy or consumption from the primary producers to the top predator. Use a different colored to identify the invasive species.

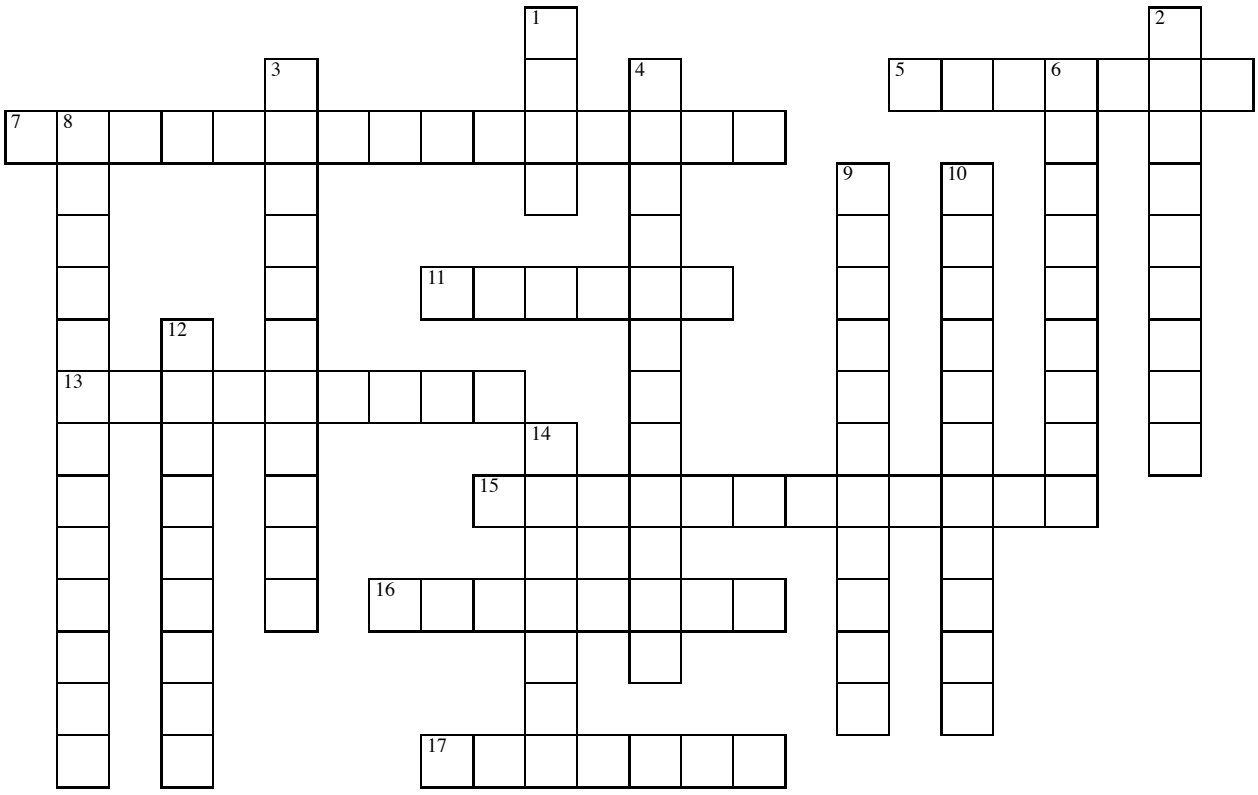
LESSON TWO | LAB 2.3 ALASKA FOOD WEB - TEACHER KEY

Label each species and draw arrows showing the transfer of energy or consumption from the primary producers to the top predator. Use a different colored to identify the invasive species.



Student Name: _____ Date: _____

Invasive Species



ACROSS

5 End of a species
7 A plant or animal not native to a specific location
11 Offspring of two different breeds or species
13 Change in inheritable traits over successive generations
15 Act of protecting or preserving natural resources
16 An organism that eats another organism
17 Natural environment in which an organism lives

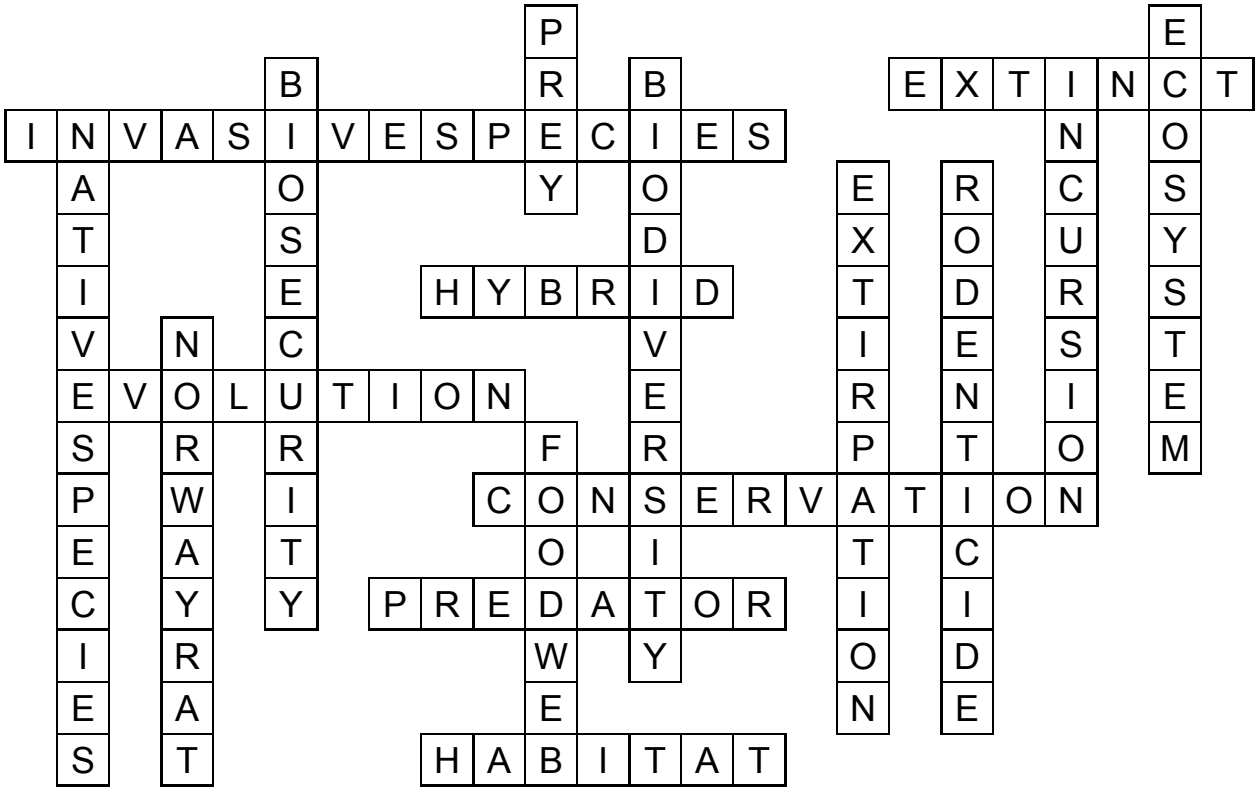
DOWN

1 The organism which the predator eats
2 Community of living organisms and their environment
3 Actions to reduce the introduction of an invasive species
4 Degree of variation of life
6 Arrival of invasive species in a non-native ecosystem
8 Species whose presence in the region is result of natural processes not human intervention
9 A species that ceases to exist in a one area but still exists elsewhere
10 Poisoned bait used to eradicate invasive species
12 Rattus norvegicus
14 Feeding relationships within an ecological community

LESSON TWO | **LAB 2.4 CROSSWORD - TEACHER KEY**

Student Name: _____ Date: _____

Invasive Species



LESSON THREE INVASIVE SPECIES: CONSEQUENCES

OBJECTIVE

Students will investigate the consequences of invasive species.

TIME REQUIREMENT

55 minutes

BACKGROUND

WHAT ARE THE CONSEQUENCES OF INVASIONS?

According to the International Union for Conservation of Nature (IUCN), invasive alien species are the second most significant threat to biodiversity after habitat loss. On islands they are the primary threat to biodiversity. In their new ecosystems, invasive species become predators, competitors, parasites, hybridizers, and cause diseases in our native and domesticated plants and animals. In these roles, invasive species can have negative consequences for the economy, human health, and the environment. Some estimates suggest that invasive species cost the USA $143 billion per year and that 42% of endangered US species have reached this status because of invasive species.

Industries such as forestry, fisheries and aquaculture, agriculture, and tourism or outdoor recreation all depend on healthy natural resources. When an invasive species impacts the productivity of one of these industries, it affects the economy of the human community that depends on it for food and jobs. For instance, the presence of invasive northern pike (*Esox lucius*), which were illegally-introduced into the waterways of south-central Alaska, is threatening local populations of salmon and trout. Pike are top-level predators in aquatic food chains and are highly piscivorous (fish eating). In lakes and rivers where pike are not native, trout, salmon, and other fish have not adapted defenses against the pike's predatory tactics and this invasive species is negatively impacting those populations. Smaller populations of salmon and trout mean less fish can be harvested by Alaskans for food.

Economic impacts caused by invasive species are most severe in agricultural systems. For example, successful invasions by agricultural pests result in greater costs to farmers who must control the new pest, often with pesticides. Consequently, food costs more to produce because of increased pest management expenses, and the risk to the environment and human health, such as accidental pollution of water and air with pesticides, increases too.

Invasive species often bring new parasites and pathogens with them to the new ecosystem, or they themselves might cause disease. These pathogens might infect native species that have no immunity to the diseases the pathogens cause. Pathogens that cause diseases in humans may also be introduced; moved either by humans as they travel the world or when animals or goods are shipped from other parts of the world. As an example, West Nile virus affects humans and has been spreading across North America since its introduction to New York in 1999.

Some of the most dramatic consequences of species invasions are environmental changes within the invaded ecosystem. As we discussed in lesson one, the arrival of an invasive species can change how the food web functions, upsetting the balance of the ecosystem. Competition, predation, disease, and hybridization can all cause reduction, extirpation, or even extinction of native species. The movement of certain invasive species around the world is leading to the homogenization of environments; the domination of geographically distinct ecosystems by the same invasive species leads to a loss of biodiversity, especially on islands.

HOW WIDESPREAD IS THE PROBLEM?

Invasive species are a global problem. Humans have explored all but the most remote and extreme environments, intentionally and unintentionally transporting plants, animals, and other organisms as we go, and helping these introduced species to become established through habitat modification and sometimes intentional breeding or propagation. Species that would otherwise be unable to spread over long distances have been carried across mountain

ranges and oceans that would normally be physical barriers to dispersal.

Of particular concern is the threat of invasive species to the biodiversity on islands. Nearly all the islands around the world have been explored by humans, and our actions have greatly increased the spread of thousands of non-native animal, plant, fungal, and protozoan species to these once untouched ecosystems. Endemic island species are particularly at risk because their small, isolated populations are highly vulnerable to predation by an invasive species. For example, 75% of bird species found on islands around the world are being threatened by invasive species, especially invasive predators such as rats and cats. Of the documented species extinctions worldwide, over half were of island species, the majority of which have been attributed to the presence of invasive species.

HOW DO INVASIVE SPECIES AFFECT NATIVE SPECIES/ECOSYSTEMS?

Invasive species affect the species and ecosystem around them in a number of ways:

Competition: Invasive species may out-compete native species for food, water, space, and other essential resources. For example, European Starlings (*Sturnus vulgaris*) out-compete native bird species such as chickadees, swallows, and woodpeckers for nest cavities.

Predation: Invasive predators can severely reduce populations of native species and cause extirpations or even extinctions, because native prey species may not have evolved defenses to respond to the threat of predation. For example, some seabird species nest on the ground or in burrows, making them easy prey for invasive rats, which also consume seabird eggs and chicks. The introduction of invasive rats to a seabird colony can cause dramatic population declines, extirpation of the colony, or in severe cases, extinction of an entire seabird species.

Habitat alteration: Invasive herbivores may change the structure and composition of a habitat and make it unsuitable for native species. In some parts of Alaska, overgrazing by introduced invasive reindeer (*Rangifer tarandus asiaticus*) has resulted in the loss of native vegetation, which has led to decreased species diversity (both plant and animal) and increased soil compaction and erosion.

Disease: Native organisms can act as hosts for invasive viruses or pathogens that in turn can infect native species with no immunity to the diseases the viruses or pathogens cause. For example, native mosquitoes have spread West Nile virus, which affects humans, across North America since its introduction to New York in 1999.

Parasitism: Some invasive species are parasites that feed on one or more native species, either killing or severely weakening them. The sea lamprey (*Petromyzon marinus*) is a parasitic fish that has been introduced to the Great Lakes, where it has parasitized native lake trout (*Salvelinus namaycush*) with devastating impacts on the native population, including the extirpation of this species from Lake Ontario. Bumblebees are both ecologically and economically important species that are experiencing considerable population declines worldwide and the spread of parasites from commercial honey bee colonies into wild bumblebee populations has been implicated recently in North America.

Hybridization: Invasive hybridization occurs when an invasive species reproduces with a closely related native species. The result may be the creation of a new species, loss of species diversity, or even extinction of the native species. Some populations of the endangered California tiger salamander (*Ambystoma californiense*) have hybridized with barred tiger salamanders (*A. tigrinum mavortium*) brought to California for fish bait, resulting in the population declines of the native species.

PREDATORS IN PARADISE: INVASIVE RATS ON ALASKA'S ISLANDS

Rats are one of the most destructive invasive species, having successfully invaded mainland and island ecosystems (including Alaska) throughout the world. Predation and ecosystem changes due to the introduction of invasive rats have caused at least 50 species extinctions and negatively affected at least 170 animal and plant

species on more than 40 islands and archipelagos worldwide.

Norway rats (*Rattus norvegicus*) were first introduced to Alaska in the 1780s, when a shipwreck occurred on the shores of Hawadax Island (formerly Rat Island) in the Aleutian Islands. Since that time the Norway rat has been accidentally introduced to many of the islands and on the mainland as far north as Nome, Alaska. It is also now found on more than 16 of the islands within the Alaska Maritime National Wildlife Refuge (AMNWR). Black rats (*Rattus rattus*) are thought to occur at low densities on Shemya Island, also in the Aleutians.

Rats are very effective invaders, having many of the characteristics discussed in lesson one:

- They are a generalist species, eating a wide variety of foods;
- They have the ability to adapt to a wide variety of habitats;
- They mature and reproduce quickly; adult females can have an average of 6 litters of approximately 9 young each year (average of 54 young per year);
- They can rapidly spread and colonize new environments both by land and water (they are excellent swimmers); and
- They are aggressive and efficient predators.

Rats have significant negative impacts on seabirds, consuming eggs, chicks, and adults and causing severe population declines; the most severe impacts are on highly vulnerable burrow-nesting or ground-nesting seabirds such as Storm Petrels (*Oceanodroma* spp.), Cassin's Auklet (*Ptychoramphus aleuticus*), and Tufted Puffin (*Fratercula cirrhata*). Often only species that nest on unreachable cliff faces escape predation. Many of the islands with invasive rats are now quiet, barren places when compared to those islands that have remained mammal-free.

In addition to direct predation of seabirds, rats also prey on a wide variety of intertidal invertebrates normally found in the mid to very low intertidal zone, affecting the abundance and the age structure of these species.

Rats can have indirect impacts on island ecosystems and native species. They feed on plants, eating seeds and seedlings and altering the structure of the plant communities within the island ecosystem, which in turn can have an indirect negative effect on the nesting habitat quality for other bird species such as songbirds. Predation of seabirds by rats can indirectly affect the productivity of the entire ecosystem because nesting seabirds transfer a great quantity of nutrients to the islands in the form of guano. The elimination of seabird colonies interrupts the transfer of nutrients from ocean to island, resulting in reduced soil nutrients, which in turn has led to a shift in plant communities from a grass, sedge, and large forb-dominated community to a less diverse dwarf-shrub tundra vegetation community. Changes to the vegetation community consequently lead to a reduction in native herbivore and predator abundance and diversity (e.g., slugs, spiders, land birds).

Black rats (*R. rattus*) are excellent climbers and also prey on nesting songbirds and their young. Rats also carry parasites and pathogens that can infect other species, including humans.

TURNING THE TIDE ON INVASIVE SPECIES

Removal of invasive species can reverse the detrimental ecosystem effects they cause and prevent extirpations and extinctions of native species. Permanently removing invasive species from islands is technically feasible, and worldwide there have been over 1,300 whole-island invasive animal eradications completed with a success rate of 80%; more than half of these targeted rats. Case studies highlighting key island restoration projects through invasive species eradication will be discussed in Lesson 4.

MATERIALS

- Internet or library
- Excel or other spreadsheet software (optional)
- 1 lb dried dark colored beans, or rat Gummy candy
- 1 lb mixed beans, jelly beans,
- Paper and pencil
- Calculator (optional)

LESSON THREE INVASIVE SPECIES: CONSEQUENCES

PROCEDURES

Labs 3.2 and 3.3 should be completed together. Lab 3.4 is a hands-on version of Lab 3.3.

LAB 3.1 RAT FACTS

Ask students to research rats, including their life history, using the Internet or other resources. Use the information to complete Lab 3.1

LAB 3.2 RAT INVASION SCENARIO

Using the information gathered from Lab 3.1 complete Worksheet 3.2.

LAB 3.3 RAT MATH

Using the information from Labs 3.1 and 3.2 calculate the population growth of rats as they invade an island and complete Lab 3.3.1 Rat Math Worksheet. Graph your results.

LAB 3.4 ISLAND RAT INVASION

Optional: Print the Rat Invasion Activity Board on the largest size paper your printer will allow or make one on butcher paper. The Activity Board is used to visually observe the changes in the rat and seabird populations but is not required to complete the activity.

Gather 1 pound of dark beans to represent rats, and 1 pound of mixed dried beans or jelly beans to represent the seabirds.

Gather the students around a table. Start with all of the seabirds in a pile in the first box under "Seabirds" and one rat in the box under "Rats". Based on the information given in the scenario and on the rat math worksheet, add rats and subtract seabirds every 2 months.

DISCUSSION

Discuss the rapid population growth of rats and the consequences for local seabirds.

Research the reproductive rates of fox or rabbits and substitute them in the exercise.

Based on what you know about rat biology, is this scenario realistic? Why or why not?

What assumptions were made about the rat and seabird populations?

What happens if each rat eats 4 birds every 2 months?

How long does it take the rats to wipe out the seabirds if only 4 rats are born to each female?

What if each rat has 14 babies each cycle?

EXPLORE AND EXTEND

LAB 3.5 ADVANCED RAT MATH

Take the rat math activity one step further and add in gestation and seabird reproduction. Use the data and information given and calculate the rat population increase and seabird population decrease.

How do the results differ from Lab 3.3?

NOTE:

This exercise is designed to simulate a rat invasion. It is actually very difficult to estimate how many birds/eggs a rat will kill/eat. There is evidence that rats will kill and cache as much as they can, particularly Norway rats. Therefore, as prey (seabird) abundance increases, the rats will 'high grade' (i.e., eat only eggs or the brains of adults). When seabird abundance is low, rats are more likely to eat whole carcasses.

RESOURCES

PBS Harriman Expedition Retraced
http://www.pbs.org/harriman/1899/rats.html

USFWS Rat Facts, Hawaii
http://www.fws.gov/pacificislands/publications/Ratsfactsheet.pdf

Alaska Department of Fish and Game
http://www.adfg.alaska.gov/index.cfm?adfg=wildlifenews.view_article&articles_id=145

National Geographic: Rat Reproduction
http://video.nationalgeographic.com/video/rat_indian_reproduction

Oh, Rat. 2006. Albert Marrin. ISBN-13: 978-0525477624

LAB 3.1 RAT FACTS WORKSHEET

Student Name: _____ Date: _____

Rat Facts	
Common Name	Scientific Name

Rat Biology

- Average weight:
- Average length:
- Average life span:
- Diet:

Habits

Reproduction

- Max litter size:
- Average litter size:
- Gestation:
- Number of litters per year:
- Weaned at:
- Young are mature and can reproduce at:

Geographical Distribution

LESSON THREE **LAB 3.1 RAT FACTS - TEACHER KEY**

Student Name: _____ Date: _____

Rat Facts	
Common Name	**Scientific Name**
Norway rat, brown rat	*Rattus norvegicus*

Rat Biology

- Average weight: 400-500 g (~1 pound)
- Average length: 400 mm including tail
- Average life span: up to 3 years, but usually only live 1 year in the wild
- Diet: omnivorous (plants and animals)
- Front teeth (incisors) continue to grow throughout their life, must constantly chew to prevent overgrowth

Habits

- Live in extensive burrow system or under ground areas such as sewers
- Live in large hierarchical groups
- Good swimmers and diggers
- Do not climb as well as the Black rat (Rattus rattus)
- Nocturnal

Reproduction

- Max litter size: 14
- Average litter size: 7
- Gestation: 3 weeks (21 days)
- Up to 12 litters/year
- Weaned at 3 - 4 weeks
- Young are mature and can reproduce at 5 weeks (35 days) old

Geographical Distribution

- Worldwide, where ever humans live
- Believed to have originated in northern China
- Spread throughout world on ships

LESSON THREE LAB 3.2 RAT INVASION SCENARIO

Student Name: _____Date: _____

Instructions:
Set up a spreadsheet or use the worksheet Lab 3.3.1 to help answer the questions below. Show the rat count by month over an 18 month period. Assume the pregnant rat has her first litter shortly after arriving on the island and she dies after giving birth.

Scenario: One pregnant rat arrives on an island in the Pacific hidden inside a box of produce. There are no other rat populations present, but the island is home to a stable population of 100,000 nesting seabirds. The local community has been working on a Biosecurity Plan, but it isn't finished because not all parties can agree on the details of how to deal with a rat invasion. Because detection measures are not yet in place, the rat invasion goes unnoticed for just over 18 months.
Question 1: What is your best estimate of the island rat population size at the end of 12 months? Assume that litter size is always 8, and that rats always have half males and half females. Use the information given on rat biology to help in your estimation.
Question 2: The resident seabird population is at sea most of the year, but occupies the cliffs and burrows of the island to nest during the rat invasion. Assuming each mature rat will kill two birds each week, how many total birds/eggs/chicks will the rats consume? What is the resulting seabird population size?

LESSON THREE LAB 3.3.1 RAT MATH WORKSHEET

Student Name: _____ Date: _____

Starting seabird population: 100,000
Each adult rat consumes 2 seabirds every two months.

Rat Invasion							
Months	Pregnant Rats	Offspring	Male Offspring	Female Offspring	Rat Population	Seabirds taken	Seabird Population
0	1						100,000
2	1	8	4	4	8*	2	
4						16	
6							
8							
10							
12							
14							
16							
18							
*Assume the original rat dies after giving birth.							

LAB 3.3.1 RAT MATH - TEACHER KEY

Student Name: _____ Date: _____

Rat Math							
Months	Pregnant Rats	Offspring	Male Offspring	Female Offspring	New Rat Population	Seabirds taken	Seabird Population
0	1				1	-	100,000
2	1	8	4	4	8*	2	99,998
4	4	32	16	16	40	16	99,984
6	20	160	80	80	200	80	99,920
8	100	800	400	400	1,000	400	99,600
10	500	4,000	2,000	2,000	5,000	2,000	98,000
12	2,500	20,000	10,000	10,000	25,000	10,000	90,000
14	12,500	100,000	50,000	50,000	125,000	50,000	50,000
16	62,500	500,000	250,000	250,000	625,000	250,000	0
18	312,500	2,500,000	1,250,000	1,250,000	3,125,000	1,250,000	0

*Assume the original female rat dies after giving birth.

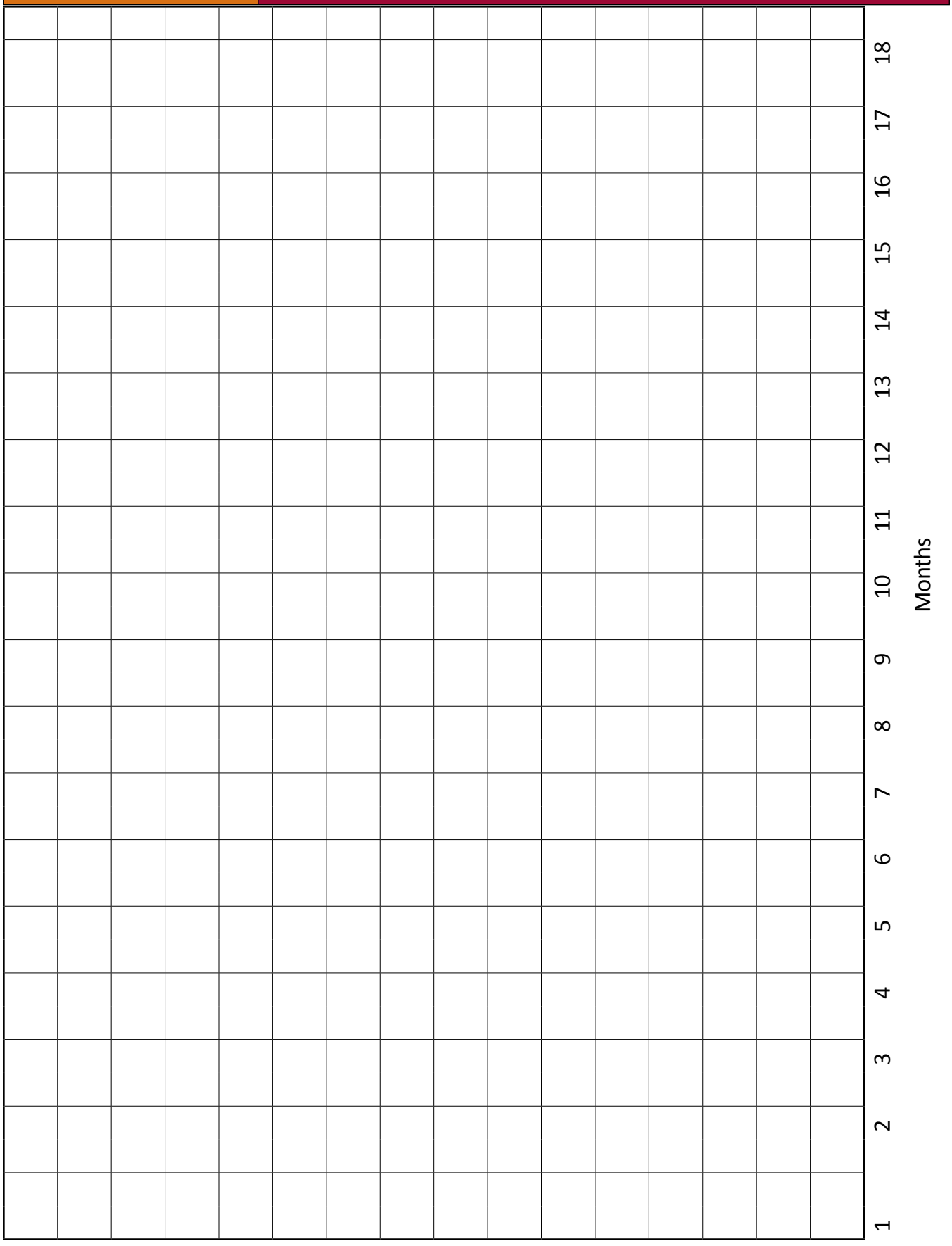
Instructions:

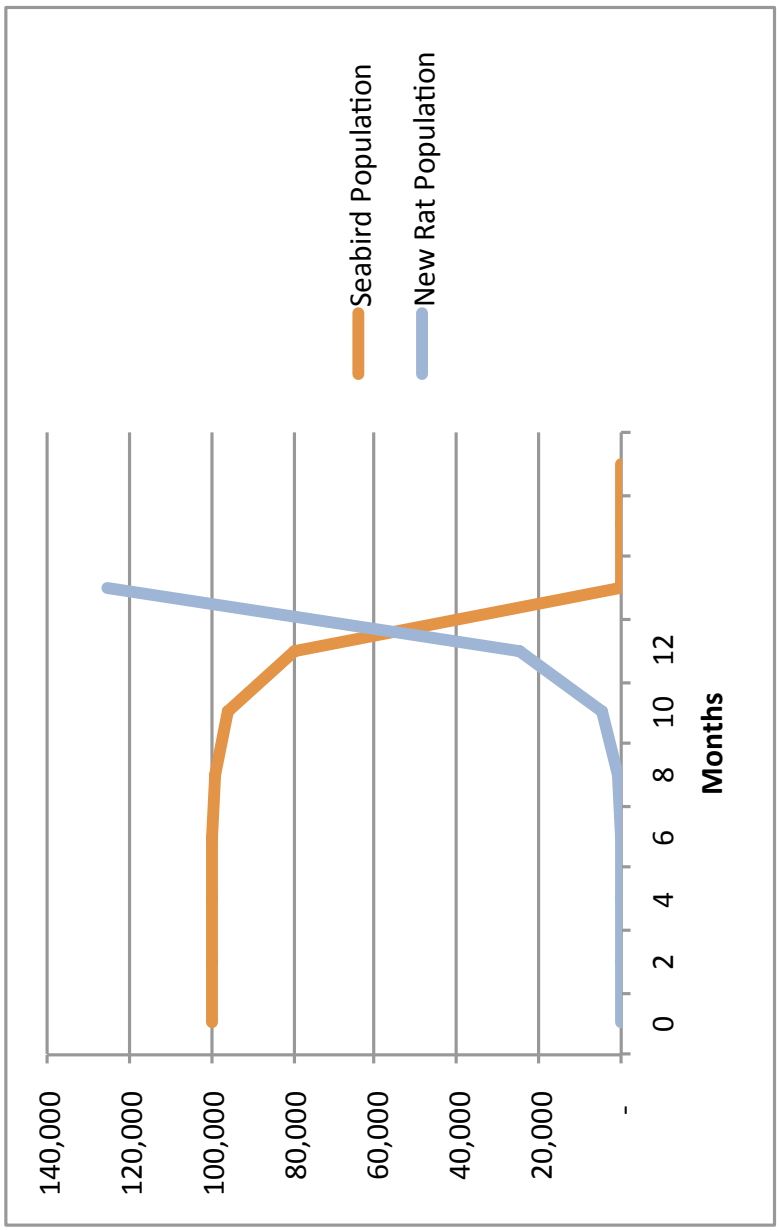
1. Start with one pregnant rat, assume she dies after raising her 8 offspring.
2. She has 8 offspring: 4 male, 4 female.
3. Rats reproduce every 2 months.
4. Each female rat has 8 babies (4 male, 4 female).
5. How many rats are on the island after one year?
6. For every adult rat 2 birds die.
7. On the island there are 100,000 seabirds.

Assumptions:

1. Every rat lives. No rats die.
2. Enough food for all the rats.
3. No new rats arrive. No rats leave.
4. No new birds arrive on the island.
5. None of the birds leave the island.

LESSON THREE LAB 3.3.2 RAT MATH GRAPHING WORKSHEET




Seabird Population
New Rat Population
140,000
120,000
100,000
80,000
60,000
40,000
20,000
-
0
2
4
6
8
10
12
Months

LESSON THREE LAB 3.4 RAT INVASION - HANDS ON ACTIVITY

PROCEDURE

Use this simple bean counting exercise to help students visualize the change in species composition that occurs with a rat invasion. In this exercise, the mixed beans represent nesting seabirds and the dark beans represent rats.

MATERIALS

- Lab 3.2 Rat Math Scenario
- Lab 3.3.1 Rat Math Worksheet
- Activity Board printed on 11 x 17 paper or drawn on butcher paper (**Optional**)
- Rats: 1 pound dried dark colored beans (e.g., black beans) or rat Gummy candy
- Seabirds: 1 pound dried mixed beans (no lentils or split peas) or jelly beans

INSTRUCTIONS

- Split students into 2 groups
- Group #1: Rats
- Group #2: Seabirds
- Gather around a table with the rats on one side and the seabirds on the other
- If you are using the Activity Board, place it on the table between the groups
- Start with one pregnant rat and all of seabirds (1 pound) in piles next to each other
- Using Lab 3.2.2 Rat Math Worksheet move down the table or Activity Board creating a new pile of rats every two months
- For every rat added to the population take away 2 seabirds until the seabird population is gone

QUESTIONS

- How long did it take the rats to eliminate all of the seabirds on the island?
  - 14-16 months
- What are the assumptions we are making about the rats and seabirds for this exercise?
  - All of the rats survive.
  - All of the females reproduce successfully.
  - No seabird chicks are born.

EXPLORE AND EXTEND

- Add seabird chicks to your population. For every two seabirds add one chick.

Rats	Seabirds
1 pregnant female	100,000
Month 2	
Month 4	
Month 6	
Month 8	
Month 10	
Month 12	

LESSON THREE LAB 3.5 ADVANCED RAT MATH WORKSHEET

PROCEDURE

Based on all of the information you have, complete the table below for the rat and seabird populations that includes gestation and maturity.

If you feel inspired, add data for the seabirds including chicks. For every 2 seabirds, one chick is produced.

Assume:

1. Gestation takes 3 weeks.
2. It takes each female rat 5 weeks to reach maturity when she can reproduce.

Rat invasion		Offspring				
Week	Adult Rat #	Immature females	Immature males	Mature females	Mature males	Life Stage
Week 0	1	0	0	1	0	
Week 1	1	4	4	1	0	birth
Week 2	1	4	4	1	0	
Week 3	1	4	4	1	0	
Week 4	1	4	4	0	0	
Week 5	1	4	4	0	0	
Week 6	8	0	0	4	4	maturity
Week 7						
Week 8						
Week 9						
Week 10						
Week 11						
Week 12						
Week 13						
Week 14						
Week 15						
Week 16						
Week 17						
Week 18						
Week 19						
Week 20						
Week 21						
Week 22						
Week 23						

LESSON THREE LAB 3.5 ADVANCED RAT MATH WORKSHEET

Rat invasion		Offspring				
Week	Adult Rat #	Immature females	Immature males	Mature females	Mature males	Life Stage
Week 24						
Week 25						
Week 26						
Week 27						
Week 28						
Week 29						
Week 30						
Week 31						
Week 32						
Week 33						
Week 34						
Week 35						
Week 36						
Week 37						
Week 38						
Week 39						
Week 40						
Week 41						
Week 42						
Week 43						
Week 44						
Week 45						
Week 46						
Week 47						
Week 48						
Week 49						
Week 50						
Week 51						
Week 52						
Week 53						
Week 54						

LESSON THREE LAB 3.5 ADVANCED RAT MATH - TEACHER KEY

Rat invasion		Offspring				
Week	Adult Rat #	Immature females	Immature males	Mature females	Mature males	"Life Stage
Week 0	1	0	0	1	0	
Week 1	1	4	4	1	0	birth
Week 2	1	4	4	1	0	
Week 3	1	4	4	1	0	
Week 4	1	4	4	0	0	
Week 5	1	4	4	0	0	
Week 6	8	0	0	4	4	maturity
Week 7	8	0	0	4	4	
Week 8	8	0	0	4	4	
Week 9	8	16	16	4	4	birth
Week 10	8	16	16	4	4	
Week 11	8	16	16	4	4	
Week 12	8	16	16	4	4	
Week 13	8	16	16	4	4	
Week 14	40	0	0	20	20	maturity
Week 15	49	0	0	20	24	
Week 16	49	0	0	25	24	
Week 17	49	80	80	25	24	birth
Week 18	49	80	80	25	24	
Week 19	49	80	80	25	24	
Week 20	49	80	80	25	24	
Week 21	49	80	80	25	24	
Week 22	209	0	0	105	104	maturity
Week 23	249	0	0	125	124	
Week 24	249	0	0	125	124	
Week 25	249	420	420	125	124	birth
Week 26	249	500	500	125	124	
Week 27	249	500	500	125	124	
Week 28	249	500	500	125	124	
Week 29	249	500	500	125	124	
Week 30	1,089	0	0	545	544	maturity
Week 31	1,249	0	0	625	624	
Week 32	1,249	0	0	625	624	
Week 33	1,249	2,180	2,180	625	624	birth
Week 34	1,249	2,500	2,500	625	624	
Week 35	1,249	2,500	2,500	625	624	
Week 36	1,249	2,500	2,500	625	624	
Week 37	1,249	2,500	2,500	625	624	
Week 38	5,609	-	-	2,805	2,804	maturity

LAB 3.5 ADVANCED RAT MATH - TEACHER KEY

Rat invasion		Offspring				
Week	Adult Rat #	Immature females	Immature males	Mature females	Mature males	"Life Stage
Week 39	6,249	-	-	2,625	3,124	
Week 40	6,249	-	-	2,625	3,124	
Week 41	6,249	11,220	11,220	2,625	3,124	birth
Week 42	6,249	10,500	10,500	2,625	3,124	
Week 43	6,249	10,500	10,500	2,625	3,124	
Week 44	6,249	10,500	10,500	2,625	3,124	
Week 45	6,249	10,500	10,500	2,625	3,124	
Week 46	28,189	-	-	13,845	14,344	maturity
Week 47	30,749	-	-	15,125	12,624	
Week 48	30,749	-	-	15,125	12,624	
Week 49	30,749	55,380	55,380	15,125	12,624	birth
Week 50	30,749	60,500	60,500	15,125	12,624	
Week 51	30,749	60,500	60,500	15,125	12,624	
Week 52	30,749	60,500	60,500	15,125	12,624	
Week 53	30,749	60,500	60,500	15,125	12,624	
Week 54 or 1 Year	138,509	-	-	70,505	68,004	maturity

LESSON FOUR ENVIRONMENTAL STEWARDSHIP/BIOSECURITY

OBJECTIVES

Students will develop a biosecurity plan for an island.

BACKGROUND

TAKING RESPONSIBILITY: WHAT IS ENVIRONMENTAL STEWARDSHIP?

Many indigenous cultures practiced environmental stewardship by caring for the region in which they lived. They harvested food and resources sustainably to ensure the survival of healthy populations of the plants and animals that they depended on. By recognizing and respecting the importance of the natural environment and the relationships amongst species (food webs), they were able to live in balance with it, as a part of the diversity of their ecosystem.

Today, environmental stewardship means protecting the natural environment and using its resources in a sustainable way. It also means practicing conservation: taking actions to ensure that native plant and animal species, and the habitats that they require, continue to survive. Environmental stewardship happens at all levels, from the creation of parks and wildlife refuges by governments, to the actions of local people, including you. Being an environmental steward in your community can be as simple as recycling, picking up garbage in a local park or around lakes and streams, properly disposing of used fishing line and fishing nets, or conserving resources (e.g., electricity and water) so that your impact on the environment is smaller.

Another form of environmental stewardship is learning about the invasive species that are threatening the native ecosystems and wildlife found in your area, including how to identify them and how to prevent their spread. For example, invasive plants should be removed when they are found but be sure to put all pieces in the garbage, not in your yard waste or compost because some invasive plants can sprout from pieces as small as half an inch. Aquatic and marine invasive species are most often spread on boats and other equipment, such as boots, waders, and fishing gear. Organizations working to prevent the spread of aquatic invasive species use campaigns such as www.dontmoveamussel.ca to teach the public to “clean, drain, and dry” their equipment every time they remove it from the water:

- CLEAN off all plants, animals, and sediment from your boat and related equipment (e.g., boots, waders, fishing gear).
- DRAIN (on dry land) any item that can hold water (e.g., buckets, wells, bilge, and ballast).
- DRY all items completely before launching the watercraft into another body of water.

Moving fish between lakes and streams must also be avoided; invasive northern pike (*Esox lucius*), which were illegally-introduced by the public into the waterways of south-central Alaska, are threatening local populations of salmon and trout. Pike are top-level predators in aquatic food chains and are highly piscivorous (fish eating). In lakes and rivers where pike are not native, trout, salmon, and other fish have not adapted defenses against the pike's predatory tactics and this invasive species is negatively impacting those populations.

PREVENTATIVE ACTIONS: BIOSECURITY

It is generally easier and less costly to prevent the introduction of an invasive species rather than attempt to remove a well-established plant or animal, although removal is possible and there have been over 1,300 whole-island invasive animal eradications completed worldwide with a success rate of 80%; more than half of these targeted rats. When there are physical barriers to colonization, as is the case with island ecosystems, preventative measures can be an effective way to keep an ecosystem free from invasive species.

In the context of invasive species, biosecurity refers to the implementation of actions to reduce the risk of invasive species introduction to a particular area (e.g., island) and how to respond to a confirmed invasive species incursion. A biosecurity plan provides the public and land managers with detailed guidelines and information that can be used to implement these actions and identifies pathways of invasion

with strategies for preventing or reducing the probability of new introductions/reinvasions.

Biosecurity is comprised of three primary components: prevention, detection, and response. These components must be implemented in concert and regularly monitored to ensure that vigilance is maintained in order to prevent, or rapidly respond, to an invasive species (re)invasion.

PREVENTION

Prevention measures include education, guidelines for visitors (e.g., checking for rats on boat before arriving at port), surveillance, and government policies and legislation. Rats are a common target of biosecurity measures on islands including the Aleutian Islands, Alaska because their introduction has significant effects on ground-nesting seabirds, as well as other native animal and plant species. Biosecurity plans are commonly implemented on islands to prevent the introduction or re-introduction of rats (if rats have been previously eradicated; see lesson 2).

Preventative measures (biosecurity) that can help to reduce the likelihood of a rat incursion to a seabird island include:

- Signage such as posters and pamphlets that are made available at all points of entry to the island or archipelago to teach visitors about the value of protecting the island, the importance of biosecurity, and how to minimize accidental introduction of rats.
- Articles and ads in popular publications, including newspapers or magazines, can help to spread information about biosecurity projects to the public, including individuals that might otherwise not see signage.
- Face-to-face information exchange is a way of fully engaging the target audience (e.g., private boat owners, commercial fishing boat operators, tour operators) through conversations with biosecurity plan representatives.
- Snap traps and bait stations armed with rodenticide (poison) on boats and planes that travel to rat-free islands can be used to reduce the risk of a rat incursion. These can also be used in buildings and other structures.
- Visitor protocols instruct visitors on ways to ensure that they do not accidentally bring rats with them to a rat-free island.
- Policies and legislation such as the regulations adopted by the Alaska Board of Game, which require mariners to check boats and gear for rats and try to eradicate them if they are found, also help to avoid accidental introductions to seabird islands in Alaska. Violators face a year in jail and a US $10,000 fine. Corporations could be fined up to US $200,000. Alaska state wildlife regulations also prohibit the feeding of rats and other “deleterious exotic wildlife”; prohibit harboring rats on boats and within facilities such as harbors, ports, and airports; and permit rats to be eradicated with rodenticides (State of Alaska, 2007).

DETECTION

Detecting invasive species is an important part of any biosecurity plan and helps to ensure that the invasive species of interest (e.g., rats) do not arrive unnoticed and have the opportunity to become established. The arrival of a single or small number of individuals of an invasive species is called an incursion.

Both passive and active detection tools can be used to confirm the presence of an invasive species such as rats. Generally a combination of tools is most effective, especially for detecting an incursion of only a few individuals. Active detection methods include snap traps, bait stations (rodenticide (poison) bait inside a locking box that is designed to allow rats to enter while preventing children, livestock, pets and other animals from accessing the bait), and live traps. Passive detection tools include remotely operated cameras, detection dogs trained to sniff out rats, wax chew blocks filled with peanut butter (rats find them irresistible and will chew on them, leaving a telltale sign of rodent presence), and tracking tunnels (rats leave foot prints on an ink-smeared white card placed inside a small plastic tunnel as they walk through to get the peanut butter baits placed at each end).

RESPONSE

Capturing a single plant or animal is easier than eradicating an established population, so rapidly

responding to a confirmed invasive species detection is critical to remove the invading individuals before they reproduce and become established. An island biosecurity plan will include a response plan that outlines specific techniques to quickly eradicate the invasive species. For example, if a rat is detected on a seabird island, the response plan will include details on how to deploy rodenticide (poison) baits, snap traps, and live traps to maximize the probability of quickly and effectively eradicating any rats that are present.

MATERIALS

- Internet
- Examples of Biosecurity Plans listed in resources

PROCEDURE

LAB 4.1 BIOSECURITY PLAN CASE STUDIES

Divide the class into groups and assign each group a biosecurity plan to review and present to the class.

LAB 4.2 DESIGN A BIOSECRITY PLAN

Based on the information presented, develop a biosecurity plan for an island community near you.

LAB 4.3 BIOSECUIRTY GAME

Create a habitat and try to protect it from an invasive species.

EXTEND AND EXPLORE

- Create your own biosecurity game.

RESOURCES

Galapagos Conservancy: Biosecurity
http://www.galapagos.org/conservation/conservation/conservationchallenges/biosecurity/

Coastal Conservation: Biosecurity Plan for Important Bird Areas of Haida Gwaii, British Columbia, Canada
http://coastalconservation.ca/projects/biosecurity-plan-for-important-bird-areas-of-haida-gwaii-british-columbia-canada/

Pribilof Islands Sensitive Area Section
https://dec.alaska.gov/spar/ppr/plans/scp_al/al_PribilofWildlifeGuidelines-Revision8(July%202014).pdf

Santa Cruz Island Restoration, California
http://www.nps.gov/chis/learn/nature/restoring-santa-cruz-island.htm

Santa Cruz Island Biosecurity Poster
http://www.esm.ucsb.edu/research/documents/santacruz_poster.pdf

Micronesia and Hawaii Biosecurity Plan (very large document)
http://www.navy.mil/submit/display.asp?story_id=86494

Palmyra Atoll Biosecurity Plan
http://pubs.usgs.gov/of/2010/1097/pdf/of20101097.pdf

Palmyra Atoll
http://www.protectpalmyra.org/

US Fish and Wildlife, Palmyra Atoll
http://www.fws.gov/refuge/palmyra_atoll/

California Trustee Councils, Seabird Colony Protection on Baja California Islands, Mexico: pp 24-36
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=8&ved=0ahUKEwjOt6-1iK3LAhUC_mMKHaPiC_cQFggMAc&url=https%3A%2F%2Fwww.doi.gov%2Frestoration%2Flibrary%2Fupload%2FPostcards-from-the-Edge-International-Restoration-Projects-from-CA-Trustee-Councils.pdf&usg=AFQjCNFwMeKGaCN7qUCCCxoL3NpiQG9k3A

Island Conservation Action in Northwest Mexico
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=6&ved=0ahUKEwiN39qW57zLAhVI7mMKHd12AMIQFghCMAU&url=http%3A%2F%2Fbio.research.ucsc.edu%2Fpeople%2Fcroll%2Fpdf%2FDonlan_2000.pdf&usg=AFQjCNEYCYkB4ohgiymQ3e-Q0n8xihFM7A&cad=rja

LESSON FOUR LAB 4.1 BIOSECURITY PLAN CASE STUDIES

INSTRUCTIONS

Learn how a Biosecurity Plan helps address invasive species and how they address the specific needs of an ecosystem and community by researching three case studies.

- Divide the class into four or more groups and assign each group one of the case studies listed on the following pages. Use the Internet to research each island and its Biosecurity Plan.
- Have each group answer the following questions and present them to the class:
  1. Describe the characteristics of the landscape. What is unique about your system?
  2. Describe the native species.
  3. What are the identified threats from invasive species?
  4. What are the different ways an invasive species could be introduced?
  5. What is the main focus of the area's Biosecurity Plan?
  6. Who is involved?
  7. How successful has the Plan been to date?
  8. What are the ongoing risks to the area?
- After all groups have presented their findings, as a class discuss:
  1. Similarities in the Biosecurity Plans for each area.
  2. Differences in the Plans among areas?
  3. What are the keys to a successful Biosecurity Plan?

BIOSECURITY PLAN FOR IMPORTANT BIRD AREAS OF HAIDA GWAII, BRITISH COLUMBIA, CANADA

Haida Gwaii, British Columbia, Canada, is an isolated marine archipelago, renowned for its rugged coastline, temperate rainforest landscape, and distinct flora and fauna that have evolved during 14,000 years of isolation from the mainland. Approximately 1.5 million seabirds from 13 species nest on more than 200 offshore islands, islets, and rocks. Given the abundance of seabirds breeding on Haida Gwaii, Birdlife International has designated 19 locations as globally important bird areas (IBAs). The IBA program is a science-based initiative that monitors and conserves the world's most important places for birds and biodiversity.

Unfortunately, the accidental introduction of Norway and black rats to several Haida Gwaii islands has resulted in a drastic decline in nesting seabird populations. In response, Parks Canada Agency and partnership organizations such as Coastal Conservation have began the process of eradicating rats from several islands within IBAs. Although rat eradication is a critical step in the process of seabird colony recovery and ecosystem restoration, the development of a detailed biosecurity plan that contains strategies to detect and prevent an incursion or (re)invasion is ultimately of greater importance to ensure long term protection of seabirds and island ecosystems.

A best management practices document for the biosecurity of important areas in Haida Gwaii was developed to provide guidelines for the creation of island-specific biosecurity plans that take into account the unique physical and environmental characteristics and the target invasive species for each island. The document includes prevention, detection, and response measures for rats, as well as invasive raccoons and deer, in order to prevent, or rapidly respond to, a (re)invasion. Of the three target invasive species, rat (re) invasions are considered a high priority and are the primary focus of the document given their significant negative impact on seabirds and ability to rapidly (re)colonize an island.

On Haida Gwaii, the most common pathway for rat (re)introductions to IBA islands is by transport aboard ocean-going vessels, including commercial and private boats or barges, specifically, vessels that anchor within a rat's swimming range to IBA islands (less than 800 m based on New Zealand studies). There is an ongoing risk of new rat introductions to IBA islands given that major Haida Gwaii port towns have healthy rat populations and some vessels from their respective harbors make regular trips to, or near IBA islands. Vessels originating from ports outside of Haida Gwaii (North America and abroad) pose an equally significant risk if the ship and/or barge anchors near an IBA island, or if a shipwreck occurs on or near the island.

LOCAL ACTION: INVASIVE SPECIES PREVENTION ON THE PRIBILOF ISLANDS, ALASKA, USA

Located approximately 200 miles north of Unalaska in the Bering Sea, the Pribilof Islands are home to large populations of breeding seabirds, including the red-legged kittiwake (*Rissa brevirostris*), which is endemic to the Bering Sea region, with 80% of the world's population nesting on St. George Island. The islands are also home to unique non-bird species such as the Pribilof Island shrew (*Sorex pribilofensis*), another endemic species found only on St. Paul Island. St. Paul and St. George islands are currently rat-free, but the presence of commercial ship harbors puts both islands at high risk for accidental rat invasions (Commercial ships may have rats on board that could come onshore while the ship is anchored in port). The local economy of the islands centers primarily on seafood processing and the associated shipping traffic is a risk factor for rat invasion. If rats became established they would severely impact populations of seabirds and shrews, and could also potentially pass diseases to marine mammals such as seals. In response to this threat a rodent invasion prevention program was initiated in 1993, and the city governments of St. Paul and St. George both passed regulations on rodent prevention, including barring infested ships from entering the harbor and requiring onshore processors to implement rat prevention programs. The U.S. Fish and Wildlife Service has also committed to retaining a rat-free status for the Pribilofs

through prevention techniques and community education.

Biosecurity measures on the Pribilofs include many of the prevention, detection, and response strategies. Additionally, community members have taken steps to reduce places for rats to hide and nest around the harbor and buildings and improve garbage control (reduced food sources for rats). The risk of rat incursions due to a shipwreck is also a concern; more than eight vessel groundings have occurred on the Pribilofs since 1987. In partnership with the communities of St. Paul and St. George, the Alaska Marine National Wildlife Reserve (AMNWR) developed a shipwreck response plan to combat the potential invasion of rats from shipwrecks. The strategy involves coordinating with the US Coast Guard to prevent potentially infested ships from running aground on or near seabird islands that are vulnerable to rat invasion, as well as defensive measures in the event that a shipwreck does occur.

BIOSECURITY ON THE GALAPAGOS ISLANDS, ECUADOR

The Galapagos Islands are an archipelago of 19 islands and scores of islets and rocks, situated over 23,000 square miles of ocean, approximately 600 miles west of the mainland of Ecuador in South America. This region has been described as one of the most unique, diverse, and scientifically important places on earth. Approximately 97% of the total emerged (above water) land surface was designated a national park in 1959 and the islands are surrounded by the Galapagos Marine Reserve, which was created in 1986. The human population of the Galapagos is approximately 30,000 and is restricted to only 4 islands, the remaining 3% of the land mass. Approximately 170,000 tourists visit the islands each year, increasing the risk of invasive species introductions.

Since the discovery of Galapagos in 1535, humans have introduced many species to the islands, both intentionally (e.g., goats, pigs, cats, and ornamental and food plants) and accidentally (e.g., rodents, insects, plants). “Invasive species pose the greatest threat to nature in the Galapagos” (Directorate of the Galapagos National Park, 2012), leading authorities to institute biosecurity measures in an attempt to protect the islands from further introductions.

The Galapagos biosecurity program includes three key components: an inspection and quarantine program; control and eradication of invasive species—both new arrivals and established species; and outreach work to create community awareness, support, and participation. All boats and airplanes arriving on the islands are inspected for foreign food and animals, and divers inspect boat hulls to check for invasive marine species. Vessels failing to pass these inspections are required to leave the Galapagos Marine Reserve.

Community involvement is essential to the prevention and control of invasions and an awareness campaign has also been implemented to help connect the local people and management organizations such as the Directorate of the Galapagos National Park. Local teachers are trained to teach their students about invasive species, and many school children participate in invasive species projects, such as invertebrate monitoring.

In addition to these biosecurity actions, the Directorate of the Galapagos National Park, the Charles Darwin Foundation, and organizations such as Island Conservation are working together to eradicate invasive species that are already established on the islands. For example, in 2006, Project Isabella was completed, with the successful eradication of feral goats and donkeys from northern Isabela Island; goats, donkeys, and pigs from Santiago Island, and goats from Pinta Island. Additional successes include the eradication of black rats from Pinzon Island, fire ants— little fire ant (*Wasmannia auropunctata*), the tropical fire ant (*Solenopsis geminata*), the Singapore ant (*Monomorim destructor*), and the big-headed ant (*Pheidole megacephala*)—from Marchena Island, rock pigeons (*Columba livia*) from Galapagos Island, feral cats from Baltra Island, and one species of blackberry from much of Santa Cruz Island.

BIOSECURITY ON SANTA CRUZ ISLAND, CALIFORNIA

The Channel Islands National Park off the southern coast of California is comprised of five islands. At over 96 miles, Santa Cruz Island is the largest of California's offshore islands. The National Park Service owns and manages 24% of the park, while The Nature Conservancy owns and manages the remaining 76%. Both organizations work closely together to maintain the biodiversity and biosecurity of the island.

Santa Cruz Island is home to 60 species and subspecies endemic to the Channel Islands. Only four native species of mammals reside on all of the Channel Islands: island fox (*Urocyon littoralis*), island deer mouse (*Peromyscus maniculatus*), harvest mouse (*Reithrodontomys megalotis*), and spotted skunk (*Spilogale gracilis amphiala*). The island fox and island deer mouse have evolved into separate sub-species on each island. Four lizards (*Xantusia riversiana*, *Sceloporus occidentalis becki*, *Elgaria m.multicarinata*, *Uta Stansburinia*) one salamander (*Batrachoseps pacificus*), one frog (*Pseudacris H. Hypochondriaca*), and two non-venomous snakes (*Pituophis catenifer pumilis*, *Coluber constrictor mormon*) are also found on the islands. Santa Cruz Island is home to eleven species of bats including a colony of Townsend's big-eared bats (*Corynorhinus townsendii*). Four species of pinnipeds breed on the Channels Islands: northern elephant seals (*Mirounga angustirostris*), California sea lions (*Zalophus californianus*), harbor seals (*Phoca vitulina*), and northern fur seals (*Callorhinus ursinus*).

Over 300,000 people per year visit the island by private passenger ferries. Private vessels and aircraft are allowed to visit the island through a permitting process.

Today, biosecurity on Santa Cruz island is focused on three species and a group of diseases identified to pose the greatest risk to island biodiversity: rats (*Rattus* spp.), Cape ivy (*Delairea odorata*), New Zealand mudsnail (*Potomopyrgus antiposarum*), and canine-vectored diseases.

Working together, the National Park Service and The Nature Conservancy have identified potential activities that pose the highest risk for introduction of these nonnative species and developed protocols for prevention and detection.

Education and outreach is a crucial component of Santa Cruz Island's biosecurity. Boaters are educated on preventing rats from swimming to shore from vessels and visitors are provided information on the restrictions of companion animals. Signage reminds visitors of the importance of keeping the islands free of invasive species.

In addition to the biosecurity plan, the National Park Service and The Nature Conservancy have been working on eradication current invasive species. Non-native feral pigs (*Sus scrofa*) and non-native fennel (*Foeniculum vulgare*, invasive weed) were identified as two of the most destructive invasive species. Pig rooting caused massive damage to native vegetation and archeological sites while piglets provided year-round prey for golden eagles allowing the birds to establish resident populations on Santa Cruz Island. The native fox also fell prey to the golden eagles causing the fox population to decline dramatically.

In 2005 the National Park Service began a pig eradication program which was completed in 2007.

BIOSECURITY ON THE CORONADO ISLANDS, MEXICO

The Coronado Islands (Islas Coronado or Islas Coronados) are a group of four islands (North Coronado, Pilón de Azúcar, Central Coronado, and South Coronado) eight miles off the northwest coast of the Baja, Mexico.

During the 1920's the islands were home to a casino and a lucrative trade in illegal alcohol during prohibition. Currently, South Coronado Island is home to two lighthouses staffed by the Mexican Coast Guard.

These are small and rocky islands, home to ten species of reptiles, California sea lions, elephant seals, and harbor seals, as well as several species of sea bird. The islands are also home to the largest known colony of the Xantus's Murrelet also known as Guadalupe Murrelet (*Synthliboramphus hypoleucus*) which is listed as

Endangered on the IUCN Red List of Threatened Species. The islands are generally not inhabited, but there is a small Mexican Coast Guard station and a small lighthouse on the largest of the four islands. The islands are regularly visited by tourist cruises from San Diego, pleasure boaters, Mexican commercial fishermen looking for abalone and sea urchins, and sport fishing charters looking for yellowtail. The Island at one point had rabbits, mice, and most damaging feral cats as introduced species. The cats had devastated the Xantus's Murrelet. Through a joint effort between the US Fish and Wildlife and the Mexican Government these introduced species have been removed.

Biosecurity actions involve boater education, habitat restoration, disturbance reduction, and monitoring. A bi-national partnership between Audubon, Conservacion de Islas, Friends of the Mexican Fund for the Conservation of Nature, and The Cornell Lab of Ornithology provides the structure and support needed for ongoing biosecurity.

BIOSECURITY ON PALMYRA ATOLL, HAWAII

Palmyra Atoll consists of many islets, most not exceeding 2 meters in height, 1,600 km southwest of Hawaii. The atoll was privately owned from 1911 until 2000 when The Nature Conservancy purchased emergent lands. From 1940-45 the U. S. Military used the island. During this time the island and lagoons were modified dramatically. The military installed an airstrip, housing, hospital, bunkers, and pillboxes that were all abandoned or destroyed at the end of World War II. In 2001 it was established as a National Wildlife Refuge. Palmyra Atoll is one of the few atolls without a long settlement history or fishing history.

Invasive species on the islets are black rat (*R. rattus*) and coconut palm (*Cocos nucifera*). A native species of coral, corallimorph (*Rhodactis howsei*), is also considered to be invasive due to the fact that it takes advantage of human-altered habitat and out competes other native species.

Native species being affected by black rats and coconut palms are *Pisonia grandis* a forest member of the Bougainvillea family and the Red-footed Booby (*Sula sula*).

In 2010 the U. S. Geological Survey prepared a Palmyra Atoll biosecurity plan for The Nature Conservancy.

Potential pathways of introduction were identified as clothing, shoes, marine vessels, aircraft, and food.

Prevention techniques involve freezing clothing for 48 hours before arriving and before travelling between islets and quarantining vessels, aircraft, food, and freight.

Early detection is key to preventing a species from becoming established. Detection methods include collecting baseline data on native and non-native species and monitoring populations. High-risk sites of introduction are areas with regular human activities.

Eradication has already been attempted on Palmyra Atoll. From 2011-2012 the U.S. Fish and Wildlife Service and The Nature Conservancy made a second and successful attempt to eradicate the population of rats introduced during World War II.

Case Study #1: Haida Gwaii

1. Describe the characteristics of the landscape. What is unique about your system?
    - Archipelago, rugged coastline, temperature rainforest
2. Describe the native species.
    - Distinct plants and animals, 1.5 million nesting seabirds, 13 different species of seabirds
3. What are the identified threats from invasive species?
    - Biggest threat is accidental introduction of Norway and Black rats that has led to a decline in nesting seabird populations. Eradication of rats is underway.
4. What is the main focus of the area's Biosecurity Plan?
    - Unique plans for each island. Prevention, detection, and response for rats, raccoons, and deer. Main focus is rats.
5. Who is involved?
    - Birdlife International, Canada Parks department, partner organizations, and community.
6. How successful has the Plan been to date?
    - Plan is new.
7. What are the ongoing risks to the area?
    - Boat traffic is the biggest threat since boats can carry rats from ports with healthy rat populations to islands with no rats.

Case Study #2: Pribilof Islands

1. Describe the characteristics of the landscape. What is unique about your system?
    - Two remote islands in the Bering Sea home to both native seabird populations and non-seabird species.
2. Describe the native species.
    - Large populations of breeding seabirds including the red-legged kittiwake which is endemic to the Bering Sea. Also home to a unique native species: the Pribilof Island shrew.
3. What are the identified threats from invasive species?
    - Rats are the primary threat. Rats could negatively impact seabird populations and also pass diseases to marine mammal populations that haul out on the islands.
4. What is the main focus of the area's Biosecurity Plan?
    - There is a large amount of commercial boat traffic which poses a constant threat of rat invasion. The Plan includes laws for vessels, education, and prevention programs for visitors and community members, partnerships to deal with shipwrecks, and community programs to reduce cover opportunities for rats and control garbage.
5. Who is involved?
    - City governments, U.S. Fish and Wildlife, U.S. Coast Guard, communities
6. How successful has the Plan been to date?
    - The plan was initiated in 1993 and the islands remain rat free.
7. What are the ongoing risks to the area?
    - Boat traffic is the largest ongoing risk. It is necessary for commerce so it is not possible to eliminate the threat.

Case Study #3: Galapagos Islands

1. Describe the characteristics of the landscape. What is unique about your system?
    - Archipelago of 19 islands. One of the most unique and diverse places on the planet. 97% is designated as a national park.
2. Describe the native species.
    - Many species are unique to the Galapagos, for example: reptiles such as the Giant tortoise and lava lizard, birds such as the Galapagos penguin and waved albatross, and mammals such as the Galapagos sea lions.
3. What are the identified threats from invasive species?
    - Many invasive species have been introduced since humans discovered the islands in the 1500s. These include goats, pigs, cats, rodents, insects, and plants.
4. What is the main focus of the area's Biosecurity Plan?
    - There are a number of plans in place. The current Plan focuses on protection from further introduction of invasive species. There are also plans taking place focused on the eradication of established invasive species.
5. Who is involved?
    - Directorate of Galapagos National Park, Charles Darwin Foundation, Island Conservation, community, school teachers, and students.
6. How successful has the Plan been to date?
    - Eradication has been successful on various islands for: rats, several ant species, goats, donkeys, pigs, cats, rock pigeons, and blackberry. The community and others actively participate to implement programs.
7. What are the ongoing risks to the area?
    - Tourists, boat, and airplane traffic.

Case Study #4: Santa Cruz Island, California

1. Describe the characteristics of the landscape. What is unique about the ecosystem?
    - Rugged coastal island
2. Describe the native species.
    - 60 endemic species
3. What are the identified threats from invasive species?
    - Rats, dogs, plants
4. What is the main focus of the area's Biosecurity Plan?
    - Educating tourists and informing boaters.
5. Who is involved?
    - National Park Service, The Nature Conservancy
6. How successful has the plan been to date?
    - Plan is new.
7. What are the ongoing risks to the area?
    - Boat traffic and tourists.

Case Study #5: Coronado Islands, Mexico

1. Describe the characteristics of the landscape. What is unique about the ecosystem?
    - Four islands of the coast of Baja Mexico. Formerly occupied by a casino and illegal alcohol traders.
2. Describe the native species.

- Seabirds: Ashy Storm-Petrel (*Oceanodroma homocroa*), Black Storm-Petrel (*Oceanodroma melania*), Brown Pelican (*Pelecanus occidentalis*) , Brandts Cormorant (*Phalacrocorax pencillatus*), Double-crested Cormorant (*Phalacrocorax auritus*), Western Gull (*Larus occidentalis*), Xantus murrelet (*Synthliboramphus hypoleucus*)
- Extirpated Seabirds: Leach's Stormpetrel (*Oceanodroma leucorrhoa*) Cassin's Auklet (*Ptychoramphus aleuticus*), Xantus' Murrelets (*Synthliboramphus hypoleucus*), and Black Storm Petrels (*O. melania*)
- Coronado rattlesnake (*Crotalus oreganus caliginis*)
- Los Coronados Song Sparrow (*Melospiza melodia coronatorum*), Los Coronados House Finch (*Carpodacus mexicanus clementis)*
- Los Coronados whiptail lizard (*Cnemidophorus tigris vividus*), Los Coronados alligator lizard (*Elgaria multicarinata nana*)
- Los Coronados white-footed mouse (*Peromyscus maniculatus assimilis*)

3. What are the identified threats from invasive species?
   - Rats and formerly feral cats are eating seabirds.
4. What is the main focus of the area's Biosecurity Plan?
   - Educating boaters and tourists.
5. Who is involved?
   - Audubon, Conservacion de Islas, Friends of the Mexican Fund for the Conservation of Nature, and The Cornell Lab of Ornithology
6. How successful has the Plan been to date?
   - Successful
7. What are the ongoing risks to the area?
   - Boaters, tourists

Case Study #6: Palmyra Atoll, Hawaii

1. Describe the characteristics of the landscape. What is unique about the ecosystem??
   - Flat atoll, consists of several islets
2. Describe the native species.
   - Coconut crab (Birgus latro)
   - Seabirds: Red-footed Booby (*Sula sula*), Brown booby (*Sula leucogaster*), Masked Booby (*Sula dactylatra*), Sooty Tern (*Onychoprion fuscata*), Black Noddy (*Anous minutus*), Brown Noddy (*Anous stolidus*) and Great Frigatebird (*Fregata minor*)
   - Migratory birds: Pacific Golden Plovers (*Pluvialis fulva*), the Bristle-thighed Curlew (*Numenius tahitiensis*), Ruddy Turnstones (*Arenaria interpres*), and Wandering Tattlers (*Heteorscelus incanus*)
   - *Pisonia grandis*
3. What are the identified threats from invasive species?
   - Boaters, researchers
4. What is the main focus of the area's Biosecurity Plan?
   - Preventing introduction of invasives from boats, food, and airplanes.
5. Who is involved?
   - The Nature Conservancy, U. S. Fish and Wildlife Service
6. How successful has the Plan been to date?
   - Successful
7. What are the ongoing risks to the area?
   - Boats, airplanes, researchers

Comparisons

1. Similarities in the Biosecurity Plans
    - Government, community, and special interest groups are all involved.
    - Plans have three main components: prevention, detection, response.
    - All areas are islands and boat traffic is a constant threat.
2. Differences in the Plans among areas?
    - Plans are unique to the landscape and native species involved.
    - Plans may have slightly different focuses such as keeping invasive species out or dealing with further incursions.
3. What are the keys to a successful Biosecurity Plan?
    - Community involvement is imperative.
    - Diligence in monitoring and enforcing the rules to prevent/control incursions.

LESSON FOUR LAB 4.2 DESIGN A BIOSECURITY PLAN

INSTRUCTIONS

Design a biosecurity plan for your island or an island near you. Illustrate how you would prevent rats or another invasive species from entering the island. Make sure to include a map of the protected area and potential points of entry.

Include all areas of potential introduction.

Areas of introduction:

- Harbor
  - Cargo/shipping containers
  - Luggage
  - Dock lines
  - Fishing gear
- Airport
  - Cargo
  - Luggage
- Shipwreck off shore
  - Floating debris
  - Swimming
- Grocery Store
  - Food containers

Describe methods of detection and prevention.

How would the community be involved?

DISCUSSION

How successful was your biosecurity plan?

What would you do differently next time?

Was it hard to develop a good plan without infringing on people's rights to privacy?

- Did you search luggage or backpacks?
- Were you able to interview people entering the area to find out if they were carrying invasive species?
- What was the most time consuming part of the project?
- What was the hardest?

LESSON FOUR LAB 4.2 DESIGN A BIOSECURITY PLAN

Student Name: _____ Date: _____

Island Name: _____

Invasive species	Protected species
Global Conservation Status	
Pathways of Entry	
Prevention Methods	
Detection Methods	
Community Involvement	

LESSON FOUR LAB 4.3 BIOSECURITY GAME

MATERIALS

- Lab 4.2 Biosecurity Plan
- School/classroom to represent an island
- 50 images or objects representing the rats (invasive species)
- 120 images or objects representing seabirds, chicks, and eggs (protected species)
- 20-30 images of traps or methods of detecting and catching rats

SET-UP

RAT TEAM

Assign 1/3 of the class or members of the school/community to act as rats. Distribute the rat images provided (or create your own). It is the job of the Rat Team to enter the bio-secure area and find the protected species habitat. Students may hide the rats in a back pack or bag to get it in the building but once in the building the invasive species must be out in the open. If you are specifically asked by the Biosecurity Team if you are haboring a rat, you must give it up and start over. If your invasive species is out in the open and you encounter a rat trap or are approached by a member of the Biosecurity Team you must give up your rat and start over.

SEABIRD TEAM

Assign 1/3 of the class or members of the school/community to act as protectors of the seabirds. Distribute the puffin images provided or create your own. It is the Seabird Team's job to figure out where the seabirds will reside on the "island". Select different areas to represent nesting colonies and breeding habitat. This information should not be shared with the Invasive Species. The invasive species will have to find them.

BIOSECURITY TEAM

Assign 1/3 of the class or members of the school/community to act as the Biosecurity Team. Distribute the images of rats or something similar to indicate the entry point or area is off limits to invasive species. Using the Biosecurity Plan created in Lab 4.2, go around your "island" (school or classroom) and post signs at entry points or any place you think an invasive species might enter. Think of ways an invasive might enter your "island" (e.g., inside a bag or box, in luggage, ventilation system). You may approach people and ask them if they are harboring a rat.

INSTRUCTIONS

1. Send the Invasive Species Team out of the area to plan their invasion before the Seabird team and Biosecurity Team start setting up.
2. Give each team time to set up and stratigize.
3. Biosecurity Team and Seabird Team: Set up the nesting areas. Use one of the Biosecurity Security Plans developed in class to protect your island's seabirds.
4. Assign one person to keep tally of the rats and seabirds.
5. Start the game.
6. 1 seabird is added to the population for every rat that is detected.
7. 2 seabirds die for every rat that enters the nesting or breeding area.
8. 5 rats are added for every rat that encounters a seabird. This rat found food and reproduced.
9. Once a rat finds a seabird and reproduces it stops searching for food.

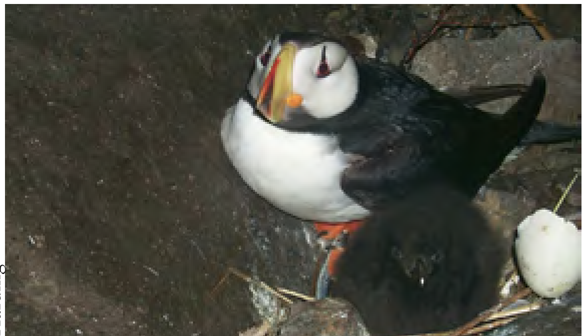
BE CREATIVE - HAVE FUN!!

LAB 4.3 BIOSECURITY GAME

Instructions: Record your progress at the end of each day. How many invasive species managed to get past the biosecurity team?

Day	Rats Detected	Rats Not Detected	Seabirds (alive)	Prevention/Elimination Methods
Start	0	0	100	
1				
2				
3				
4				
5				
Total				
Suggestions for improving the Biosecurity Plan.				

LESSON FOUR | LAB 4.2 BIOSECURITY GAME



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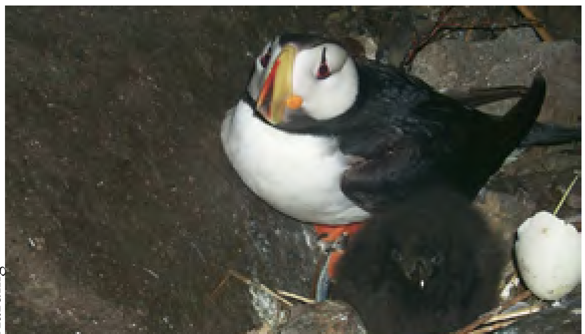
Horned Puffin (*Fratercula corniculata*)

©Ann Harding

Horned Puffin (*Fratercula corniculata*)



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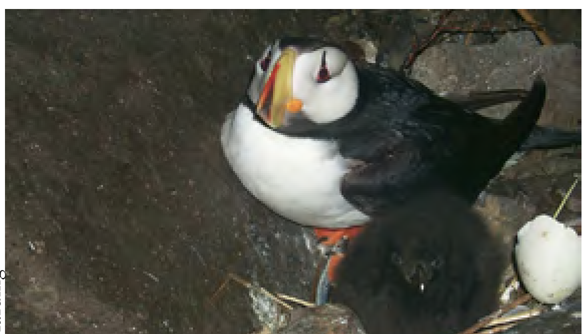
Horned Puffin (*Fratercula corniculata*)



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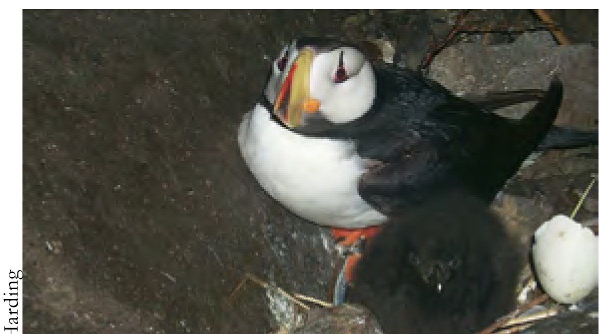
Horned Puffin (*Fratercula corniculata*)



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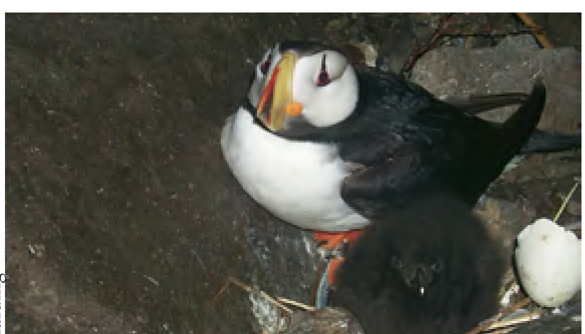
Horned Puffin (*Fratercula corniculata*)



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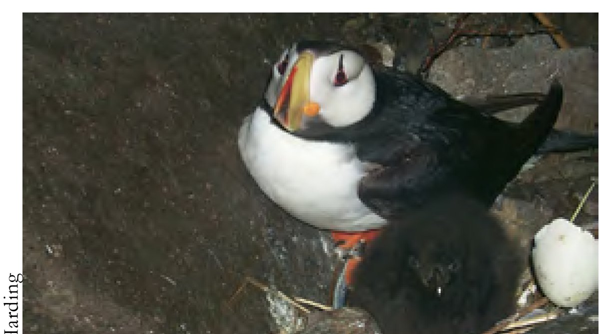
Horned Puffin (*Fratercula corniculata*)



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Horned Puffin (*Fratercula corniculata*)

©Ram Papish

Least Auklet (*Aethia pusilla*)

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Least Auklet (*Aethia pusilla*)

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Least Auklet (*Aethia pusilla*)

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Least Auklet (*Aethia pusilla*)

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Least Auklet (*Aethia pusilla*)

LESSON FOUR LAB 4.2 BIOSECURITY GAME

LESSON FIVE CASE STUDIES: ERADICATION

OBJECTIVES

Students will learn about the eradication of Invasive Species including the process, measures of success and unintended consequences. Case studies include the problem, solution, challenges, and outcome in four distinct island ecosystems.

- Haida Gwaii (British Columbia) rat removal
- Guadalupe Island (Mexico) goat removal
- Isle of Scilly (Great Britain) rat eradication
- Juan Fernández Islands (Chile) invasive species removal

BACKGROUND

When considering invasive species, biosecurity refers to the implementation of actions to reduce the risk of invasive species introduction to a particular area (e.g., island) and also respond if there is an invasive species incursion. A biosecurity plan provides the public and land managers with detailed guidelines and information on how to address an invasive species incursion. The plan includes actions that can be taken to identify pathways of invasion, along with strategies for preventing or reducing the probability of new introductions/reinvasions. Biosecurity is comprised of three primary components: prevention, detection, and response. These components must be implemented in concert and regularly monitored. For the plan to work, vigilance must be maintained in order to prevent, or rapidly respond, to an invasive species (re)invasion.

ERADICATING INVASIVES

If an invasive species has become established, the best course of action is the rapid removal of all individuals of the target species. Eradication is the complete and permanent removal of an invasive plant or animal species from the target region such as an island. The goal of an invasive species eradication is to encourage the natural restoration of native wildlife and ecosystems that have been negatively impacted by that invasive species. An eradication is not the same as permanent control (reducing the population) or containment (preventing the spread) of an invasive species.

Invasive species eradications for the purpose of wildlife and habitat conservation have become an important management tool, particularly for island restoration projects targeting invasive vertebrate species. To date, the majority of eradication projects undertaken worldwide have targeted invasive terrestrial (land) mammal species, for example rats, mice, rabbits, domestic goats, feral pigs, and domestic cats. To date, more than 1300 whole-island invasive animal eradications have been carried out worldwide with a success rate of 80%; more than half of these have targeted rats. It is much more difficult to eradicate or even control invasive aquatic species, including vertebrates such as Asian carp (of which there are several different species) and invertebrates such as zebra mussels (*Dreissena polymorpha*); invasive aquatic plants [e.g., water hyacinth (*Eichhornia crassipes*)]; and terrestrial plants [e.g., orange hawkweed (*Pilosella aurantiaca*)] because these organisms spread easily (e.g. on wind or ocean currents) and have high reproductive rates (i.e., they produce a large number of seeds, larvae, or young).

Every invasive species eradication operation is different. However, there are three fundamental principles that maximize the chances of success, i.e. of removing 100% of the target population:

1. Every individual of the target species must be at risk of the eradication technique;
2. The target species must be eradicated faster than they can breed/replace themselves;
3. Immigration must be maintained at zero, or be manageable (i.e., land managers must be able to rapidly respond to and eliminate potential invaders).

Eradication projects have significant risk factors which must be taken into account during the planning process. These projects are only feasible when all breeding individuals of a population can be removed and the risk of immediate or rapid reinvasion of the area is either zero or low enough that managers can quickly respond to new incursions. The biology of the target species must be well understood, including how they reproduce and how often, where they live and what they eat, and potential ability to spread.

LESSON FIVE CASE STUDIES: ERADICATION

The eradication method(s) used must be effective when the population is large or small to ensure that all individuals are detected and removed.

In addition to how effective the eradication method is on the target species, care must be taken to ensure that potential impacts to non-target species (e.g. native species) are minimized. These impacts may be direct, such as poisoning of non-target species if they ingest rodenticide (poison) used to eradicate mice or rats. Impacts can also be indirect when poisoned invasive species are consumed by scavenger species (e.g., Common Raven, Bald Eagle) and become poisoned themselves. All possible impacts to non-target species must be considered when choosing an eradication method.

Measures can be taken to help minimize potential impacts on non-target species. However, the need to reduce impacts must be balanced with the probability of eradication success. Successful eradication campaigns can have significant long-term and long-lasting benefits to island ecosystems and communities. Therefore, short-term impacts of an eradication process to non-target species on an individual animal basis (i.e., not impacting a species at a population level) are generally acceptable In the case of rat eradications, the presence of native rodents on the target island will determine how a rodenticide can be applied and what potential mitigative measures can be used to minimize impacts to the native rodents. Measuring the outcome of an eradication operation, including whether it was a success or failure, any negative effects on non-target species, and the response of the ecosystem to the removal of the target invasive species, is an important aspect of conservation projects. A conservation measures program is used to monitor, measure, and map certain native plants and animals before and after invasive vertebrate removal to help scientists understand the outcome of the conservation action, including how it affected native species. Quantitative assessments provide data to measure the effectiveness of the eradication and are also important to inform other planned island restoration techniques that might be used in combination with the eradication, such as invasive weed management or the need to re-introduce a species to the project island (e.g., repopulating an ecosystem with a previously extirpated species). Collecting data before and after each eradication project also contributes to our global understanding of how invasive vertebrate eradications can be improved upon (e.g., what techniques work or don't work) and help us better understand how and why native species may be negatively impacted by eradication operations.

The recovery of native island species following an eradication of invasive species can sometimes occur rapidly, but may also take many years to be fully realized. To monitor recovery, biologists use short-term conservation measures (1-5 years post invasive species removal) that are indicative of longer term change. Innovative techniques such as automated recording units (ARUs) are used to record bird vocalizations that can be used to identify the species present on an island and identify changes in bird calling activity over time (this can help to determine if the population size of a particular species is changing). Other proven techniques, such as studying the number and extent of plant species, breeding success of seabirds, and encounter rates of reptiles are also used to measure ecosystem change over time.

MATERIALS

Case studies, see below.

PROCEDURE

Divide the class into four groups. Ask each group to give a presentation on one of the case studies. Encourage the students to use PowerPoint, Prezi, or create a poster to present their information.

DISCUSSION

What were the different techniques used to eradicate the invasive species?

Were there any unintended consequences?

How was the community involved?

How do these communities plan to continue monitoring the ecosystem to avoid re-invasion?

RESOURCES

Case Study 1: Haida Gwaii, British Columbia, Canada
http://coastalconservation.ca/projects/night-birds-returning-haida-gwaii-british-columbia/

Case Study 2: Guadalupe Island, Mexico
https://mbgecologicalrestoration.wordpress.com/2015/03/11/guadalupe-island-baja-california-invasive-mammal-eradication-and-perspectives-for-ecological-restoration/

Case Study 3: Isles of Scilly Seabird Recovery Project, Great Britain
http://ios-seabirds.org.uk/

Case Study 4: Juan Fernández Islands Invasive Species, Chile
http://oikonos.org/juan-fernandez-islands-conservancy/

Rat Island, Predators in Paradise and the World's Greatest Wildlife Rescue. 2011. William Stolzenburg. ISBN: 978-1608191031

LESSON FIVE LAB CASE STUDY #1: HAIDA GWAII

SGin Xaana Sdiihltl'lxa: Night Birds Returning - Rat removal on Haida Gwaii, British Columbia

Haida Gwaii, British Columbia, Canada, is an isolated marine archipelago, renowned for its rugged coastline, temperate rainforest landscape, and distinct flora and fauna that have evolved during 14,000 years of isolation from the mainland. Approximately 1.5 million seabirds from 13 species nest on more than 200 offshore islands, islets, and rocks. Given the abundance of seabirds breeding on Haida Gwaii, Birdlife International (www.birdlife.org) has designated 19 locations as globally important bird areas (IBAs). The IBA program is a science-based initiative that monitors and conserves the world's most important places for birds and biodiversity.

THE PROBLEM:

The accidental introduction of Norway and black rats to several Haida Gwaii islands has resulted in a drastic decline in nesting seabird populations, including that of the Ancient Murrelet (*Synthliboramphus antiques*). Rats have significant negative impacts on seabirds, consuming eggs, chicks, and adults and causing seabird population declines, with the most severe impacts on highly vulnerable burrow-nesting seabirds. Ecologically, impacts to colonial nesting seabirds are also of great concern due to the potential for population-level impacts, which may lead to extirpation or even extinction of a particular species.

In addition to direct predation of seabirds, rats also prey on a wide variety of intertidal invertebrates normally found in the mid to very low intertidal zone, affecting the abundance and the age structure of these species. Rats also feed on plants, eating seeds and seedlings and altering the structure of the plant communities within the island ecosystem, which in turn can have an indirect negative effect on the nesting habitat quality for other bird species such as songbirds.

THE SOLUTION:

The goal of the Night Birds Returning project is to restore seabird habitat and associated ecosystem processes on several remote islands within Gwaii Haanas National Park Reserve, National Marine Conservation Area Reserve, and Haida Heritage Site (Haida Gwaii, British Columbia) through the removal of invasive rats from affected islands.

The project was undertaken in two phases. Phase One was completed in 2011 and involved the removal of Norway rats (*Rattus norvegicus*) from Arichika and the Bischof islands using specialized locking bait stations containing rodenticide bait, arranged on a 50 x 50 metre grid across the islands to ensure a lethal quantity of bait was present in every potential rat territory on the islands. During the eradication operation the bait stations were regularly monitored and rodenticide bait replenished until preliminary eradication success was confirmed when bait was no longer being removed from the stations. The success of the project was officially assessed two years after the eradication operation. This time frame gives any remaining rats enough time to reproduce and repopulate the island to densities that can be easily detected; the longer you wait the easier it becomes to detect rats if they remain.

Phase Two, which was completed in 2013, focused on the eradication of black rats (*Rattus rattus*) from Murchison and Faraday islands, two islands within the Ramsay and Juan Perez Sound Islands IBA. International eradication experts from New Zealand, Mexico, and the United States were involved in the planning and implementation of the eradication operation to maximize the probability of successfully removing the rats while minimizing impacts to native species during the eradication operation.

The size and complex terrain of these islands (e.g., cliffs, steep slopes, and jagged coastlines) required the use of an aerial application of rodenticide bait pellets rather than a bait station approach, which is more suited to smaller islands that lack challenging topography. Aerial broadcast of rodenticide bait pellets has become the most common method of rodent eradication on large islands internationally and has been used in the majority of successful rodent eradications worldwide.

The rodenticide bait pellets were spread over Murchison and Faraday islands by a helicopter using a bait-dispersing hopper. Care was taken to ensure that the bait was evenly distributed to all areas of each island at a pre-determined application rate, ensuring that all rat territories received bait and all rats had access to a lethal amount of rodenticide bait. Two applications of bait, three weeks apart, ensured that the bait was present long enough for every rat to encounter it including any young rats that were still in the nest during the first application.

During and after the eradication operation, both islands were intensively searched for rat carcasses as well as non-target carcasses (native species), which were collected and removed from the islands to reduce the risk of secondary and tertiary poisoning of non-target species such as Bald Eagles (*Haliaeetus leucocephalus*) and Common Ravens (*Corvus corax*).

CHALLENGES:

Rat neophobia: rats will often avoid novel objects in their territory, a behavior that is referred to as neophobia. During Phase 1, the plastic bait stations on certain project islands caused rat neophobia. Several methods were used to overcome this, including placing bait near the entrance of the bait stations and/or adding sardine oil to the bait blocks to make them more attractive to the rats. Both methods eventually helped the rats to overcome their neophobia to the bait stations.

Bait competition:
During Phase 2, the presence of non-native Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) on Murchison and Faraday islands presented two issues: (1) bait competition with black rats (deer were attracted to and consumed the bait), which could impact eradication success through reduced bait availability for rats; and (2) potential for primary poisoning of deer through the consumption of the rodenticide bait. Primary poisoning of deer also increased the risk of secondary poisoning to scavenging native species such as Bald Eagles, Common Ravens, Northwestern Crows (*Corvus caurinus*), black bears, and gulls (e.g., California Gull [*Larus californicus*] and Glaucous-winged Gull [*Larus glaucescens*]).

To address this bait competition, most of the deer were removed (culled) from the project islands before the eradication operation was undertaken. This greatly reduced bait competition and therefore maximized the probability of successfully eradicating rats.

Bait interception by the forest canopy:
During Phase 2, the high forest canopy closure (the presence of large trees) on Murchison and Faraday islands was predicted to intercept a portion of the aerially broadcasted rodenticide bait. Bait interception by the forest canopy would reduce the bait application rate on the ground. Lower bait application rates might mean that not all rats would have access to a lethal amount of the rodenticide bait; allowing some rats to survive the eradication operation would lead to eradication failure. The bait application rates were consequentially increased to compensate for the amount of bait that was predicted to be intercepted by the forest canopy.

Minimizing impacts to non-target species:
The use of rodenticide bait to eradicate rats from a target island also places some individuals of native birds and mammals at risk of poisoning, either directly through consumption of bait pellets (primary poisoning), or indirectly through scavenging poisoned animals (secondary or tertiary poisoning). In order to minimize impacts to non-target species, the eradication of Norway rats during Phase 1 involved the use of locking, tamper-resistant bait stations. These stations prevented non-target species such as Common Ravens from directly accessing the bait. However, some scavenging species (individual animals) did die as a result of eating other animals (e.g., rats) that had consumed the bait.

During Phase 2, the eradication operation was planned to occur when most migratory birds had left the island (i.e., less non-target species present during the eradication operation, which was predicted

to reduce the risk of non-target poisoning). The bait pellets were also designed to be too large for small song birds such as Song Sparrows (*Melospiza melodia*) to easily consume and were dyed green, which appears to make the pellets less visible, and presumably less attractive, to some bird species.

During both phases, quantified, systematic, and intensive searches were also undertaken by field personnel on all treated islands. Any animal remains (rat and non-target species) that were found were collected in order to minimize the risk of secondary and tertiary poisoning of non-target species as a result of scavenging by species such as Bald Eagles and Common Ravens.

Personnel safety:
Weather conditions on Haida Gwaii are often unpredictable from the late fall to early spring, when severe storms regularly batter the islands, often for days or weeks at a time, making the islands a risky work environment for the project team members. Both phases were implemented in the late summer and early fall when weather conditions are most favorable on Haida Gwaii.

COMMUNITY INVOLVEMENT:

Night Birds Returning is a joint project of Parks Canada Agency, the Haida First Nation, and the Archipelago Management Board. Phase 1 and Phase 2 were also undertaken with significant involvement of local community members under the direction of non-governmental organizations specializing in invasive species eradications, such as Coastal Conservation and Island Conservation. Involving locals in the Night Birds Returning project resulted in a sense of community ownership of the project and increased awareness regarding the negative impacts of invasive species such as rats, not only on seabirds but on entire island ecosystems.

OUTCOME:

Arichika Island (Phase 1) was declared rat free in April 2015, and while the Bischof islands eradication was also declared a success, rats appear to have re-invaded the island. Preliminary results suggest that Phase 2 was also successful. However, eradication success is not confirmed until two years post-eradication. This provides sufficient time for any residual rat populations to increase to detectable levels using various monitoring techniques.

Continued monitoring of the project islands is essential, both to evaluate the success of the project, and to ensure that the islands remain rat-free. Surveys of Arichika and the Bischof islands indicate that native species are already benefitting from the eradication operations. Native shrew populations have already reached numbers comparable to other rat-free islands, and Black Oystercatchers (*Haematopus bachmani*), a shorebird that responds quickly to changes in ecosystem health, are increasing in numbers and fledging more chicks than they did when rats were present on the islands.

In order to continue to monitor the islands' wildlife, automated recording units (ARUs) have been installed both on Arichika and the Bischof islands. Recordings from these devices will be used to determine the frequency and distribution of various bird species; a measure that can be used to gauge the project's success.

Parks Canada Agency has also implemented a long term monitoring program to measure rat presence/absence on the Night Birds Returning project islands over the coming years. This monitoring program is also being used to track ecosystem health over time, and will continue for several years to determine how native species are responding following the removal of black rats from Murchison and Faraday islands.

Removal of feral mammals from Guadalupe Island, Mexico

Guadalupe Island is a 100 square-mile volcanic island located 150 miles off the west coast of Baja California Peninsula, Mexico. One of the most biodiverse and unique islands in the Pacific, Guadalupe Island is home to more than 150 native species, including more than 34 endemic plants, 7 extant (living) endemic bird species or subspecies, 8 breeding seabirds, and more than 29 endemic invertebrates. The southern part of the island is bare, while the northern end is rich with trees and fertile valleys. A small military garrison (Mexican Navy) and a community of approximately 70 fishermen and their families also live on the island. The island and surrounding marine environment have been a pinniped (seal) sanctuary since 1975 and were protected as the Guadalupe Biosphere Reserve in 2005.

THE PROBLEM:

Non-native species of plants (46) and animals (8) were introduced to Guadalupe Island in the 19th and 20th centuries. Four of the introduced mammals (goats, dogs, cats, and mice) became feral. Feral cats are thought to have been responsible for the extinction of six endemic bird species and the reduced populations of other birds and invertebrates. The most devastating effects on the island's ecosystem were caused by a population of feral goats, which consumed the majority of native plant vegetation—including the seeds and seedlings of the rare and endemic Guadalupe Cypress (*Cupressus guadalupensis guadalupensis*) and Guadalupe Island Monterey Pine (*Pinus radiata* var. *binata*)—eating the vegetation down to bare rock in some areas. An expedition to evaluate the status of the island in 2000 concluded that there had been no new recruitment (new seedlings) of pines, palms, oaks, or cypress trees in 150 years (most trees were at least 100 years old) and found that many species were on the brink of extinction. It was clear that the feral goat population (estimated in 2000 to be 4000 goats; Leon de la Luz et al., 2003) on the island needed to be eradicated immediately; failure to do so was estimated to cause the disappearance of the remaining native flora and fauna within 10 to 20 years.

THE SOLUTION:

The first step in the restoration project was to inventory the existing native plant species and exclude the goats from 12 of the most sensitive areas using fences so that native flora could have an opportunity to reproduce in the absence of goat herbivory. After an extended planning period, a combination of trapping, ground hunting, and helicopter hunting by trained professionals was used to successfully remove all goats from the island.

Feral dogs, which were a threat to native birds and pinnipeds, were also eradicated from the island in 2007. The eradication of feral cats and mice poses yet another major challenge, due to the size and complexity of Guadalupe Island. As yet, these species have not been removed, although options for their removal are being assessed. In the meantime, cats have been controlled around seabird nesting areas on the island since 2003 to prevent further extinctions.

CHALLENGES:

Geography: A number of challenges were faced during this project, and continue to be faced today during ongoing monitoring and conservation efforts. The island is very large, rugged, and remote. Two volcanos, Mount Augusta and El Picacho, reach heights of 4,259 and 3,199 ft., respectively, and the coastline of the island is comprised of steep rock bluffs, making access difficult and providing places for smaller, more agile creatures such as cats and mice to take refuge.

Legal protection of the island's flora and fauna: A the beginning of this project, there was no legal protection for the island or infrastructure to support conservation efforts. This has changed with the creation of the Guadalupe Biosphere Reserve, and Grupo de Ecologia y Conservación de Islas (GECI) has built a research station on the island to facilitate year round research and monitoring.

LESSON FIVE LAB CASE STUDY #2: GUADALUPE ISLAND

COMMUNITY INVOLVEMENT:

The Mexican Navy and the local fishing community have both been involved with the eradication activities throughout the project. Both communities participated in the trapping and removing of goats, assisting GECI and Mexican ranchers from Sonora, who were enlisted to help with the project. Environmental education and public outreach has been undertaken to educate residents about how invasive species eradications help to improve quality of life, not only for native plants and animals but also for people.

OUTCOME:

The eradication of goats and other invasive species from Guadalupe Island is having a profound positive effect on native plant species. Seedlings of endemic trees such as cypress, pine, palms, and oaks have begun to grow again and critically rare plant species, including 5 species that were believed to have been extinct or absent from the island, are also recovering; demonstrating the longevity of native seed banks. The recovery of trees on the island is providing vital habitat for the endemic Guadalupe Island Junco (*Junco insularis*), and the regrowth of native ground cover plant species will create much needed soil and ground cover to support the recovery of a variety of burrow and crevice-nesting seabirds.

The Isles of Scilly Seabird Recovery Project

The Isles of Scilly form an archipelago of five inhabited islands approximately 140 rocky islets, located 28 miles west of the southwestern tip of the Cornish peninsula of Great Britain. The islands are the breeding habitat for 14 species of seabirds, approximately 20,000 birds in all, including the European Storm Petrel (*Hydrobates pelagicus*) and Manx Shearwater (*Puffinus puffinus*), and are also home to the native Scilly shrew (*Crocidura suaveolens*).

THE PROBLEM:

Introduced Norway rats were impacting seabird populations on the inhabited islands of St. Agnes and Gugh, as well as affecting the native Scilly shrew and an unknown number of invertebrates and rare plants. The rats were also impacting the local community by causing a nuisance in homes, shops, and restaurants, and on farms. Seabird populations on the islands have been in decline since 1983 and, in 2006, were found to have dropped by 25%.

THE SOLUTION:

The Isles of Scilly Seabird Recovery project is a partnership between government agencies, non-profit organizations, and the local community that is focused on the removal of Norway rats from the Isles of Scilly. Started in 2006, this 25 year project aims to prevent further declines in seabird populations on the isles through the removal of invasive rats, maintaining the rat-free status of the uninhabited seabird islands (biosecurity), and educating both the community and visitors about the risks of invasive rats and the benefits of seabird recovery.

Between October 2013 and April 2014, a ground-based eradication operation was undertaken on St. Agnes and Gugh islands. Locking bait stations containing rodenticide bait blocks were placed across all parts of the islands, as well as within the homes of all residents (74 homes). Passive detection methods, including flavored wax chew blocks, tracking tunnels, and remotely triggered cameras, were also used to monitor the progress of the eradication, and long-term monitoring will continue for two years before the eradication outcome is known (success or failure).

A detailed biosecurity plan for the islands of St. Agnes and Gugh was developed and implemented to reduce the risk of invasive species introduction and ways to respond to a confirmed invasive species incursion. Prevention involves inspecting all high risk items that are transported to the islands (e.g., hay, animal food, fresh produce). Harbors and boats maintain bait stations, and all boats are checked regularly for rat sign, especially if they have visited an island (or mainland) inhabited by rats. Residents and visitors are also asked to manage waste well (i.e., reduce food sources for rats). Detection of potential incursions is achieved through monitoring stations containing wax chew blocks that have been placed around the islands as well as the vigilance of residents and visitors who keep a look out for rats or rat sign. A dedicated phone line (“Rat on a Rat”) is maintained to report rat sightings.

CHALLENGES:

Unlike most eradication operations, the challenges faced by this project were easily overcome. Funding was readily available and all homeowners agreed to install the bait stations in their houses and outbuildings, which maximized the probability of successfully eradicating the rats. Occasional storm events resulted in some coastal bait stations being destroyed but these were quickly replaced following the inclement weather. The project team also observed some cattle tampering with the bait stations but this was addressed by employing a more sturdy method of securing the bait stations in place.

LESSON FIVE LAB CASE STUDY #3: ISLAND OF SCILLY

COMMUNITY INVOLVEMENT:

The community of St. Agnes and Gugh have been involved with this project since the earliest consultation stages and have assisted both with the eradication itself (moving equipment and bait around the island for deployment, reporting the location of any rat or non-target carcasses) and the long-term and biosecurity monitoring (community members were trained to identify rats and rat sign to assist with the permanent biosecurity measures on the islands).

During the eradication operation, school students took part in the "Rat Awareness Days" community event and acted as "Seabird Ambassadors", informing visitors to the islands about the project and how to report any rat sightings or other issues of concern. Following completion of the eradication operation the students have begun to monitor native species recovery and continue to educate visitors about invasive species issues.

OUTCOME:

Although only one year has passed since the eradication was completed, initial results appear promising. Active Manx Shearwater (*Puffinus puffinus*) burrows were recorded during the 2014 breeding season (immediately following the eradication), and the first chick to fledge (leave the nest) on St. Agnes in living memory was observed in September 2014. Scilly shrew population numbers appear to be higher than prior to the eradication. A four-year monitoring project measuring changes to vegetation, invertebrates, native mammals (namely the Scilly shrew), and birds (both land and seabirds) will report annually on changes on the islands.

The Isles of Scilly Environmental Trust (now Isles of Scilly Wildlife Trust) has been removing Norway rats from the uninhabited islands within the Isles of Scilly since 1998. Because of this ongoing biosecurity work, the most important seabird islands are being maintained "rat-free," although incursions of rats from the inhabited islands still occur frequently in the winter months.

Juan Fernández Islands

The Juan Fernández Islands are an archipelago comprised of three islands, Robinson Crusoe, Alejandro Selkirk, and Santa Clara, and several small rock stacks located approximately 670 km (415 miles) off the coast of central Chile. The seabird community of the islands contains six breeding species, four of which are globally listed as Vulnerable and which breed only in Chile. The six species include the Pink-footed Shearwater (*Ardenna creatopus*), four species of petrels (*Pterodroma* sp.) and the White-bellied Storm-Petrel (*Fregetta grallaria*). In addition, there are two Critically Endangered land birds, the Másafuera Rayadito (*Aphrastura masafuerae*) and Juan Fernández Firecrown (*Sephanoides fernandensis*), whose entire global populations are restricted to single islands in the archipelago.

THE PROBLEM:

The archipelago was only discovered in 1574, with a permanent human community only established in the late 1870s. Despite centuries of only sporadic visitation and after only slightly more than 125 years of permanent settlement, the archipelago's ecosystems have suffered from the cumulative impacts of humans, including extensive deforestation and the widespread effects of introduced plants and mammals. Invasive mammals, including feral cats, rats, coatimundis, European rabbits, and goats have impacted native ecosystems and species through habitat alteration, competition, and predation.

THE SOLUTION:

There have been several different efforts focused on controlling and eradicating invasive species on the islands. From 1998-2003, the Proyecto Holanda (Holland Project) significantly reduced the feral goat population on Alejandro Selkirk Island, developed control techniques for several extremely aggressive invasive plant species, and, significantly, eradicated European rabbits from Santa Clara Island. The removal of rabbits from Santa Clara left the island free of introduced mammals, and the responses by breeding Pink-footed Shearwaters and native plant species have been impressive.

Island Conservation has led efforts to develop feasibility studies for eradication programs on the two main islands, Robinson Crusoe and Alejandro Selkirk, and to build capacity in Chilean government agencies for eradication efforts of the magnitude required for these islands. In addition, Island Conservation and Oikonos have worked extensively with the local community to build awareness of the impacts of invasive species and, ultimately, support for eradication goals for the archipelago.

At present, eradication programs are still in the evaluation and planning stages and additional community support will be required before any eradications can take place. Biosecurity programs are also being developed by the Chilean government for the islands but have not yet been implemented on a permanent basis.

CHALLENGES:

The challenges confronting eradication efforts in the archipelago are significant and varied. They include the considerable size (approximately 4,900 ha or 11,000 acres each) and rugged topography of the two main islands, Robinson Crusoe, and Alejandro Selkirk. The relatively remote location of the islands, hundreds of miles off the coast of Chile, also makes eradication efforts logistically more complex. Because there are several invasive mammal species on the two main islands, an eradication program cannot focus on a single species but must address multiple species simultaneously, thereby adding considerable complexity.

The local community of the islands is generally supportive of eradication efforts, but there is still resistance to the idea of eliminating certain species, notably feral goats on Alejandro Selkirk and

European rabbits on Robinson Crusoe. Both species are still hunted and, therefore, are considered supplemental food sources by the community.

Given that eradication is a relatively new conservation strategy in the country, the Chilean government is still developing the capacity to support and manage eradication projects.

COMMUNITY INVOLVEMENT:

The community of the islands has been invited to participate in discussions, both formal and informal, about eradication from early on in the process. Although virtually the entire archipelago is national park and, thus, under control of a Chilean federal agency (Corporación Nacional Forestal, CONAF), the park administration has wisely included the local community in considerations related to eradications in the archipelago. Local support is obviously essential for long-term success of any eradications and CONAF, along with Island Conservation and Oikonos, have focused considerable efforts on engaging the community, building awareness and creating opportunities to train residents to work on projects related to biodiversity conservation, including the construction of mammal-excluding fences to protect seabird nesting colonies, restoration of native plant communities, and control of invasive plant species. In addition, trained residents work on a project focused on eradicating incipient (newly established) invasive plant species on both main islands, with the goal of eliminating them before they become widely established and, therefore, damaging to local ecosystems.

OUTCOME:

The only eradication outcome to date is the elimination of European rabbits from Santa Clara. The eradications necessary to safeguard the biodiversity of the two main islands, Robinson Crusoe and Alejandro Selkirk, are still pending, with the ultimate decision about whether or not to allow them in the hands of the Chilean government. Interim outcomes include the construction of cattle, rabbit and cat-proof fences to protect important breeding colonies of Pink-footed Shearwaters, the restoration of native plant communities in shearwater colonies, the ongoing control of invasive plant species in critical habitat, and the eradication of incipient invasive plant species. Community support continues to increase, but it will likely be several years before island-wide eradications.

APPENDIX I Glossary

abundance The number of individuals in a population.

autotroph "self-feeding", from the Greek autos "self" and trophe "nourishing" or "producer". An organism that produces complex organic compounds (such as carbohydrates, fats, and proteins) from simple substances present in its surroundings, generally using energy from light (photosynthesis) or inorganic chemical reactions (chemosynthesis). They are the producers in a food chain and include plants, algae, and bacteria.

Bering Sea Waters off the coast of Alaska north of the Aleutian Islands and south of the Bering Straits

biodiversity the degree of variation of life. It is a measure of the variety of organisms present in different ecosystems. This can refer to genetic variation, ecosystem variation, or species variation (number of species) within an area, biome, or planet.

biosecurity the implementation of actions to reduce the risk of introduction of an invasive species. A biosecurity plan provides guidelines and information to the public and land managers that can be used to help prevent the spread of invasive species, quickly detect a new invading species, and/or rapidly respond to new invasions (ecosystem security). A biosecurity plan attempts to identify pathways of invasion and strategies for preventing or reducing new introductions.

colonial nesting seabirds (seabird colony) A seabird colony is a large congregation of individuals of one or more species of bird that nest or roost in proximity at a particular location (e.g., on an island). Many kinds of birds are known to congregate in groups of varying size; a congregation of nesting birds is called a breeding colony.

competitor (competition): a contest between organisms, animals, individuals, and/or groups, for territory, a niche, resources (food, shelter, etc.), mates, or group or social status.

conservation The act of protecting or preserving natural resources in order to prevent depletion or loss.

detritivore also known as detritophages, detritus feeders, detritus eaters, or saprophages that obtain nutrients by consuming detritus (decomposing plant and animal parts as well as faeces). By doing so detritivores contribute to decomposition and the nutrient cycles and are thus an important aspect of many ecosystems. They can live on any soil with an organic component, including marine ecosystems, where they are termed interchangeably with bottom feeders. Typical detritivorous animals include but are not limited to millipedes, woodlice, dung flies, slugs, many terrestrial worms, sea stars, sea cucumbers, and fiddler crabs.

disease a particular abnormal, pathological condition that affects part or all of an organism.

ecological community an assemblage or associations of populations of two or more different species occupying the same geographical area and in a particular time.

ecosystem A community of living organisms and their environment, and the interactions between the two. Humans are an integral part of an ecosystem.

endemic species (Endemism) the ecological state of a species being unique to a defined geographic location, such as an island, nation, country or other defined zone, or habitat type; organisms that are indigenous to a place are not endemic to it if they are also found elsewhere.

environmental Stewardship protecting the natural environment and using its resources in a sustainable way. It also means practicing conservation: taking actions to ensure that native plant and animal species, and the habitats that they require, continue to survive.

eradication (invasive species) the intentional (purposeful) local extinction, or extirpation of a species; e.g., eradicating rats to protect breeding seabirds on an island.

APPENDIX I Glossary

evapotranspiration the combination of evaporation and plant transpiration from the Earth's land and ocean surface to the atmosphere.

evolution the change in heritable traits of biological populations over successive generations. Evolutionary processes give rise to diversity at every level of biological organization, including the level of species, individual organisms, and at the level of molecular evolution.

extinct the end of an organism or of a group of organisms (taxon), normally a species. The moment of extinction is generally considered to be the death of the last individual of the species, although the capacity to breed and recover may have been lost before this point.

extirpation the condition of a species (or other taxon) that ceases to exist in the chosen geographic area of study (local extinction) although it still exists elsewhere.

fauna animals of a particular region or habitat. The grouping of animals to a location or time.

feral (animal) one that has itself escaped from a domestic or captive status and is living more or less as a wild animal, or one that is descended from such animals.

food web a graphical representation of feeding relationships within an ecological community implying the transfer of food energy from its source in plants through herbivores to carnivores.

forage fish generally a small schooling fish that feed on plankton and preyed upon by larger fish, marine mammals, and seabirds.

genetic variation the diversity in gene frequencies. Genetic variation can refer to differences between individuals or to differences between populations. Mutation is the ultimate source of genetic variation, but mechanisms such as sexual reproduction and genetic drift contribute to it as well

gizzard an organ found in the digestive tract of many animals, including birds, reptiles, earthworms, and some fish. It's a specialized stomach with thick muscular walls and containing previously eaten stones or grit that are used for grinding up food. The stones act as "teeth" in the gizzard, breaking down hard food like seeds, and making digestion more efficient. The stones are worn down and can be passed or regurgitated when they no longer good for grinding.

guano the excrement of birds, cave-dwelling bats, and pinnipeds. Guano is a highly effective fertilizer due to its exceptionally high content of nitrogen, phosphate, and potassium, three nutrients essential for plant growth.

habitat an ecological or environmental area that is inhabited by a particular species of animal, plant, or other type of organism. It is the natural environment in which an organism lives, or the physical environment that surrounds a species population.

herbivore an animal anatomically and physiologically adapted to eating plant material, for example foliage, for the main component of its diet. As a result of their plant diet, herbivorous animals typically have mouthparts adapted to rasping or grinding.

heterotrophy (heterotrophic) an organism that cannot fix carbon and uses organic carbon for growth. Heterotrophs can be further divided based on how they obtain energy; if the heterotroph uses light for energy, then it is considered a photoheterotroph, while if the heterotroph uses chemical energy, it is considered a chemoheterotroph. Most bacteria and all animal and fungal species are heterotrophic.

homogenization (homogenous) identical in composition or character.

hybrid an offspring of two animals or plants of different breeds, varieties, species, or genera.

hybridize the process of combining different varieties of organisms to create a hybrid.

APPENDIX I Glossary

incursion an invasion or attack, especially a sudden or brief one. In the context of invasive species, the arrival of a single or small number of individuals of an invasive species in an ecosystem to which they are not native.

invasive species (invasive alien species, exotic species) a plant or animal that is not native to a specific location (an introduced species); and has a tendency to spread, which is believed to cause damage to the environment, human economy and/or human health.

mitigative measures In respect of a project, the elimination, reduction, or control of the adverse environmental effects of a project. Mitigation measures prevent or reduce potentially negative effects as, for example, in stockpiling excavated soil well away from streams to prevent or minimize the potential for increased sedimentation and the destruction of fish spawning habitats.

mortality the state of being mortal, or susceptible to death.

native/indigenous species in biogeography, a species is defined as native (or indigenous) to a given region or ecosystem if its presence in that region is the result of only natural processes, with no human intervention. Every natural organism (as opposed to a domesticated organism) has its own natural range of distribution in which it is regarded as native.

natural range the geographical area within which a particular species is commonly found.

NWFWS An abbreviation for the Northwest Fish and Wildlife Service.

overgrazing when plants are exposed to intensive grazing for extended periods of time, or without sufficient recovery periods.

parasite (parasitism) a non-mutual symbiotic relationship between species, where one species (the parasite) benefits at the expense of the other (the host).

pathogen an infectious agent such as a virus, bacterium, fungus, or parasite that causes disease in its host.

pathology a term that may be used broadly to refer to the study of disease in general mostly through the analysis of tissue, cell, and body fluid samples.

pelagic Inhabiting the water column as opposed to being associated with the sea floor; generally occurring anywhere from the surface to 1,000 meters.

predator (predation) an organism that eats another organism.

prey the organism which the predator eats.

primary poisoning (non-target species) Poisoning of a native species that occurs when it directly consumes the rodenticide (poison) baits used to eradicate mice or rats during an eradication operation.

protozoa unicellular (one cell) microorganisms with animal-like behaviour, such as movement.

richness A measure of biodiversity showing how many effective species were in a given haul.

rodenticide a bait containing a poison that is used to eradicate invasive rodents including rats. Currently, rodenticides are the only known technique that maximizes the chances of successfully eradicating invasive rodents (Howald et. al. 2007). Rodenticide baits can be placed in bait stations on the target island, broadcasted by hand, or aerially broadcasted by helicopter.

salt gland a gland in marine birds that concentrates salt from the blood. Salt is collected near the nostrils and "sneezed" out.

secondary poisoning (non-target species) Poisoning of a scavenging species such as a Common Raven or Bald Eagle that occurs when it feeds on an animal such as a rat that has consumed the rodenticide (poison) baits used to eradicate mice or rats during an eradication operation.

soil moisture regime the changing state of soil moisture through the year, which reflects the changing balance of monthly precipitation and potential evapotranspiration above the ground surface.

APPENDIX I Glossary

species richness the number of different species represented in an ecological community, landscape or region. Species richness is simply a count of species and does not take into account the abundances of the species or their relative abundance distributions.
symbiotic the close and often long-term interaction between two or more different biological species.
tertiary poisoning (non-target species) Poisoning of a scavenging species such as a Common Raven or Bald Eagle that occurs when it feeds on an animal which has eaten another animal that has consumed the rodenticide (poison) baits used to eradicate mice or rats during an eradication operation. For example, a rat eats the rodenticide bait and is then eaten by a sea gull (secondary poisoning), which is then eaten by a Bald Eagle (tertiary poisoning).
tunicate a marine filter feeder with a water-filled, sac-like body structure and two tubular openings, known as siphons, through which they draw in and expel water.
ungulate a diverse group of large mammals that includes horses, cattle, pigs, giraffes, camels, deer, and hippopotamuses. Most terrestrial ungulates use the tips of their toes, usually hoofed, to sustain their whole body weight while moving. The term means, roughly, "being hoofed" or "hoofed animal".

APPENDIX II EDUCATIONAL STANDARDS

ALASKA STATE SCIENCE STANDARDS

Science as Inquiry and Process

SC2 Students develop an understanding of the structure, function, behavior, development, life cycles, and diversity of living organisms.

SC3.2 The student demonstrates an understanding that all organisms are linked to each other and their physical environments through the transfer and transformation of matter and energy by analyzing the potential impacts of changes within an ecosystem.

SE1 Students develop an understanding of how scientific knowledge and technology are used in making decisions about issues, innovations, and responses to problems and everyday events.

ALASKA STATE SCIENCE STANDARDS

Statistics and Probability Standards

- Interpreting Categorical and Quantitative Data

NEXT GENERATION SCIENCE STANDARDS: DISCIPLINARY CORE IDEAS

LS2.A: Interdependent Relationships in Ecosystems

- Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. (MS-LS2-1)
- In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. (MS-LS2-1)
- Growth of organisms and population increases are limited by access to resources. (MS-LS2-1)
- Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared. (MS-LS2-2)

LS2.B: Cycle of Matter and Energy Transfer in Ecosystems

- Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. (MS-LS2-3)

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

- Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. (MS-LS2-4)
- Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health. (MS-LS2-5)

LS4.D: Biodiversity and Humans

- Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling. (secondary to MS-LS2-5)

ETS1.B: Developing Possible Solutions

- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (secondary to MS-LS2-5)

APPENDIX III SEABIRD FACT SHEET: PINK-FOOTED SHEARWATER

PINK-FOOTED SHEARWATER *Ardenna creatopus* (formerly *Puffinus creatopus*)

Conservation Status

CHILE: Endangered GLOBAL: Vulnerable

Breed	Eggs	Incubation	Fledge	Nest	Feeding Behavior	Diet
Oct-May	1	50-55 days	90 days	burrow	shallow surface dives	fish, squid, crustaceans

DESCRIPTION

Pink-footed Shearwaters are a fairly heavy-bodied, large broad-winged shearwater. Head and upperparts are dull gray-brown. The sides of the head and neck have brownish mottling along the sides of the breast, which continues down the flanks. The lower belly is more solidly brown, along with the under-tail coverts and thighs with slight pale mottling. The rest of the underparts are a dull white. The underwing has brown mottling on a paler background, with a pale patch on the primaries. The bill is pale pink with a dark tip. As befits its name, the webbed feet are pale pink. The extent of dark on the underwings and underparts varies between individuals.

DISTRIBUTION

The species is endemic to Chile and breeds on only three islands in the world: Robinson Crusoe and Santa Clara islands in the Juan Fernández Islands and Mocha Island. Pink-footed Shearwaters typically travel several hundred kilometers from the colonies on foraging trips during the breeding season. Their foraging distribution during the breeding season occurs primarily in the Humboldt Current system, along the outer continental shelf and shelf-break off the central Chilean coast.

Pink-footed Shearwaters migrate out of Chilean waters during the winter months, with a portion of the population wintering in Peruvian waters and the remainder of the population spending the winter in waters of the Pacific coast of North America, from Baja California to British Columbia. The species is generally found in waters of the outer continental shelf and along the shelf-break throughout its wintering range.

CONSERVATION CONCERNS AND ACTIONS

The species is globally listed as Vulnerable by the International Union for the Conservation of Nature. It is also listed as Endangered by Chile. There are threats to the species both on the breeding colonies and at sea.

Pink-footed Shearwater©Peter Hodum

- On the breeding colonies, principal threats include predation by introduced mammals (cats, dogs, coatimundis), breeding habitat loss and alteration, chick harvesting on Mocha Island, and competition with introduced European rabbits for burrows.
- At sea, the principal threats are bycatch in fisheries, plastic ingestion and contaminants/ pollution.

CULTURAL USE

There is no evidence of traditional use of the species in the Juan Fernández Islands. However, on Mocha Island, local residents have harvested chicks during the late-nestling stage for consumption. Although this practice has been illegal for decades, only in the past few years has the Chilean government begun to enforce the prohibition on chick harvests.

COOL FACT

Pink-footed Shearwaters can cover more than 40,000 km during the non-breeding season, ranging from their breeding grounds in Chile all the way up to the waters of Washington and British Columbia before returning in time for the next breeding season.

APPENDIX III SEABIRD FACT SHEET: PINK-FOOTED SHEARWATER

PINK-FOOTED SHEARWATER *Ardenna creatopus* (formerly *Puffinus creatopus*)

Conservation Status

CHILE: Endangered GLOBAL: Vulnerable

REFERENCES

BirdLife International species account page:
http://www.birdlife.org/datazone/species/factsheet/22698195

VIDEO COVERAGE

Arkive species account:
http://www.arkive.org/pink-footed-shearwater/puffinus-creatopus/

Oikonos videos:
https://vimeo.com/tag:fardela+blanca

WEBSITES

Oikonos species account:
http://oikonos.org/pink-footed-shearwater/

Cornell Lab or Ornithology Neotropical Birds species account:
http://neotropical.birds.cornell.edu/portal/species/overview?p_p_spp=101276

Arkive species account:
http://www.arkive.org/pink-footed-shearwater/puffinus-creatopus/

Government of Canada Species at Risk Species Profile:
http://www.registrelep-sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=819

Government of Canada Species at Risk COSEWIC assessment and status report:
http://www.registrelep-sararegistry.gc.ca/document/default_e.cfm?documentID=490

Government of Canada Species at Risk Recovery Strategy:
http://www.registrelep-sararegistry.gc.ca/virtual_sara/files/plans/rs_short_tailed_albatross_and_pink_footed_shearwater_final_0408_e.pdf

APPENDIX III SEABIRD FACT SHEET: HORNED PUFFIN

HORNED PUFFIN *Fratercula corniculata*

Conservation Status

ALASKA: Moderate GLOBAL: Least Concern

Breed	Eggs	Incubation	Fledge	Nest	Feeding Behavior	Diet
June-July	1	40 days	34-43d	burrow	surface dives	fish, squid, other invertebrates

DESCRIPTION

The Horned Puffin is one of the most sought after seabirds in Alaska by tourists and photographers.

In summer they have a black back, and a white belly and face. They have small black leathery skin protrusions above the eyes (up to 12 mm) that create the horned appearance from which they are named after. The large bill is bright yellow with a red tip, and their legs and feet are a bright orange to reddish.

In winter their bill is smaller and duller (some of the outer sheath covers fall off), "horns" are lost, the face turns grey and feet become a pale fleshy color.

DISTRIBUTION

The species is widespread in the North Pacific Ocean. During the breeding season it nests in the Gulf of Alaska, Aleutian Islands, and islands in the Bering and Chukchi Seas, and the Sea of Okhotsk. Rare breeder in British Columbia. 87% of world population breeds in Alaska, and 13% breed in Russia.

Horned Puffins spend their winter at-sea, never visiting land. They can be found offshore throughout the North Pacific during winter months.

CONSERVATION CONCERNS

- Hunting and harvest. Adults and eggs harvested for subsistence in some areas of Alaska, particularly in Bering Strait region, but this harvest is minimal and localized (largely because of their inaccessible nesting sites).
- Vulnerable to oil pollution because of marine habitats and flightless period during the winter months (during molt), but major oil mortality events have not been reported.
- Plastic particles are frequently found in gizzards.
- Fishing nets. Bycatch in gill nets is widespread in the North Pacific.
- Introduced mammals. Mammalian predators were once absent from most islands in the Northeast

Pacific, but arctic fox (*Alopex lagopus*), red fox (*Vulpes vulpes*), Norway rats (*Rattus norvegicus*), and ground squirrels (*Spermophilus undulatus*) have been introduced onto many seabird colonies in Alaska. These predators have had large impacts on many seabird populations, although Horned Puffins were less affected than some species because they usually nest in less accessible crevices.

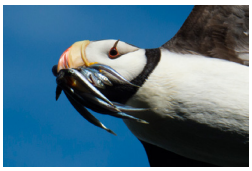
- Puffins may desert their nests if humans disturb them during the breeding season.

CULTURAL USE

Unangan (indigenous people of the Aleutian Islands of Alaska (USA) and Kamchatka Krai (Russia)) used the skin of Horned Puffins for clothing. It could take over 40 puffin skins to make one parka. Feathers were worn outside during rainy weather and inside during colder dry weather. The colorful puffin bills were used as ornaments on clothing, in children's rattles, and on mittens worn in ceremonial dances.

COOL FACT

Spines on a puffin's tongue and the roof of the mouth act as hooks holding on to fish while the beak is open catching more fish. The average catch is 10 fish but the record is 62 by an Atlantic Puffin in Britain!



APPENDIX III SEABIRD FACT SHEET: HORNED PUFFIN

HORNED PUFFIN	*Fratercula corniculata*
Conservation Status	
ALASKA: Moderate	GLOBAL: Least Concern

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Cornell Lab of ornithology species account page:

http://www.allaboutbirds.org/guide/horned_puffin/lifehistory

VIDEO COVERAGE

http://www.youtube.com/watch?v=MVOndUJqx0Q

http://www.youtube.com/watch?v=Xd_XuX05m0k

http://www.youtube.com/watch?v=Y7A3LEUu37o

WEBSITES

http://video.nationalgeographic.com/video/puffin_atlantic_iceland

http://www.ngkids.co.uk/did-you-know/puffin_facts

http://easyscienceforkids.com/all-about-puffins/

http://projectpuffin.audubon.org/history-project-puffin

http://www.bbc.co.uk/nature/life/Atlantic_Puffin#intro

APPENDIX IV INVASIVE SPECIES WITH GLOBAL IMPACT

TWELVE TYPES OF INVASIVE SPECIES THAT ARE HAVING A GLOBAL IMPACT

The following are examples of some of the worst types of invasive species that are having a global impact. They originate from all continents except Antarctica, illustrating the diverse variety of organisms that can be invasive and the different ways in which invasive species are problematic. A list of 100 of the world's worst invasive alien species is included in Appendix VI.

MICRO-ORGANISM

Avian malaria is a mosquito-borne disease that occurs worldwide and is caused by *Plasmodium relictum*, a parasitic protozoan. These parasites occur in many avian species but primarily affect passerines (songbirds) that have not evolved in the presence of the parasite. On the islands of Hawaii, avian malaria has contributed to the extinction of at least 10 native bird species and threatens many more. Researchers have reported mortality rates of 65–90% for some native bird species after being bitten by a single infective mosquito. Many native birds can no longer breed in their historic breeding grounds at lower elevations because of avian malaria, forcing them to breed in higher elevations where food and cover may be scarce.

FUNGI

The parasitic chytrid fungus *Batrachochytrium dendrobatidis* causes a fungal infection of the skin of amphibian species, killing the individual and leading to significant population declines. Thought to originate in Africa, this fungus is now found in North and South America and Australiasia-Pacific.

AQUATIC PLANT

Water hyacinth (*Eichhornia crassipes*) is one of the world's worst aquatic weeds. Originally from the Amazon basin in South America, this plant is now found in more than 50 countries throughout Africa, Asia, North America, Australia, and New Zealand, where it clogs up waterways with dense growth, preventing native plants and animals from surviving.

LAND PLANT

Japanese knotweed (*Fallopia japonica*) is an aggressive semi-woody perennial plant that is native to eastern Asia. In the 1800s, it was introduced to North America as an ornamental species and also planted for erosion control. It has since spread throughout the United States (including southeast Alaska) and Canada. It spreads quickly, creating dense thickets that degrade wildlife habitats, and reduces plant biodiversity by competing with other native vegetation.

LAND INVERTEBRATE

The Argentine ant (*Linepithema humile*) is a widely distributed invasive species that displaces native ants throughout its introduced range by creating super colonies and outcompeting native species for food and habitat resources. The vast colonies can contain billions of workers and queens spread over hundreds of square miles.

AQUATIC INVERTEBRATE

The European green crab (*Carcinus maenas*) is a small, aggressive, intertidal crab that is not known to occur in Alaska but has been introduced in the Pacific Northwest, as far north as British Columbia. This invasive crab competes with native crab species and is a major predator of clams, mussels, and juvenile fishes.

APPENDIX IV INVASIVE SPECIES WITH GLOBAL IMPACT

AMPHIBIAN

The American bullfrog (*Lithobates catesbeianus*) is native to North American and has been introduced to more than 40 countries and 4 continents around the world, most often with the intent of establishing a new food source for humans. They are voracious predators, and have had devastating effects on native amphibian, fish, and bird populations.

FISH

The common carp (*Cyprinus carpio*) is a freshwater fish originating from Europe and Asia (two subspecies); today carp occur on every continent except Antarctica and are the third most frequently introduced species in the world. Their bottom-feeding behavior stirs up sediments and uproots aquatic plants, reducing water quality and altering aquatic habitats.

BIRD

Native to Europe, Asia, and Northern Africa, the European Starling (*Sturnus vulgaris*) was introduced to North American, Southern Africa, Australia, and New Zealand, where they can form large flocks that feed on agricultural crops and compete aggressively with native birds for nest cavities.

REPTILE

The brown tree snake (*Boiga irregularis*) was introduced to the island of Guam from its native range of Australia, Indonesia, the Soloman Islands, and Papua New Guinea. Lacking natural predators, the population on Guam exploded, causing the extirpation of nearly all of the native forest birds, including the extinction of the Guam Rail (*Gallirallus owstoni*) and the Micronesian kingfisher (*Todiramphus cinnamominus*). Nine of the eleven bird species present at the time of the brown tree snake's introduction have since been extirpated. The ecosystem of Guam has become extremely fragile as a result.

MAMMAL HERBIVORE

Domestic goats (*Capra hircus*), originally native to Asia, are raised for food around the world. Feral goat populations are extremely damaging to native ecosystems, overgrazing a wide variety of native plant and tree species and resulting in ecosystem degradation, soil compaction, soil erosion, and altered soil moisture regimes, especially when they are introduced to islands.

MAMMAL PREDATOR

Rats (*Rattus rattus*, *Rattus norvegicus*, *Rattus exulans*) have been introduced worldwide, where they quickly adapt to a wide variety of habitats and prey on most animal species smaller than themselves, such as reptiles, birds (including seabirds), bird eggs, and freshwater and intertidal species. Their presence in an ecosystem results in significant declines and even extinctions of native species and major changes to the ecosystem, especially on islands.

APPENDIX V INVASIVE SPECIES IN ALASKA

VERTEBRATES

ARCTIC FOX (*VULPES LAGOPUS*) AND RED FOX (*VULPES VULPES*)

Both arctic and red foxes are native to mainland Alaska and occur naturally on some but not all Alaskan islands. Between 1750 and the 1930s, foxes, primarily the Arctic fox, were introduced intentionally to more than 450 other Alaskan islands to be hunted for the fur trade. On islands where there were abundant bird and sea mammal populations, the foxes were left to roam free. Ground and burrow-nesting seabirds such as Storm Petrels (*Oceanodroma* spp.), Cassin's Auklet (*Ptychoramphus aleuticus*), and Tufted Puffin (*Fratercula cirrhata*;) including their chicks and eggs were especially vulnerable to fox predation. Without thriving bird populations to fertilize the ecosystem, plant productivity and the populations of the rest of the ecosystem also declined. Efforts to eradicate foxes from the islands to which they were introduced began in 1949.

ATLANTIC SALMON (*SALMO SALAR*)

Atlantic salmon are native to coastal drainages in eastern North America from northern Quebec, Canada, to Connecticut, USA, and inland to Lake Ontario. They are also native to Europe. Atlantic salmon are raised in fish farming operations along the coasts of Washington and British Columbia, and escaped fish began showing up in Alaskan streams starting in 1998. This species could potentially compete with native salmon and trout species for spawning and rearing habitat. Atlantic salmonids (young salmon) are also more aggressive than Pacific salmon such as sockeye (*Oncorhynchus nerka*) and could out-compete native salmon species for food resources if this species successfully spawns in Alaska. They may also introduce disease or parasites to the native salmon populations, which could severely impact the salmon fishery in Alaska.

CARIBOU (*RANGIFER TARANDUS ARCTICUS*) AND REINDEER (*RANGIFER TARANDUS ASIATICUS*)

Caribou and reindeer are different subspecies of the same species, *Rangifer tarandus*. Caribou are native to mainland Alaska, but were introduced to Adak Island in the late 1950s for sport hunting. Reindeer are a domesticated species that is native to Eurasia and was introduced to Alaska in the 1800s.

Like the native Caribou, reindeer are herbivores, foraging for lichens, mosses, herbs, ferns, grasses, and shoots and leaves of deciduous shrubs and trees, especially *Salix* spp. (willow) and *Betula* spp. (birch). Prior to the introduction of reindeer, lichens were abundant in the vegetation on islands such as St. Matthew and Hall islands, in some places forming mats 8–12 cm thick (Klein, 1968). Reindeer introduction has resulted in overgrazing, trampling of the vegetation, soil erosion, and permanent loss of native plant communities.

EUROPEAN STARLING (*STURNUS VULGARIS*)

Native to Eurasia, the European Starling was introduced to New York City in the 1890s and has since spread all across North America. It was first reported in Alaska in the 1960s. Starlings compete with other cavity nesters for nest sites, either nesting earlier in the season or physically removing eggs and chicks from nests. They are generalists, and compete with native bird species that eat fruits, grains, and insects. Starlings are more of a concern in disturbed areas and near human habitation.

GROUND SQUIRREL (*SPERMOPHILUS PARRYII*)

Ground squirrels occur naturally on mainland Alaska and on some Alaskan islands. Two different subspecies were intentionally introduced to the Aleutian Islands and also to the islands south of

the Alaska Peninsula to provide furs and food to the and to early Russian settlers. They were also introduced to feed introduced foxes after native seabird populations declined. In addition to their impacts on native vegetation, ground squirrels eat songbird eggs as well as the eggs and chicks of seabirds.

NORTHERN PIKE (*ESOX LUCIUS*)

Northern pike occur naturally throughout Canada and the United States, but are not native to all regions. In Alaska, they do not occur naturally south and east of the Alaska Mountain Range, except for a small population near Yakutat. This species was introduced illegally by humans into waterbodies in southcentral Alaska in the 1950s for sport fishing. A top-level predator, Northern pike hunt native coho (*Oncorhynchus kisutch*), sockeye (*O. nerka*), and Chinook salmon (*O. tshawytscha*) and rainbow trout (*O. mykiss*). Northern pike are ambush predators, so the shallower, weedy habitats found in waterbodies in southcentral Alaska are prime hunting habitats and the lack of deep water means that there are few places for prey species such as native salmon and rainbow trout to hide. In lakes and rivers where pike are not native, trout, salmon, and other fish have not adapted defenses against the pike's predatory tactics; thus, this invasive species is negatively impacting those populations. Smaller populations or salmon and trout mean less fish can be harvested by Alaskans for food.

RATS (NORWAY RAT *RATTUS NORVEGICUS* AND BLACK (SHIP) RAT *RATTUS RATTUS*)

Norway rats spread to Europe from Asia in the Middle Ages and are now found in most major human settlements around the world. The Black rat is native to the Indian subcontinent, but has similarly spread throughout the world, living both in forests and woodlands, and in and around buildings. Rats are frequent stowaways on ships, and most of Alaska's rat infestations have resulted from rats coming ashore while a ship is in port or as a result of a shipwreck. Norway rats were first introduced to Alaska in the 1780s, when a shipwreck occurred on the shores of Hawadax Island (formerly Rat Island) in the Aleutian Islands. Since that time the Norway rat has been accidentally introduced on many of the islands and on the mainland as far north as Nome, Alaska. It is also now found on more than 16 of the islands within the Alaska Maritime National Wildlife Refuge (AMNWR). Black rats are thought to occur at low densities on Shemya Island, also in the Aleutians.

RED-LEGGED FROG (*RANA AURORA*)

Red-legged frogs are native to western North America. In Alaska, they were introduced to Chichagof Island in 1982, where they are successfully reproducing and spreading into nearby wetlands. The tadpoles of the red-legged frog compete with the native wood frog (*Lithobates sylvaticus*) and western toad (*Anaxyrus boreas*) for algae, their primary food source. This may alter the abundance and species composition of algae, which in turn could cause changes to the aquatic food web in the wetlands they invade. Red-legged frogs may also spread disease or pathogens to native amphibians.

ROCK DOVE (*COLUMBA LIVIA*)

Rock doves are native to western and southern Europe, North Africa, and south Asia. A domesticated form is now common throughout the world, especially in cities. Once established, this species often occurs in large flocks, displacing native birds, and damaging grain crops. They may also spread parasites and diseases to native bird populations and are a known carrier of avian influenza, which may affect humans.

APPENDIX V INVASIVE SPECIES IN ALASKA

INVERTEBRATES

DIDEMNUM TUNICATE (*DIDEMNUM VEXILLUM*)

D. vexillum (a marine invertebrate) was first identified in Alaska in 2010 in Whiting Harbour, and the public has been asked to avoid using this waterway to prevent the possible spread of this highly invasive species to other parts of Alaska. Thought to have originated in Japan, *D. vexillum* is a colonial tunicate or ascidian, sometimes called "carpet tunicate" or "leather glove tunicate" because of its spreading character and soft, leather-like appearance. It is accidentally introduced to new locations by ships (by attaching to the hull or being transported in the ship's ballast water), and has undergone rapid population expansions wherever it has been reported, including Europe, Japan, New Zealand, and on the east and west coasts of North America. The invasive character of this tunicate results in dramatic habitat modifications. It spreads rapidly on hard surfaces underwater, smothering and killing native sessile (unable to move) marine animals and serving as a barrier between demersal (living close to the ocean or lake floor) and benthic (on the ocean floor) organisms. Potential economic impacts to the mariculture industry, shell fisheries, and ground fisheries are also a concern.

LARCH SAWFLY (*PRISTIPHORA ERICHSONII*)

Native to Europe, the Larch Sawfly was first introduced to Alaska in 1965. Today, it occurs throughout Canada and the northeastern US, where it attacks Larch trees (*Larix* spp.). In Alaska, larval stages of this species defoliate (feed on the leaves) native tamarack (*Larix laricina*) and ornamental Siberian larch (*Larix siberica*, also introduced), leaving them weakened and susceptible to infestation by other insects. Sustained infestations by this species have caused the mortality of up to 80% of the tamarack trees in Alaska.

PLANTS

JAPANESE KNOTWEED (*FALLOPIA JAPONICA*)

Native to Asia, Japanese knotweed is one of the worst plant invaders globally. Originally imported to North America as an ornamental plant in the late 1800s, it is now found throughout the continent, including in southeast Alaska. Once established, this species forms dense, monotypic stands that rapidly grow to reach 10 feet tall, outcompeting native vegetation, clogging waterways and reducing stream habitat quality for native trout and salmon species, and causing damage to man-made structures such as drainage ditches and pavement. It spreads both by seeds and via underground rhizomes, which can extend as far as 65 feet from the original plant, and can sprout from root and stem fragments as small as half an inch, making it extremely difficult to eradicate.

ORANGE HAWKWEED (*PILOSELLA AURANTIACA*)

Orange hawkweed is a perennial plant that is native to northern and central Europe. First reported in Alaska in 1961, it is now found throughout southeast and south-central Alaska, where it can form near-monotypic (only one species) stands on roadsides, in pastures, and in grassy riparian and wildlife areas, reducing native plant diversity, decreasing pasture productivity, and reducing forage for wildlife. Established plants spread and form dense patches locally via stolons (a horizontal stem or runner) and new patches are formed by windblown seeds. This species is highly invasive and difficult to eradicate.

100 OF THE WORLD'S WORST INVASIVE ALIEN SPECIES

MICRO-ORGANISM

avian malaria	*(Plasmodium relictum)*
banana bunchy top virus	*(Banana bunchy top virus)*
rinderpest virus	*(Rinderpest virus)*

MACRO-FUNGI

chestnut blight	*(Cryphonectria parasitica)*
crayfish plague	*(Aphanomyces astaci)*
Dutch elm disease	*(Ophiostoma ulmi)*
frog chytrid fungus	*(Batrachochytrium dendrobatidis)*
phytophthora root rot	*(Phytophthora cinnamomi)*

AQUATIC PLANT

caulerpa seaweed	*(Caulerpa taxifolia)*
common cord-grass	*(Spartina anglica)*
wakame seaweed	*(Undaria pinnatifida)*
water hyacinth	*(Eichhornia crassipes)*

LAND PLANT

African tulip tree	*(Spathodea campanulata)*
black wattle	*(Acacia mearnsii)*
Brazilian pepper tree	*(Schinus terebinthifolius)*
cogon grass	*(Imperata cylindrica)*
cluster pine	*(Pinus pinaster)*
erect pricklypear	*(Opuntia stricta)*
fire tree	*(Myrica faya)*
giant reed	*(Arundo donax)*
gorse	*(Ulex europaeus)*
hiptage	*(Hiptage benghalensis)*
Japanese knotweed	*(Fallopia japonica)*
Kahili ginger	*(Hedychium gardnerianum)*
Koster's curse	*(Clidemia hirta)*
kudzu	*(Pueraria montana var. lobata)*
lantana	*(Lantana camara)*
leafy spurge	*(Euphorbia esula)*
leucaena	*(Leucaena leucocephala)*
melaleuca	*(Melaleuca quinquenervia)*
mesquite	*(Prosopis glandulosa)*
miconia	*(Miconia calvescens)*
mile-a-minute weed	*(Mikania micrantha)*
mimosa	*(Mimosa pigra)*
privet	*(Ligustrum robustum)*
pumpwood	*(Cecropia peltata)*
purple loosestrife	*(Lythrum salicaria)*
quinine tree	*(Cinchona pubescens)*
shoebutton ardisia	*(Ardisia elliptica)*

LAND PLANT (CONTINUED)

Siam weed	*(Chromolaena odorata)*
strawberry guava	*(Psidium cattleianum)*
tamarisk	*(Tamarix ramosissima)*
wedelia	*(Sphagneticola trilobata)*
yellow Himalayan raspberry	*(Rubus ellipticus)*

AQUATIC INVERTEBRATE

Chinese mitten crab	*(Eriocheir sinensis)*
comb jelly	*(Mnemiopsis leidyi)*
fish hook flea	*(Cercopagis pengoi)*
golden apple snail	*(Pomacea canaliculata)*
green crab	*(Carcinus maenas)*
marine clam	*(Potamocorbula amurensis)*
Mediterranean mussel	*(Mytilus galloprovincialis)*
Northern Pacific seastar	*(Asterias amurensis)*
zebra mussel	*(Dreissena polymorpha)*

LAND INVERTEBRATE

Argentine ant	*(Linepithema humile)*
Asian longhorned beetle	*(Anoplophora glabripennis)*
Asian tiger mosquito	*(Aedes albopictus)*
big-headed ant	*(Pheidole megacephala)*
common malaria mosquito	*(Anopheles quadrimaculatus)*
common wasp	*(Vespula vulgaris)*
crazy ant	*(Anoplolepis gracilipes)*
cypress aphid	*(Cinara cupressi)*
flatworm	*(Platydemus manokwari)*
Formosan subterranean termite	*(Coptotermes formosanus shiraki)*
giant African snail	*(Achatina fulica)*
gypsy moth	*(Lymantria dispar)*
khapra beetle	*(Trogoderma granarium)*
little fire ant	*(Wasmannia auropunctata)*
red imported fire ant	*(Solenopsis invicta)*
rosy wolf snail	*(Euglandina rosea)*
sweet potato whitefly	*(Bemisia tabaci)*

AMPHIBIAN

bullfrog	*(Rana catesbeiana)*
cane toad	*(Bufo marinus)*
Caribbean tree frog	*(Eleutherodactylus coqui)*

FISH

brown trout	*(Salmo trutta)*
carp	*(Cyprinus carpio)*
large-mouth bass	*(Micropterus salmoides)*

FISH (CONTINUED)

Mozambique tilapia	*(Oreochromis mossambicus)*
Nile perch	*(Lates niloticus)*
rainbow trout	*(Oncorhynchus mykiss)*
walking catfish	*(Clarias batrachus)*
Western mosquito fish	*(Gambusia affinis)*

BIRD

Indian myna bird	*(Acridotheres tristis)*
red-vented bulbul	*(Pycnonotus cafer)*
starling	*(Sturnus vulgaris)*

REPTILE

brown tree snake	*(Boiga irregularis)*
red-eared slider	*(Trachemys scripta)*

MAMMAL

brushtail possum	*(Trichosurus vulpecula)*
domestic cat	*(Felis catus)*
goat	*(Capra hircus)*
grey squirrel	*(Sciurus carolinensis)*
macaque monkey	*(Macaca fascicularis)*
mouse	*(Mus musculus)*
nutria	*(Myocastor coypus)*
pig	*(Sus scrofa)*
rabbit	*(Oryctolagus cuniculus)*
red deer	*(Cervus elaphus)*
red fox	*(Vulpes vulpes)*
ship rat	*(Rattus rattus)*
small Indian mongoose	*(Herpestes javanicus)*
stoat	*(Mustela erminea)*

Species were selected for the list using two criteria: their serious impact on biological diversity and/or human activities, and their illustration of important issues of biological invasion. To ensure a wide variety of examples, only one species from each genus was selected. **Absence from the list does not imply that a species poses a lesser threat**.

Development of the *100 of the World's Worst Invasive Alien Species* list has been made possible by the support of the Fondation d'Entreprise TOTAL (1998 - 2000).

For further information on these and other invasive alien species consult The *Global Invasive Species Database*:

www.issg.org/database

APPENDIX VII REFERENCES

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