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)

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.

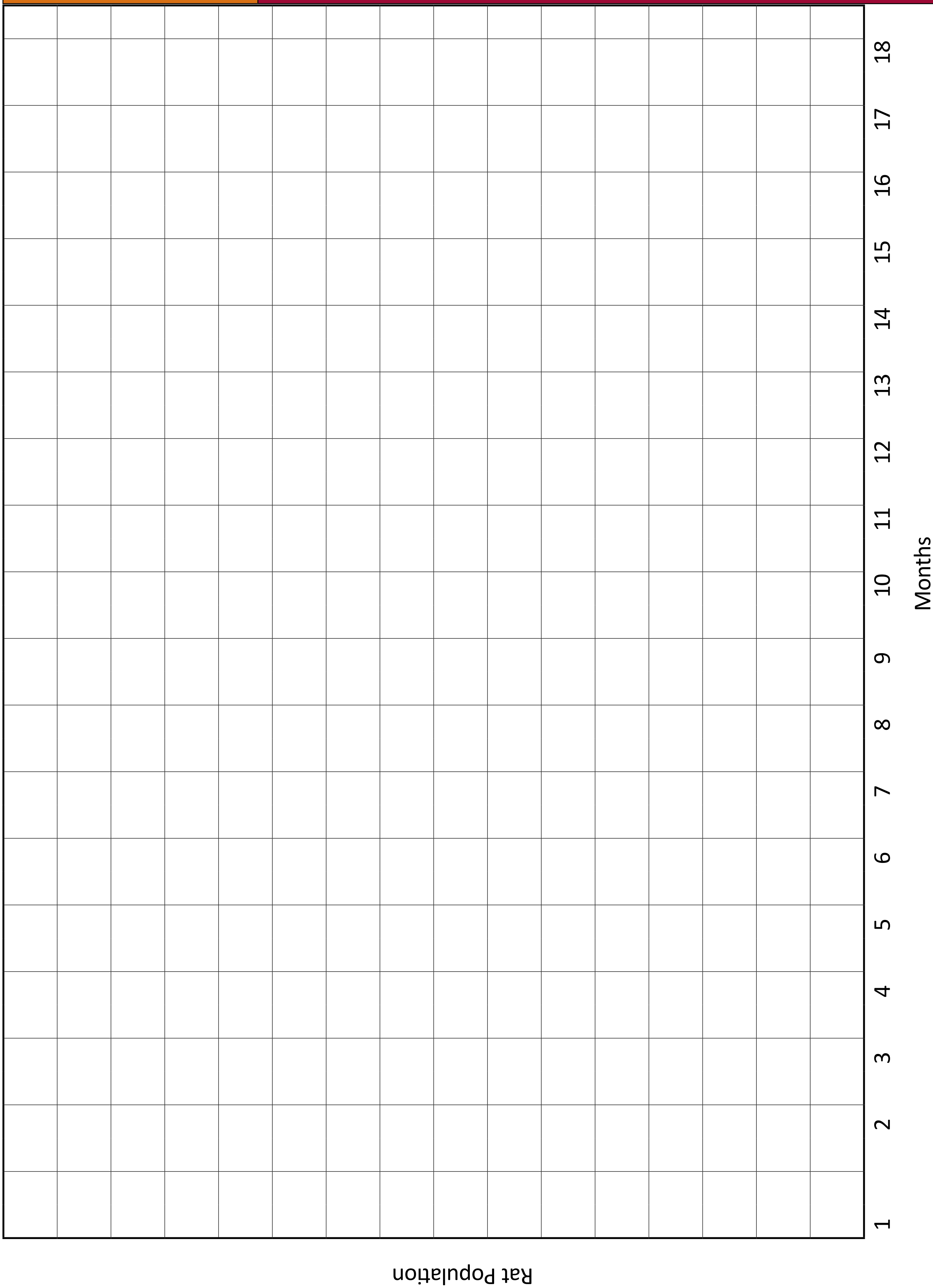
Instructions:

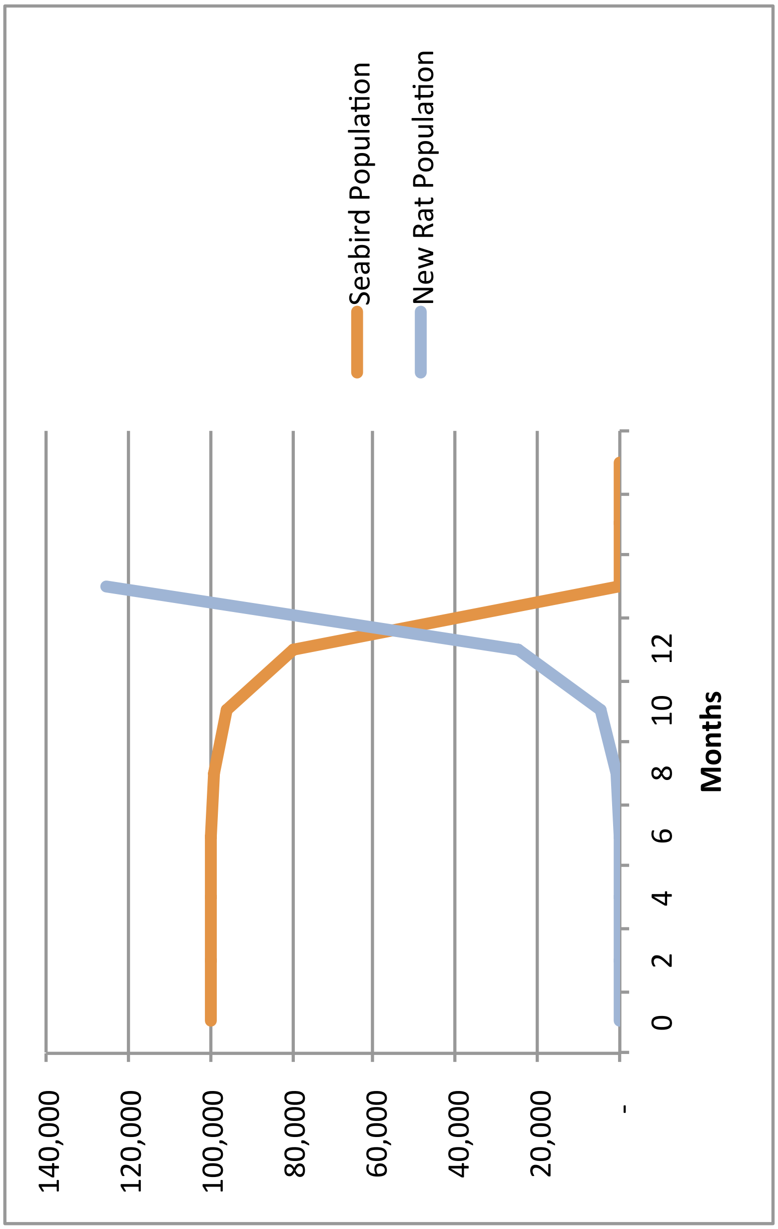
1. Start with one pregnant rat, assume she dies after raising her 8 offspring.
2. She has 8 offspring: 4 male, 4 female.
3. Rats reproduce every 2 months.
4. Each female rat has 8 babies (4 male, 4 female).
5. How many rats are on the island after one year?
6. For every adult rat 2 birds die.
7. On the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

LAB 3.4 RAT INVASION - ACTIVITY BOARD

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						

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