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, 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
- "Making Bar Graphs in Excel" or "Making Bar Graphs in GoogleSheets" handout

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

Next Generation Science Standards* Addressed:

*GSS Lead States. 2013. *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press.

MS-LS2-2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

MS-LS4-2. Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.

Science and Engineering Practices:

Analyzing and Interpreting Data

Analyzing data in 6-8 builds on K-5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

- Analyze displays of data to identify linear and nonlinear relationships. (MS-LS 4-3)
- Analyze and interpret data to determine similarities and differences in findings. (MS-LS4-1)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 6-8 builds on K-5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories

- Apply scientific ideas to construct an explanation for real-world phenomena, examples, or events. (MS-LS4-2)
- Construct an explanation that includes qualitative or quantitative relationships between variables that predict phenomena. (MS-LS2-2)

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)

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 students are familiar with: a squirrel. What factors define a squirrel's niche? We'll focus on the eastern gray squirrel (*Sciurus carolinensis*), as it is a common North American squirrel (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?
    - How many types (species) of foxes are there in North America?

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 five species of fox on mainland North America: the Arctic fox (*Vulpes lagopus*), kit fox (*Vulpes macrotis*), swift fox (*Vulpes velox*), red fox (*Vulpes vulpes*), and gray fox (*Urocyon cineoargenteus*). If students didn't already know this, share this fact now (Slide 2 in the Outfoxed PowerPoint shares these species' photos and ranges), and prompt them with some questions about niches and these many types of foxes. *Are the facts they listed on the board likely for all foxes? Which fox have they seen or heard about more often?* And, the most important question for today's lesson: *If these foxes all live in North America, 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 North America's two most common foxes, red and gray foxes, can coexist here. 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.

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!

2. 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.

3. 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 is only found in spruce-fir forests. See Outfoxed PowerPoint for images.

4. 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:	(Generalist)	or	Specialist?	(Generalist)	or	Specialist?
Habitat:	(Generalist)	or	Specialist?	Generalist	or	(Specialist?)

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 areas of high human density?

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 eMammal Urban to Wild Project, 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 students might recognize), 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: $\geq$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

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 the Urban to Wild study? 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?

THE LESSON: DAY 2

STEP 5: The Effects of Human Density on 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.

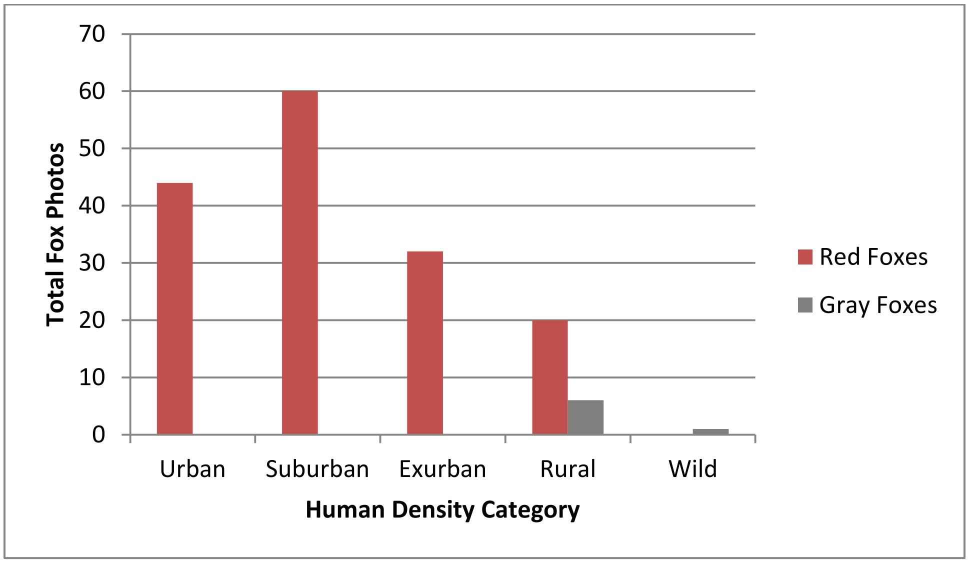
2. Distribute the 13 sheets in "Fox Photos" among small groups of students and have them identify and tally the number of fox pictures (NOT number of foxes – even if a photo has more than one fox, it should be counted as one fox photo), noting the human density type in which the pictures were taken. 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**

   *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.

3. Next, students will graph their data in Excel or GoogleSheets using the "Making Bar Graphs in Excel/GoogleSheets" guide. They should graph tallies of gray foxes and the red foxes x4.



4. Have students revisit their predictions from the previous day, reflecting on whether their predictions were correct, if incorrect, why they might have seen the pattern they did?

<u>Prediction (i)</u>: More red or gray foxes?	*There are more red foxes, because they can live in more habitat types.*
<u>Prediction (ii)</u>: Density variety?	*Red foxes are found in a wider variety of habitats.*
<u>Prediction (iii)</u>: Red fox density level?	*Suburban, because they like edge habitats.*
<u>Prediction (iv)</u>: Gray fox density level?	*Rural, because they like forests and old fields.*

STEP 6: Adaptations

1. 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 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 many states. 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.

1. Use the eMammal Virginia Camera Trap Field Guide to complete Table 1 below. (http://www.inaturalist.org/guides/3098)

TABLE 1

	Red Fox	Gray Fox
Length		
Weight		
Diet		
Habitat		
Active at what time of day?		
Fun Fact(s)		

2. Based on the information you recorded in Table 1, compare and contrast the niches of red and gray foxes. How are their niches similar? Do you see any differences?

3. Take a look at the diet and habitat of the red and gray fox and circle the term below that best fits each species for their diet and the term that best fits their habitat preferences.

	Red Fox	Gray Fox
Diet:	Generalist or Specialist?	Generalist or Specialist?
Habitat:	Generalist or Specialist?	Generalist or Specialist?

4. Based on what you've learned about red and gray foxes, develop predictions about where we might photograph each of these species. Remember our habitat options are *urban, suburban*, *exurban*, *rural*, and *wild*. To do so, answer the following questions in complete sentences:
    i. Do you expect to find more red or gray foxes in the Urban to Wild study? Why?

    ii. Do you expect red or gray foxes to be found in a wider variety of human densities? Why?

    iii. In which human density category would you expect to find the most red foxes? Why?

    iv. In which human density category would you expect to find the most gray foxes? Why?

5. Your teacher will distribute sheets with fox photos from the Urban to Wild Project. Using the knowledge you've acquired on red and gray foxes, identify the foxes in your assigned pictures and tally the number of fox PHOTOS in the space below. ***If there are multiple foxes in a photo, that photo should be counted as one fox photo.***

Sheet Name (e.g. Rural 1)	**Gray Foxes**	**Red Foxes**
___________________	___________________	___________________
___________________	___________________	___________________
___________________	___________________	___________________

Once all groups in your class have tallied their fox photos, enter the class data in the table below. NOTE: The Urban to Wild Project found a LOT of red foxes, but counting them all would take longer than we have in class today. To get numbers that are accurate to the real data set, multiply your red fox numbers by 4 and enter this number in the last column below.

TABLE 2: Count Data

Density	**Gray Foxes**	**Red Foxes**	**Red Foxes x4**
Urban			
Suburban			
Exurban			
Rural			
Wild			
TOTAL			

6. Enter your data (red foxes x4 and gray foxes) in an Excel spreadsheet and graph them as a bar graph using the instructions your teacher has provided. Have your teacher check your graph.

7. Once you have graphed your data, revisit your predictions in Question 4, and circle whether your prediction was correct or incorrect.

<u>Prediction (i)</u>: More red or gray foxes? Correct or Incorrect

<u>Prediction (ii)</u>: Habitat variety? Correct or Incorrect

<u>Prediction (iii)</u>: Red fox habitat? Correct or Incorrect

<u>Prediction (iv)</u>: Gray fox habitat? Correct or Incorrect

Use the space below to explain any predictions that were incorrect. Why might the pattern have been different than you originally predicted?

8. What adaptations might make red and gray foxes good at catching and eating the food they do?

9. Given their habitat preferences, what adaptations might a gray fox need that a red fox doesn’t?

HOMEWORK: In a short essay, reflect on this lesson and the following question: Red and gray foxes are closely related and have a lot in common, and yet they are able to coexist in many U.S. states. How is this possible?

Making Bar Graphs in Google Sheets

A bar graph is used to display data for which the independent variable (on the x-axis) is in categories. Such data are known as discrete or categorical data. In the example given below, we want to graph the number of carnivore species in four U.S. states. Because U.S. states are categories and can't be placed on a number line, this is best graphed as a bar graph. In Google Sheets, a graph with categories on the x-axis is called a "column graph" so these instructions will refer to our graph as a column graph from now on.

STEP 1: Organize and Highlight Data

1. To easily graph your data in Google Sheets, it is important to organize your data in your spreadsheet. Your categories can either be in columns, like so:

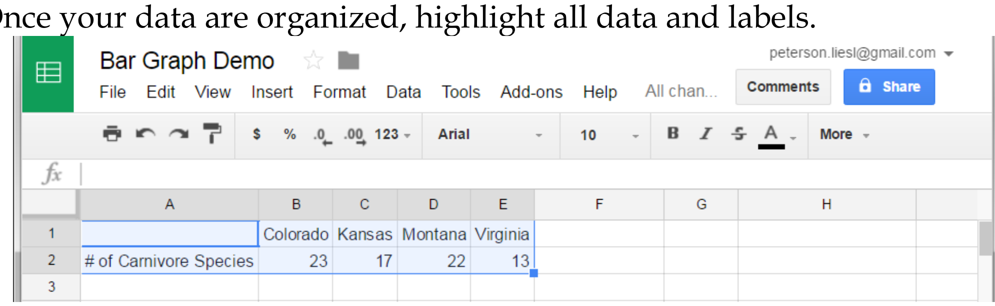
	Colorado	Kansas	Montana	Virginia
# of Carnivore Species	23	17	22	13

or in rows, like so:

	# of Carnivore Species
Colorado	23
Kansas	17
Montana	22
Virginia	13

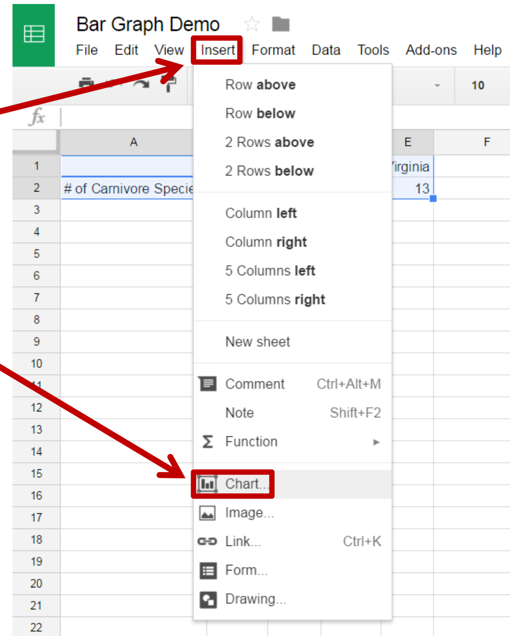
In addition to labels for each of your categories, including a label for your dependent variable (in this case, # of Carnivore Species) will make the graphing process easier. For the remainder of this example, we will assume your categories are in columns, to keep things simple.

2. Once your data are organized, highlight all data and labels.

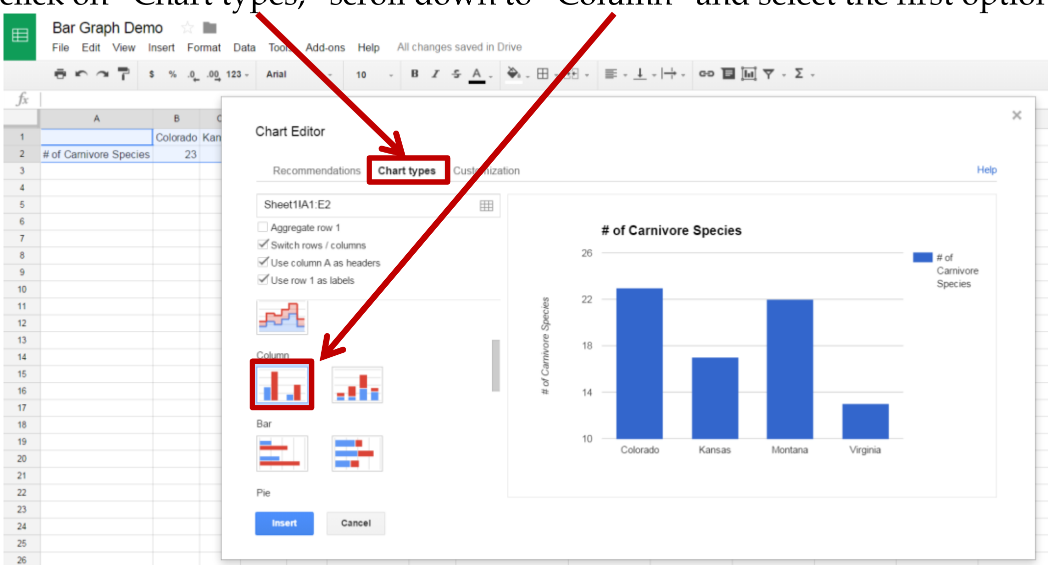


STEP 2: Insert a Graph

1. With data and labels highlighted, click “Insert” → “Chart”



2. With your data organized as above, the graph should already appear as a column chart by default, as pictured below. If a column chart doesn’t appear, click on “Chart types,” scroll down to “Column” and select the first option.

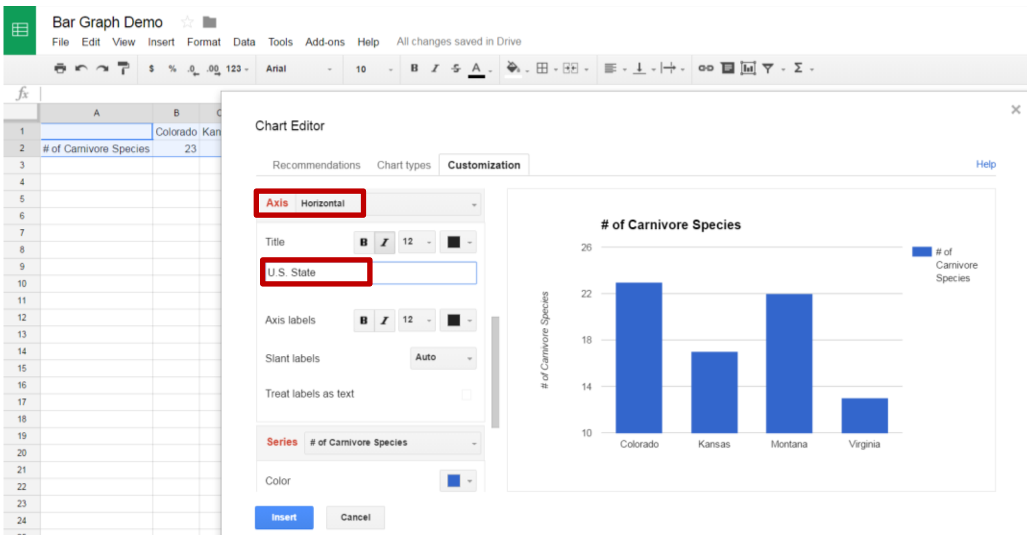


STEP 3: Customize Chart

Clicking "Customization" allows you to customize your chart, including changing or eliminating a title, and changing axes and their labels.

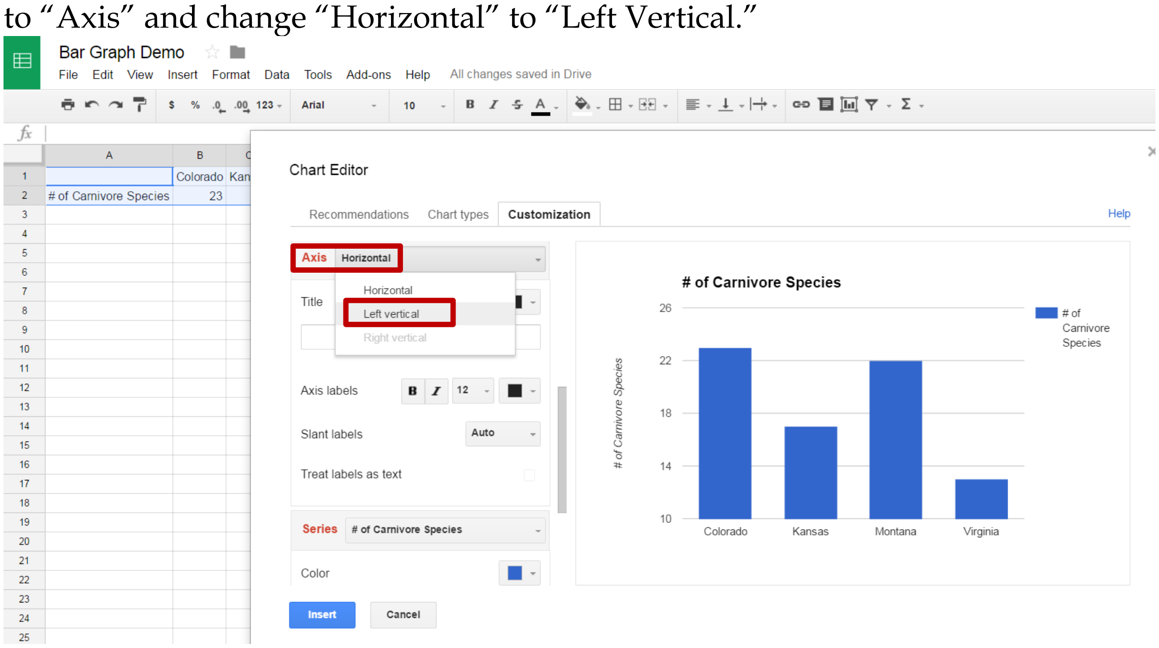
Adding Axis Labels

1. While there are some labels on the x-axis, it is important to provide an over-arching label for all your categories. In this case, that label would be "U.S. State."
2. To add this label, scroll down to "Axis" and type your desired title in the box below "Title."

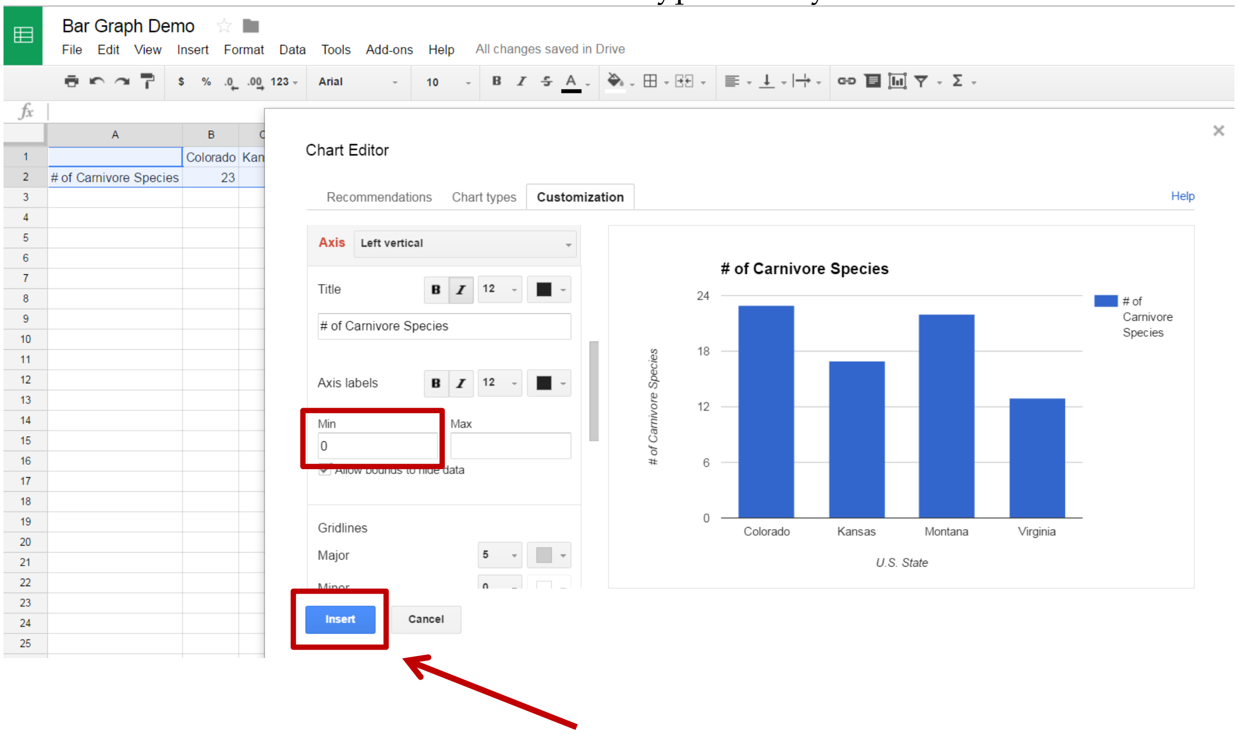


Changing Axis Limits

1. A common issue is that the y-axis does not start at 0. To change this, scroll down to "Axis" and change "Horizontal" to "Left Vertical."



2. Then click in the box below "Min" and type "0" as your minimum value.



3. To complete your chart, click "Insert."
4. If at any point you would like to edit your graph again, you can return to the Customization screen by clicking the small arrow in the top right corner of your chart and selecting "Advanced Edit."