



LESSON 2: Outfoxed?

Red and Gray Fox Niches and Adaptations

GRADES: 6-8

OBJECTIVE:

The goal of wildlife ecologists is to study how wild animals interact with their environment. One of the most common questions wildlife ecologists ask is where certain species live, and conservation biologists add to this question, asking how humans impact where species choose to live. This lesson uses online tools and data from the Smithsonian's Urban to Wild camera trapping project to find out how two different fox species use the habitat available to them in Virginia, how their adaptations help them live in different habitats, and how humans affect these species.

KEY QUESTIONS:

- What is a niche?
- How can closely related species live together?
- What is a generalist vs. a specialist, and how are they affected by human activity?
- What are adaptations, and what specific adaptations help species exploit certain niches?

LEARNING GOALS:

After completing this activity, students will be able to:

- Understand niches and niche partitioning
- Be able to recognize generalist and specialist species
- Make a bar graph in Excel/Google Sheets

TIME: Two 50 minute class periods

MATERIALS:

- Paper
- Pens/pencils
- PowerPoint presentation: "Outfoxed"
- Student worksheet for "Outfoxed: Animal Adaptation"
- White/blackboard or large format paper
- Access to <http://www.inaturalist.org/guides/3098>
- "Fox Photos" PowerPoint file, printed in color
- "Excel Graphing Tutorial" file

Throughout this lesson, items in **bold blue font** indicate that students should answer a question on their worksheets.



Outfoxed: Animal Adaptation

STANDARDS:

Virginia State Science Standards Addressed:

(From “Science Standards of Learning for Virginia Public Schools – January 2010”)

- LS.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which:
 - i) patterns are identified in data and are interpreted and evaluated.

- LS.8 The student will investigate and understand interactions among populations in a biological community. Key concepts include:
 - c) competition and cooperation;
 - e) niches.

- LS.9 The student will investigate and understand how organisms adapt to biotic and abiotic factors in an ecosystem. Key concepts include
 - c) adaptations that enable organisms to survive within a specific ecosystem.

- BIO.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which:
 - a) observations of living organisms are recorded in the lab and in the field;
 - b) hypotheses are formulated based on direct observations and information from scientific literature;
 - e) conclusions are formed based on recorded quantitative and qualitative data;
 - g) validity of data is determined.

- BIO.8 The student will investigate and understand dynamic equilibria within populations, communities, and ecosystems. Key concepts include:
 - a) interactions within and among populations including carrying capacities, limiting factors, and growth curves;
 - d) the effects of natural events and human activities on ecosystems; and
 - e) analysis of the flora, fauna, and microorganisms of Virginia ecosystems.



Outfoxed: Animal Adaptation

THE LESSON: DAY 1

STEP 1: *The Niche Concept*

1. If you haven't already done so in this class, introduce the concept of a **species' ecological niche**, or its *role in an ecosystem, including its interactions with other species and its environment*. Niches are defined by many factors, including what a species eats, where it lives, and what it needs to survive.
2. It can help to use an example, so we would suggest one most Virginia students are familiar with: a squirrel. What factors define a squirrel's niche? We'd suggest focusing on the eastern gray squirrel (*Sciurus carolinensis*), as it is the most common squirrel in this region (photos included in the "Outfoxed" PowerPoint presentation). Have students brainstorm key features and ecological facts about the eastern gray squirrel and write them on the board. These may include:
 - they live in trees, specifically deciduous trees – they find food, shelter, and raise their young in trees, though they often visit the ground to find food as well;
 - they are mammals, which means they have fur and feed their babies milk. This has lots of consequences, including that squirrels can be active year round, rather than just in warm temperatures like reptiles or amphibians;
 - squirrels are rodents, and like all their rodent cousins, they have chiseling front teeth, which makes them good at getting into seeds found in the forest;
 - they are mostly herbivorous (eat plant material), but they are opportunists, so their food includes many kinds of seeds and nuts (including acorns, hickory nuts, walnuts, and beechnuts), fruits (including apples, grapes, holly berries), fungi, insects, baby birds, eggs, and even some amphibians (e.g. frogs and salamanders);
 - they don't always eat their food right away – they often hide (or "cache") their food to dig up later, in winter, when food is scarce;
 - because they don't always return to the food they hide, they help many forest plants to disperse their seeds, basically planting their seeds for them!
 - they are food for many forest predators, including birds of prey (hawks and owls), foxes, raccoons, and snakes.

STEP 2: *Brainstorm and research foxes*

1. Now that students have a sense for the traits of an animal that make up its niche, let's focus on foxes. Individually, have students write down everything they know about foxes. Among the questions they should think about:
 - What is a fox?
 - What do foxes eat?
 - Where do they live?



Outfoxed: Animal Adaptation

- How many types (species) of foxes do we have in Virginia?
2. Have students discuss their answers in small groups and then share their ideas as a class. Accumulate students' ideas about foxes on the board. It is important to note at this point that the fox facts students list here are based on their observations and opinions, but aren't necessarily based in science. Students will research more on foxes in a later portion of the lesson, comparing their opinions and observations from a reputable science source: the Encyclopedia of Life.
 3. There's a catch in this story - there are two species of fox in Virginia: the red fox (*Vulpes vulpes*) and the gray fox (*Urocyon cinereoargenteus*)! If students didn't already know this, share this fact now, and prompt them with some questions about niches and these two foxes. *Are the facts they listed on the board likely for both foxes? Which fox have they seen or heard about more often? And, the most important question for today's lesson: If both of these foxes live in Virginia, are their niches the same?*
 4. As you discuss this question, it is important that students learn that **no two coexisting species can have identical niches**. Ecological theory says that one species will always *competitively exclude* the other if their niches overlap, meaning that they won't coexist in that space for a long time. So species with similar niches in an ecosystem often *partition* their resources, meaning that each species takes a different part of a resource. This consequently leads to slightly different niches and the ability to coexist. Resources that are partitioned can be food, habitat, den/nest sites, hunting times (e.g. nocturnal vs. diurnal activity), and many others. For example, two birds living and feeding on insects in the same tree species might appear to have identical niches, but, upon closer look, one bird might feed in the new needle bundles at the top of the tree, while another feeds on the old needles and bare lower branches, allowing them to coexist in those trees due to slightly different niches.

STEP 3: Defining Red and Gray Fox Niches

1. So, how does this relate to foxes? The goal of this lesson is for students to determine how two fox species can coexist in Virginia. The first step is to define the niches of each fox. Again, there are MANY factors that are involved in defining a niche, but we're going to simplify and focus on a few key factors today. Have students use the online eMammal Virginia Camera Trap Field Guide (<http://www.inaturalist.org/guides/3098>) to confirm/check the fox information they came up with as a class and **complete Table 1 on their worksheets**. Suggested answers for Table 1 are listed below.



Outfoxed: Animal Adaptation

TABLE 1 - ANSWERS

	Red Fox	Gray Fox
Length	827-1097 mm	800-1125 mm
Weight	3-7 kg	3.6-6.8 kg
Diet	voles, rabbits, hares, small mammals, birds, fruit, invertebrates	small mammals, fruit, invertebrates
Habitat	edges, cropland, farmland, brush, pastureland, mixed hardwood, suburban, NOT dense forests	deciduous forests, old fields
Active at what time of day?	dusk, dawn, night, sometimes day	night and twilight
Fun Fact(s)	e.g. most widely distributed wild carnivores in the world	climb trees!

- Based on their answers in Table 1, have students write down how the niches of red and gray foxes are similar and how they are different (**Question 2** on their worksheet).
 - They should notice that most features are very similar for these two species. They are about the same size and eat the same foods.
 - The only major difference is habitat – the gray fox lives almost exclusively in deciduous forests and sometimes old fields, while the red fox seems to be able to live in nearly all habitats except dense forests.
- Some species may be more flexible in their niche than others. One feature of a species that relates to niche flexibility is whether a species is a **generalist** or a **specialist**. A **generalist** is a species that can tolerate many different conditions. A species can be a dietary generalist (like humans) and eat many different types of food or a habitat generalist and live in many different habitat types. On the other hand, a **specialist** has features or **adaptations** that make them well suited to a single condition. A dietary specialist in the extreme is a species like a koala, which only eats leaves from eucalyptus trees, and a habitat specialist might live in only one kind habitat, like the northern flying squirrel (*Glaucomys sabrinus*), which in Virginia is only found in high elevation spruce-fir forests.
- Explain the concept of generalists and specialists to the class and have them answer **Question 3** on their worksheet. Answers are below.

	Red Fox		Gray Fox
Diet:	<u>Generalist</u> or Specialist?		<u>Generalist</u> or Specialist?
Habitat:	<u>Generalist</u> or Specialist?		Generalist or <u>Specialist?</u>



Outfoxed: Animal Adaptation

STEP 4: Predicting the Effects of Human Density on Foxes in Virginia

1. The list in Table 1 is based on information from throughout these two species' ranges, but does it hold in Virginia? One of the reasons Virginia is an interesting place to study wildlife is that human impacts in the commonwealth are quite variable – some areas, including those in the Washington, D.C. area are among the most densely populated in the United States, while other areas are largely uninhabited by humans, such as some parts of Shenandoah National Park or the George Washington National Forest. Whereas it is sometimes difficult to measure the habitat in an animal's niche, we have standard measures of human density and are going to use those measures to explore these niches further.
2. Scientists at the Smithsonian Institution wanted to know how these two species, along with many other medium and large mammals, react to differences in human density, and they did this through camera trapping. Today we'll be using data from the Urban to Wild Project (<http://emammal.si.edu/urban-wild>¹), in which scientists and volunteers set up camera traps in five different levels of human population density. Some students may best understand human density as an average lot size for a single house (provided in football fields for a size reference), while it might make more sense to others to think of these categories as the number of houses in a square mile. We've provided both descriptors below, to be used at the teacher's discretion. These density classifications are:
 - i. *urban*
 - lot size: housing lots smaller than 0.25 acres (or 1/5 of a football field...how does that work? Most cities have very tall buildings!)
 - density: ≥ 1000 houses per square mile
 - ii. *suburban*
 - lot size: housing lots between 1/5 of a football field ~1 football field
 - density: 147-1000 houses per square mile
 - iii. *exurban*
 - lot size: housing lots ranging from 1 to 30 football fields
 - density: 12-147 houses per square mile
 - iv. *rural*
 - lot size: lots > 30 football fields, mostly farmland
 - density: 0.5-12 houses per square mile
 - v. *wild* = protected areas with minimal human development
 - density: 0-0.5 houses per square mile

¹Note: When looking at summaries of camera trap projects on eMammal, you may wonder about the words "deployments" and "sequences." We categorize camera-trap data as hierarchical and in four levels (Project, Deployment, Image Sequence, and Image). The terms used in the standard are: (1) A *Project* is a scientific study that has a certain objective, defined methods, and a defined boundary in space and time. (2) A camera *Deployment* is a unique placement of a camera trap in space and time. (3) An image *Sequence* is a group of images that are all captured by a single detection event, defined as all pictures taken within 60 seconds of the previous picture or another time period defined by the Project. A sequence can either be a burst of photographs or a video clip. (4) A camera-trap *Image* is an individual image captured by a camera trap, which may be part of a multi-image sequence.



Outfoxed: Animal Adaptation

3. Once you've explained how the Urban to Wild study was designed, ask students: "Based on what you've learned about these foxes, where in Virginia would you expect to get pictures of each species?" This is a good chance to discuss the alignment of scientific predictions and methods. In the Urban to Wild dataset we don't have specific vegetation data, but we do have human density for each site. So, specifically, their predictions should address these questions, which they can [answer on their worksheets, Question 4](#):
- Do you expect to find more red or gray foxes in northern Virginia? Why?
 - Do you expect red or gray foxes to be found in a wider variety of human densities?
 - In which human density category would you expect to find the most red foxes?
 - In which human density category would you expect to find the most gray foxes?
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THE LESSON: DAY 2

STEP 5: The Effects of Human Density on Virginia Foxes

1. In the "Fox Photos" PowerPoint file associated with this lesson, you will find real fox photos from the Urban to Wild project. The human density classification for each group of photos is listed on each slide.
2. Distribute the 13 sheets in "Fox Photos" among small groups of students and have them identify and tally the number of fox pictures (NOT number of foxes – even if a photo has more than one fox, it should be counted as one fox photo), noting the human density type in which the pictures were taken. Have students report their numbers on the board and enter these data in [Table 2 on their worksheets \(Question 5\)](#).

NOTE: The Urban to Wild Project found a LOT of red foxes; more red foxes than students have time to identify in today's class. To accurately portray Urban to Wild numbers*, students should multiply their red fox photo tally by 4 and enter them in the last column. Answers are below.

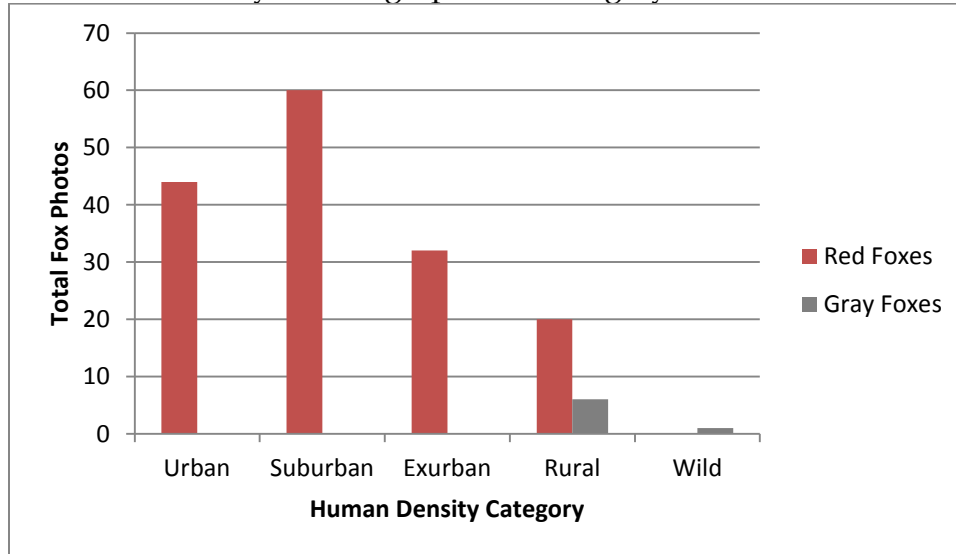
Density	Gray Foxes	Red Foxes	Red Foxes x4
Urban	0	11	44
Suburban	0	15	60
Exurban	0	8	32
Rural	6	5	20
Wild	1	0	0
TOTAL	7	39	156



Outfoxed: Animal Adaptation

*NOTE: These data were adapted from the real Urban to Wild data set from 10 cameras each set in urban and suburban habitats and 20 cameras each in exurban, rural, and wild habitats. All cameras were set for approximately 28 days. So, for example, ~44 red foxes were found over 280 trap nights (10 cameras x 28 days each) in urban areas.

- Next, students will graph their data in Excel using the Excel Graphing Tutorial from eMammal. They should graph tallies of gray foxes and the red foxes x4.



- Have students revisit their predictions from the previous day, reflecting on whether their predictions were supported. If not, why they might have seen the pattern they did?

Prediction (i): More red or gray foxes?

There are more red foxes, because they can live in more habitat types.

Prediction (ii): Density variety?

Red foxes are found in a wider variety of habitats.

Prediction (iii): Red fox density level?

Suburban, because they like edge habitats.

Prediction (iv): Gray fox density level?

Rural, because they like forests and old fields.

STEP 6: Adaptations

- Over millions of years, species have developed **adaptations** that help them extract the most basic needs from their niche in an ecosystem. University of California's Understanding Evolution program (<http://evolution.berkeley.edu/evolibrary/home.php>) defines an adaptation as "a feature that is common in a population because it provides some improved function. ... Adaptations can take many forms: a behavior that allows better



Outfoxed: Animal Adaptation

evasion of predators, a protein that functions better at body temperature, or an anatomical feature that allows the organism to access a valuable new resource.”

2. Returning to our squirrel example from yesterday, brainstorm with students some adaptations that a squirrel has that reflect adaptations to its specific niche. These features might include:

- i. sharp claws for grasping and climbing
- ii. dexterous toes for “ ”
- iii. a long tail for balance
- iv. chisel-like teeth for opening nuts

(See photos of each of these in the “Outfoxed” PowerPoint presentation.)

3. Have students look at their answers in Table 1 and brainstorm in small groups what kind of adaptations red and gray foxes might need to best exploit their niches, specifically, what adaptations might they expect given each species’ diet and habitat preferences? It may help to compare the fox pictures in the “Outfoxed” PowerPoint to photos of other species included in the presentation, including the gray squirrel and bobcat. Adaptations that BOTH foxes have include:

- i. Traits for hunting (“Outfoxed” SLIDE 4):
 - i. Binocular vision (eyes at the front of the head, vs. to the sides like most prey animals, including squirrels)
 - ii. Large ears
- ii. Carnivore dentition, but teeth (particularly molars) are built for some omnivory (compare to the bobcat’s skull – felids [cats] are meat-eating specialists, and lack the grinding molars of canids [dogs]) (“Outfoxed” SLIDE 5)

Adaptations distinguishing the two species are mostly due to the gray fox’s proclivity for climbing trees, including more curved front claws and a more flexible wrist joint.

4. To allow students to synthesize the information they learned over this two day lesson, have them write a short essay reflecting on the following question: Red and gray foxes are closely related and have a lot in common, and yet they are able to coexist in Virginia. How is this possible?

Ideal answers to this question would include a discussion of niche partitioning, including different habitat and hunting habits, and the adaptations that go along with these behaviors.