INTERACT EDUCATIONAL TOOL-KIT

Arctic invasions!

Worksheet for students – teacher's version

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Task 1: Digging deep

Digging deep will teach students about invasive species in the Arctic, what we know and what we do not know about invasive species. In addition, it will teach students about the ecological and economic consequences of invasive species.

Students are supposed to answer a series of questions with the help of information that can be found on the websites listed below. The links provide background information for both students and teachers for additional classroom activities. The teachers decide how many of the links they will give the student upfront. The students must cite their source for the answers given. The more original and scientific sources, the better. Teachers can discuss in-class the importance of keeping a critical mind.

https://www.invasive-species.org/about/

https://www.arctictoday.com/invasive-species-still-rare-arctic-soon-change/

https://www.invasivespeciesinfo.gov/subject/ballast-water

https://reclaimingreds.co.uk/whats-on/invasive-species-week-exotic-pet-trade/

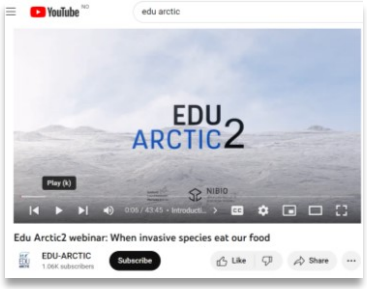
https://www.treehugger.com/exotic-pets-released-into-wild-invasive-species-4869094

https://www.arctictoday.com/invasive-arctic-crab-species-in-norway-are-expanding-to-new-shores/

https://www.arctictoday.com/invasive-pink-salmon-are-surging-in-the-european-arctic-even-as-native-atlantic-salmon-decline/

https://www.nature.org/en-us/what-we-do/our-priorities/protect-water-and-land/land-and-water-stories/invasive-plant-species-invasive-species-education-1/

There are also relevant webinars from Edu-Arctic available for the students:



https://youtu.be/ZCIzT_ldYoU

https://youtu.be/xD7-0clKIB0

https://youtu.be/5tmMfNDoSro

Q1. How many invasive species are there in the Arctic?

ANSWER: Currently, there are only few invasive species found in the Arctic. The essence is that there are far fewer than in warmer climates. Answers giving specific numbers in the low range should be considered correct. Answers saying 'nobody really knows' is also a good answer (but should be combined with the knowledge that there are few).

Q2. Why do scientists believe more invasive species will invade the Arctic in the future?

ANSWER: There are two main reasons: climate change and human travel. Species that are usually found in more southern geographical regions and are adapted to warmer temperatures will be able to survive in more northern regions. Due to climate change, temperatures are especially rising in the Arctic and therefore, researchers are worried that more invasive species will establish stable populations in the north. Additionally, the main way for many invasive species to get to the Arctic is human travel. The tourism going into the Arctic has increased substantially over the last two decades, now offering routes all the way to the North pole!

Q3. How can invasive species be transported and released in new geographical regions?

ANSWER: There are several pathways that add to the transport of invasive species into the Arctic (and elsewhere). One common way is the ballast water discharged from ships. Ships pump water into compartments to stabilize the ship when no cargo is transported. By doing so, they also can pump larvae and eggs, small animals (e.g., mussels, crabs, lobsters, etc.) and plants (e.g., algae) into the ship. At the destination harbour, the water is released and with it the animals and plants in it. Small invasive species can also be tag-alongs to people or their pets or luggage travelling into the Arctic on these ships or by other means. A third pathway is found in aquaculture and fisheries where in the past species have been released in new geographical regions to provide additional food sources for humans. Infamous examples from Arctic areas include the king crab and pink salmon.

Q4. What can YOU do to avoid the spread of invasive species?

ANSWER:

- Verify that the plants you are buying for your yard or garden are not invasive. Replace invasive plants in your garden with non-invasive alternatives. Ask your local nursery staff for help in identifying invasive plants!
- When boating, clean your boat thoroughly before transporting it to a different body of water.
- Clean your boots before you hike in a new area to get rid of hitchhiking weed seeds and pathogens.
- Don't "pack a pest" when traveling. Fruits and vegetables, plants, insects and animals can carry pests or become invasive themselves. Don't move firewood (it can harbour forest pests), clean your bags and boots after each hike, and throw out food before you travel from place to place.

- Don’t release aquarium fish and plants, live bait or other exotic animals into the wild. If you aspire to own an exotic pet, do your research and make sure you can commit to looking after it.
- Volunteer at your local park, refuge or other wildlife area to help remove invasive species. Help educate others about the threat.

Q5. What are some of the consequences of invasive species?

ANSWER:

- Competition with native species regarding resources. These can be of abiotic nature (e.g., competition for oxygen in a pond) or biotic (food competition).
- Environmental change/degradation: invasive species can lead to changes in oxygen levels in water, for example, that impact other species.
- Reduced biodiversity: In the long-term, invasive species can lead to the extinction of other species in the ecosystem.
- Transfer of diseases: Invasive species can transfer diseases to native species; thereby killing native species.
- Economic impacts can be considerable as income from fishing or agriculture can be significantly reduced. This can also lead to social insecurity.

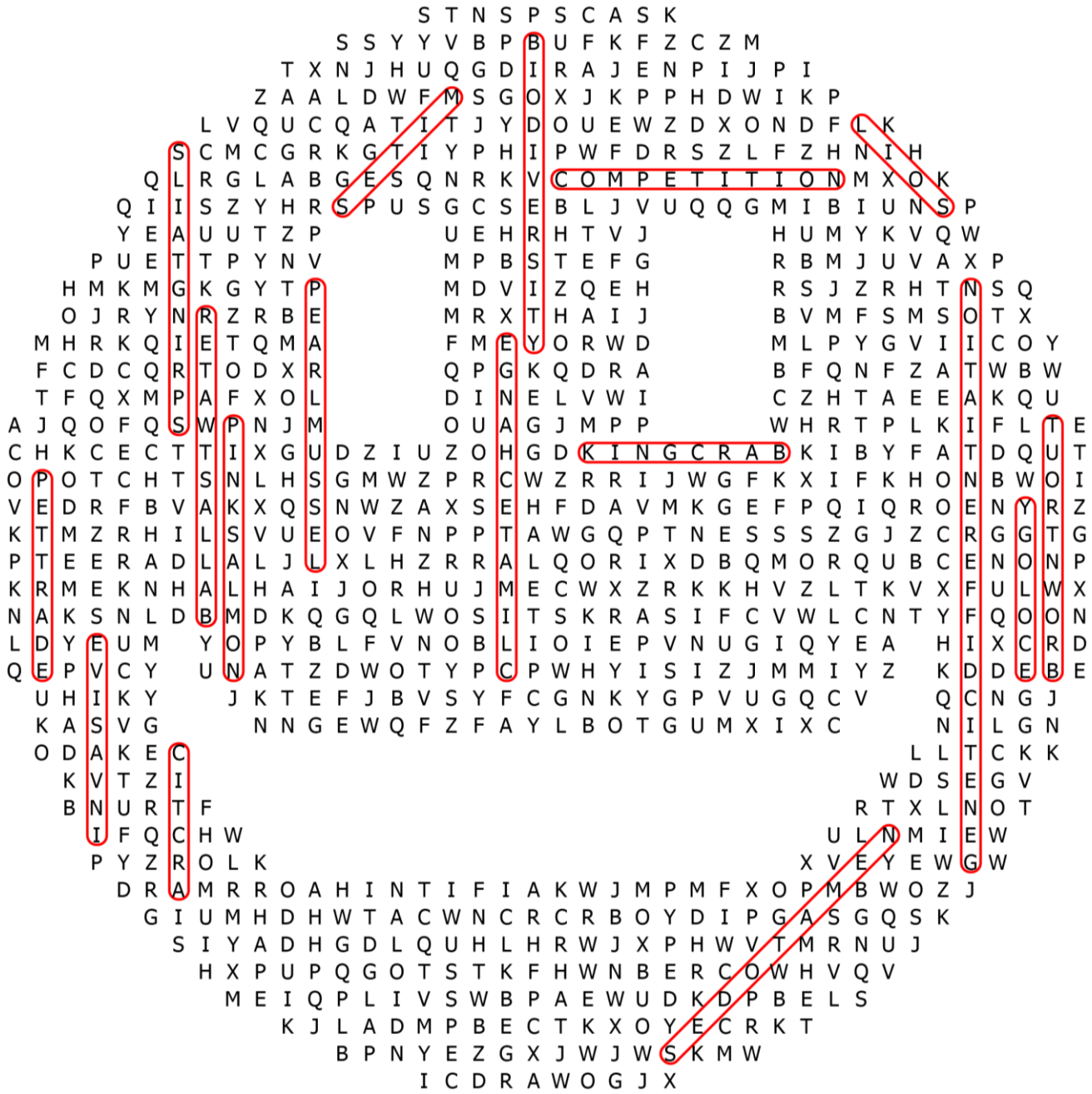
Task 2: Match it!

Answer:

Terms	**Definitions**
Biodiversity	All the different kinds of life you'll find in one area
Invasion pathway	The means and routes by which invasive species get into new environments
Food web	Consists of all food chains in an ecosystem
Invasive species	Is not native to the area, but still gets a dominant role
Exotic species	Is not native to the area
Food chains	Each and any species are part of multiple…

Task 3: Word salad

Answer: See next page


COMPETITION
KINGCRAB

Task 4: OH' ALL THE CHOICES

1. Why are invasive species so successful?

a) They often have high reproduction rates.
b) People like them, bring them to the area and throw a nice party for them
c) They are often generalists, meaning that they can survive in a wide range of conditions
d) All of the above.

NOTE: answer d) can also be correct, and you can use this to do an in-class discussion about alternative b. Multiple invasive species became indeed invasive because people liked them!

2. How much of the global biodiversity is found in soil?

a) 10%
b) 25%
c) 50%
d) 75%

3. Why do we know so little about soil organisms?

a) Few taxonomic experts able to identify soil species
b) They hide very well
c) Research focus has been on species aboveground
d) They are too fast to be captured.

4. What is an example of a social impact of invasive species?

a) Local businesses have financial losses because tourists do not visit the area.
b) They are no longer liked and not invited to parties anymore.
c) An invasive species can give increased income as they are seen as a delicacy.
d) All of the above.

NOTE: answer d) can also be correct, and you can use this to do an in-class discussion about alternative b. Multiple invasive species became indeed invasive because people liked them!

5. Some people feed goldfish in park ponds. What do you think about that?

a) I think, this is a good idea. If we feed them, they will not compete for food sources with other species and therefore, even though they are invasive in many places, they will do no harm.
b) I think this is a bad idea. Feeding them helps them survive and reproduce in areas where they are dangerous to the environment.
c) Well, it can't hurt to feed them. They are cute and if people are enjoying them, then there is nothing wrong with a snack.
d) A and C.

Task 5: Do you know'em?

		
Pink salmon	King crab	European green crab

Task 6: Wanted dead or alive

This task will introduce students to a few more invasive species found in (northern) regions that we have not talked about in the presentations. Students will try to search the web for clues where these species originated, where they were introduced to, and some other characteristics. The three species were chosen to demonstrate that different species can be invasive species (i.e., species on land or flying species rather than aquatic species like in many of the other examples). In addition, one plant species is included here to clarify that also those can be invasive, not only animals! Two species are invasive in Europe and one species is in North America to clarify that this is a worldwide problem. The plant species is also an example for northwards distribution shift of a species. Thus, the variety of examples given here should allow for some discussions in the classroom. The links given below offer the opportunity to adapt this task to more regionally important invasive species. Therefore, one empty poster is included here as well that can be printed out.

Some good starting points for the students to find the missing information are:

http://www.iucngisd.org/gisd/

http://www.controlinroad.org/invasive-plants/norway

https://www.adfg.alaska.gov/index.cfm?adfg=invasiveprofiles.rockdove_distribution

https://www.audubon.org/field-guide/bird/rock-pigeon

Answer: In the students' worksheet only a few parts of the Dead or Alive posters are given. Below all parts are completed (plus the empty sheet if you want to make local ones).

WANTED

DEAD OR ALIVE

Species name:

Photo of culprit!

Crimes:

Features (morphology)

Last seen (origins and current distribution)

Suspected hideouts (habitats, bite marks, and tracks)

WANTED

DEAD OR ALIVE

Species name:

Nutria (*Myocastor coypus*; also known as coypu)

Photo of the culprit

Crimes:

Eating away plants that hold soil in place (avoiding soil erosion) in marshes and wetlands. Killing and robbing local wildlife and fish of their homes. Nutria also transmits various diseases to humans and animals mainly through water contamination.

Features (morphology)

Large rodent with large yellow front teeth (see also the photo on the right). Disguises itself as a beaver but has a round tail. Weighs between 7 and 18 kg and is active at night as many culprits!

Last seen (origins and current distribution)

Originally native to subtropical & temperate South America, it has since been introduced primarily by fur farmers to North America, Europe, Africa, and Asia.

Suspected hideouts (habitats, bite marks, and tracks)

Look for them in wetlands and around marshes, swamps, and drainage canals.

WANTED

DEAD OR ALIVE

Species name:

Narrow-leaved ragwort (*Senecio inaequidens*; also known as South African ragwort)

Crimes:

It is a prolific achene producer and has a vigorous growth and contains pyrrolizidine alkaloids, which are toxic to livestock and other mammals.

Photo of the culprit!

Photo: Sven Follak

Features (morphology)

Perennial (= plant that lives more than two years) herbaceous or woody shrub; up to 1 m in height. Looks lovely with yellow flowers, but do not let this fool you!

Last seen (origins and current distribution)

It is native to Southern Africa, including Lesotho, South Africa, Eswatini, Namibia, Mozambique, and Botswana. Seeds have accidentally been introduced to several locations in Europe in the late 19th and early 20th centuries with wool transports. In Europe the ports of entry were Bremen, Calais, Mazamet, and Verviers. Invasive in: Austria, Germany, Norway, Slovenia, Sweden, and The Netherlands.

Suspected hideouts (habitats, bite marks, and tracks)

Narrow-leaved ragwort commonly lives and travels in ruderal habitats such as railroads, roads, and motorways, vacant or disused land. Plants can be seen on disused land as pioneer species but so far often disappear in an ecological succession. In Central Europe where it first spread, the plant so far seems to use previously unoccupied ecological niches.

WANTED

DEAD OR ALIVE

Species name:

Rock dove, rock pigeon, or common pigeon (*Columba livia*)

Crimes:

Rock doves can be crop pests. In addition, due to their large aggregations, they can displace native birds in developed areas. Rock doves carry a variety of parasites and pathogens that could negatively impact the health of native birds. It is less probable that rock doves will transmit diseases to humans, but it has been a concern because rock doves are a known carrier of avian influenza.

Photo of the culprit!

Photo: Photo: hedera.baltica/Flickr (CC BY SA 2.0)

Features (morphology)

Adult rock doves are 12–14½ in (32-37 cm) long with 25–28 in (64-72 cm) wingspan. This species has a bluish-gray head, neck, and chest with glossy yellow, green, and purple iridescence along its neck and wing feathers. Rock doves have reddish eyes, and their bills are grey with a conspicuous off-white cere. Look out for the red feet! They are masters of disguise because they can look very different in different geographical regions!

Last seen (origins and current distribution)

The Rock Dove is native to western and southern Europe, North Africa, and South Asia and doves have been domesticated for about 10,000 years. Its domesticated form has been widely introduced elsewhere, and is common, especially in cities, over much of the world.

Suspected hideouts (habitats, bite marks, and tracks)

Wild pigeons reside in rock formations and cliff faces, settling in crevices to nest. They nest communally, often forming large colonies of many hundreds of individuals. Wild nesting sites include caves, canyons, and sea cliffs. They will even live in the Sahara so long as an area has rocks, water, and some plant matter. They prefer to avoid dense vegetation. Feral pigeons are usually unable to find these accommodations, so they must nest on building ledges, walls or statues. They may damage these structures via their feces; starving birds can only excrete urates, which over time corrodes masonry and metal.

Task 7: The Earth Puzzle

The student should learn first about the terms below about food webs, nutrient cycles, and invasive species. They can read the following articles themselves and/or the teacher explains some of the background. In short, soil organisms like mites, earth worms, and microorganisms break down organic matter, like, for example, dead leaves or animals. This process, also called decomposition, is important because it leads to release of essential nutrients and natural fertilization of soils. One of the online lessons provided through INTERACT may also serve as background material.

https://kids.frontiersin.org/articles/10.3389/frym.2019.00041

https://kids.frontiersin.org/articles/10.3389/frym.2022.638736

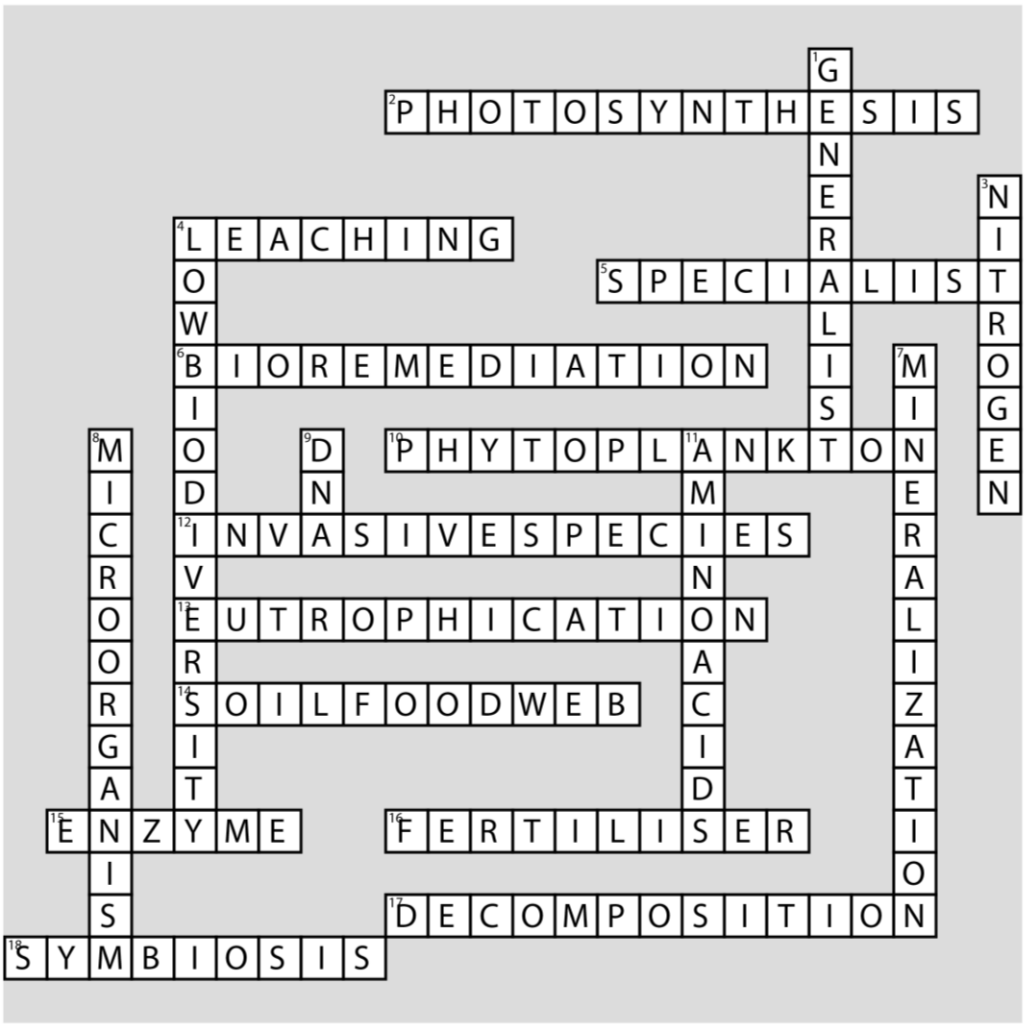
https://kids.frontiersin.org/articles/10.3389/frym.2020.544803

Terms	**Definitions**
Nitrogen	The most abundant element in our atmosphere
Fertiliser	An industrial or natural substance added to soil or land to increase its fertility.
Eutrophication	Excessive amount of nutrients (especially nitrogen) in a lake or other waters, which causes a dense growth of aquatic plant life, such as algae
Microorganism	A very tiny living thing, like a bacterium or virus
Decomposition	The breaking down of organic matter like dead leaves into soil
Photosynthesis	The process in which energy from the sun and carbon dioxide from the air is used by green plants to generate carbohydrates (sugar).
DNA	Carrier of genetic/hereditary information
Amino acids	Substances that contain nitrogen and hydrogen and are building blocks for creating cells, organs, muscles, and tissue
Leaching	The process by which substances, like nitrogen, are leaking from soil into aquatic systems or groundwater
Phytoplankton	Smelly algae (but not only bad)
Bioremediation	Using other microorganisms or tiny living creatures to eat and break down pollution to clean a polluted site.
Symbiosis	Interaction between two different organisms living in close physical association, typically to the advantage of both.
Mineralization	When microbes act on dead organic material, such as animal poo or decomposing plants or dead animals and convert its chemical

	components, like nitrogen, to a form that can be absorbed by plant roots to create new life.
Enzyme	Protein that can break down large and complex molecules into smaller and simpler molecules
Feces	Poo
Soil food web	All the links indicating who eats whom or what in soil
Generalist	Organisms that can eat very different food
Specialist	Organisms that can eat only one or a few types of food
Invasive species	Organisms from another region that do not belong in their new environment but still spread a lot
Low biodiversity	Consequence of invasive species in terms of number of species in the area

ANSWER:

The Earth Puzzle!



Task 8: The multiplying muskrat (*Ondatra zibethicus*).

Acknowledgement: The muskrat challenge was made with inspiration from:
https://seagrant.oregonstate.edu/sites/seagrant.oregonstate.edu/files/nu-t-myocaster_multiplier_0_0.pdf

Introduction

This is an advanced task for higher school levels and includes a mathematic model and calculations to understand how fast an invasive species can grow in a few years. It includes a basic and an advanced level to be widely applicable. In this exercise, students will learn how to calculate population growth and deepen their understanding of possible effects of an invasive species with high reproduction rates. High reproduction rates are one of the characteristics of many successful invaders. The development of math skills, logical thinking, use of scientific models, and evaluation of model assumptions is nurtured as well.

Important note: The background information regarding numbers given below should not be used in the model and it is important to clarify this to students!

Materials needed: Graph paper (or use empty graphs provided), student worksheets, pencil.

Vocabulary: invasive, litter, mathematical model, model assumption, muskrat, rate of change, slope of a graph, wetland, habitat, gestation

Background to teach

The original geographical distribution range of muskrats (or musquash, *Ondatra zibethicus*) included Canada, the United States, and a small part of Northern Mexico. They became an invasive species in north-western Europe because they were introduced in the beginning of the 20th century as a potential fur resource. Since then, they have expanded their distribution range into Russia and parts of Asia.

Muskrats, like other rodents, are prolific breeders. Muskrats can reproduce throughout the year and can have 2 - 3 litters a year of 6 - 8 young each. The babies are born small and hairless and weigh only about 22 grams (0.8 ounces). In southern climates, young muskrats reach sexual maturity in approx. 6 months, while in colder northern climates this development takes about a year. The gestation period (= period of development during the carrying of an embryo, and later fetus) is about 28-30 days.

Muskrat populations, like those of some other rodents, appear to go through a regular pattern of rise and dramatic decline spread over a six- to ten-year period.

As an invasive species, muskrats can cause structural damages to dams and levees as well as railroad/roadbeds; leading to substantial economic damage. They can carry rabies and can negatively impact water quality.

More background on the species can be found here:

https://portal.ct.gov/DEEP/Wildlife/Fact-Sheets/Muskrat

https://en.wikipedia.org/wiki/Muskrat

https://www.newworldencyclopedia.org/entry/Muskrat

Preparation

Teach the background. In addition, students should be provided with an overview on models. Briefly, a scientific model helps people understand scientific concepts and representing them in a visual medium. Models are used to make predictions (for example, climate models). In ecology and in this example, models can be used to predict population growth to inform natural resource management what actions need to be taken to avoid further spread of an invasive species, like the muskrat.

The websites below can be of help with this:

https://www.sciencelearn.org.nz/resources/575-scientific-modelling

https://www.texasgateway.org/resource/scientific-models

https://investigatingsciencehsc.com/scientific-models/

https://study.com/learn/lesson/scientific-models.html

Calculations

Basic level

Assuming no external forces (e.g., no hunting, predation, or extreme weather events) affect the muskrat population, calculate the population size over a period of three years and then prepare a graph showing the changes in population size and number of offspring.

Scenario: One female muskrat and one male muskrat were released in your neighbourhood. In year 1, this female will give birth to 6 surviving young in each of 3 litters. We assume that each litter has an equal number of females and males in it and that each females gives birth to the same number of young each time (this is not how it happens in nature, but for the exercise we must simplify a bit). We also assume that no muskrats die within the three years, and that there are no muskrats migrating into or out of the population.

Start with year 1.

ANSWERS in bold.

1. What is the number of initial females?

   The number of initial females is 1 as only one female muskrat was released.

2. Calculate the total number of muskrats born in year 1.

   Total born per year = initial females × no. of young per female = 3 x 6 = 18

3. How many of those total young are female muskrats?

   In the scenario, it is clarified that a sex ratio of 1:1 is present in muskrats. Therefore, if we have 18 young, then 9 should be female and 9 should be male.

Move into year 2

4. Calculate the total number of female muskrats after year 1, keeping the initial female(s) in mind.

   Total females = (9 young females) + (1 initial female) = 9 + 1 = 10

5. Females are 50% the muskrat population. How many muskrats are there in total after year 1?

   Total muskrats = (total females) × 2 = 10 x 2 = 20 (10 females and 10 males).

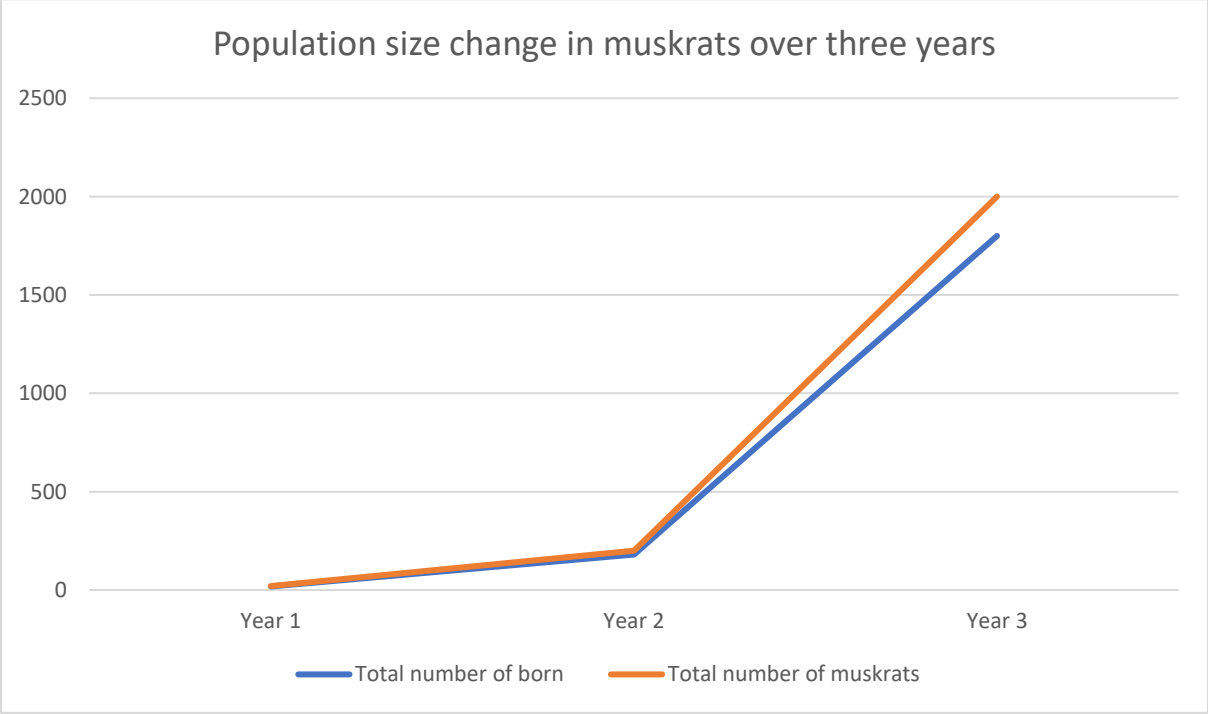
6. What is the number of initial females in the second year?

   Equals the total females after year 1, because we assume no deaths or migrations =10

With these calculations in mind, fill in the rest of the table.

	Year 1	Year 2	Year 3		
Initial females	**1**	**10**	**100**		
Total number of born	**18**	**180**	**1800**		
Females born	**9**	**90**	**900**		
Total females	**10**	**100**	**1000**		
Total number of muskrats	**20**	**200**	**2000**		

Make your own graph or draw on the premade graph below.



Graph: shows how rapidly the population size increases in just 3 years. It demonstrates why high reproduction rates are a key characteristic of many invasive species.

Advanced level

ANSWERS IN BOLD.

Now we expand to five years, and we assume that there is an annual predation rate of 20% in addition to the scenario described above. We also assume that the sex ratio is 1:1 among the muskrats that die from predation.

1. If we take a predation rate of 20% into account, how many muskrats survived year 1?

Total surviving number of muskrats = (total number of muskrats in years 1) × (predation in decimal form) gives the predation in number of individuals = 20 x 0.2 = 4

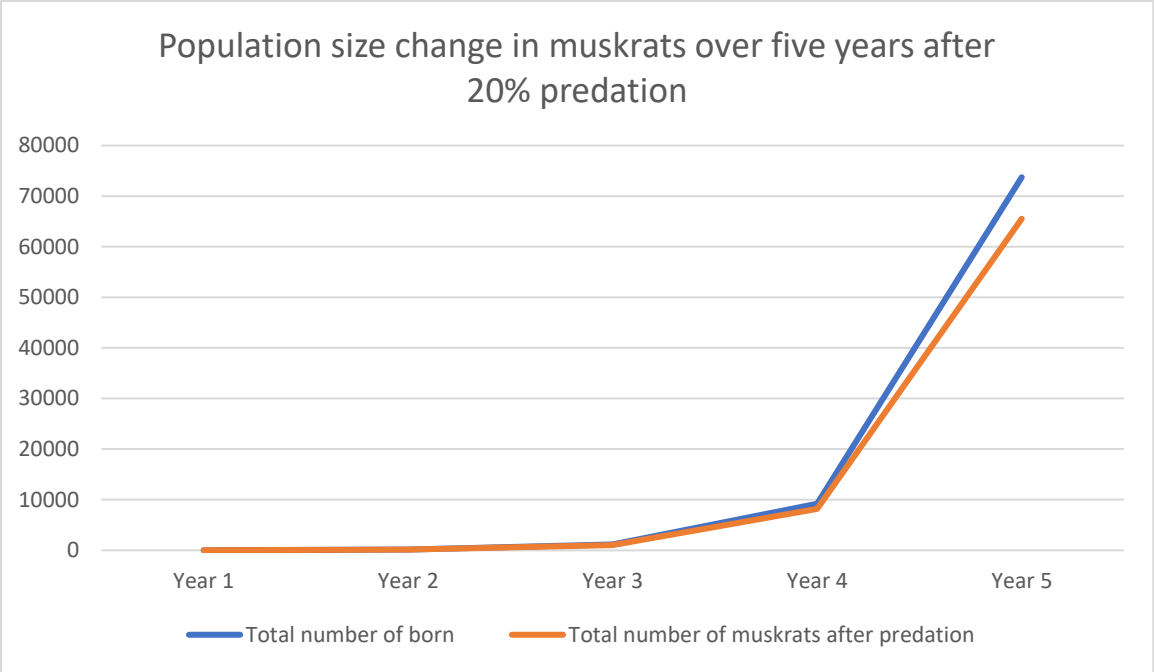
Then, we subtract this value from the total number of muskrats in year 1: 20 – 4 = 16 number of surviving muskrats.

2. Repeat the calculations for the basic level, but take predation into account, and fill in all the empty rows in the table below. Note that you may have to round up or down numbers depending on the initial numbers. Muskrats don't come in halves or thirds :)

   The additional step here compared to the basic level, is to calculate the total number of female muskrats that have survived year 1, to find the number of initial females for the next year. Because we assume that the sex ratio is 1:1 also among the muskrats that die from predation, total surviving females = (total surviving muskrats) / 2, which equals year 2's initial females = 16 / 2 = 8

	Year 1	Year 2	Year 3	Year 4	Year 5
Initial females	**1**	**8**	**64**	**512**	**4096**
Total number of born	**18**	**144**	**1152**	**9216**	**73728**
Females born	**9**	**72**	**576**	**4608**	**36864**
Total females	**10**	**80**	**640**	**5120**	**40960**
Total number of muskrats	**20**	**160**	**1280**	**10240**	**81920**
Total surviving number of muskrats after predation	**16**	**128**	**1024**	**8192**	**65536**
Total surviving females	**8**	**64**	**512**	**4096**	**32768**

Make your own graph or draw on the premade graph below.



Graph: Students' graphs do not have to be 100% exact as the main message should be clear regardless. The main difference between the basic level and the advanced level graphs is that the slope is slower to rise in the advanced scenario (due to predation). In year 3, the muskrat population size is about half in comparison to the numbers without predation.

ANSWERS to Discussion questions

1. Based on the information given in this exercise and the model assumptions as well as calculations - how realistic is this model?

ANSWER: The model captures the high reproductive rates well and demonstrates clearly how fast an invasive species can reproduce in a new habitat. The advanced model is more realistic than the basic model because it includes an additional factor influencing population size and growth. In addition, we expect that the litter sizes and how often females breed will vary from year to year and between females. Also, muskrats will die from other causes than predation, and they will migrate both into and out of the area; thus, the model is a simplification of reality but still demonstrates well how invasive species can rapidly multiply.

2. How likely is it that the population will stay isolated (no immigration or emigration)?

ANSWER: This is not likely at all, unless the muskrats had been placed on an island far into a big ocean. Grown-up muskrats, like most species, want their own home and not stay with their siblings and parents forever. The young will seek out to find partners to mate with that they are not related to, and to find habitats that have free resources.

3. What factors in addition to predation could limit population growth?

ANSWER: In addition to predation, extreme weather events (e.g., very cold or hot weather) may lead to lower population sizes because of higher mortality rates. Other factors may be

limited resources (e.g., not enough food) or diseases that can lower population sizes. In this case, muskrats have been hunted in the past for their fur and this was also a factor limiting their population size. If humans blacklist them, persecution by humans will likely be efficient and the most limiting factor.