2019

Atlantic Wolffish: A Tale of Missing Teeth. Subjects: Life Science, Biology, Marine/Ocean Science - Grades: 6-8

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ATLANTIC WOLFFISH: A TALE OF MISSING TEETH

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Grade Level
7th Grade

Subject area
Biology and Life Science

The VA SEA project was made possible through initial funding from the National Estuarine Research Reserve System Science Collaborative, which supports collaborative research that addresses coastal management problems important to the reserves. The Science Collaborative is funded by the National Oceanic and Atmospheric Administration and managed by the University of Michigan Water Center. VA SEA is currently supported by the Chesapeake Bay National Estuarine Research Reserve, Virginia Sea Grant, and the Virginia Institute of Marine Science Marine Advisory Program.

Title Atlantic Wolffish: A Tale of Missing Teeth

Focus Use graphing to examine patterns of tooth replacement in the Atlantic Wolffish

Grade Level Life Sciences, Biology; target 7th grade, with ability to scale up to high school Biology

VA Science Standards

LS.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which:

- Data are organized into tables showing repeated trials and means
- A classification system is developed based on multiple attributes
- Data are organized, communicated through graphical representation, interpreted, and used to make predictions
- Patterns are identified in data and are interpreted and evaluated
- Current applications are used to reinforce life science concepts

LS.8 Student will investigate and understand interactions among populations in a biological community:

- Relationship between predators and prey (what happens if the predator must change prey seasonally?)

LS.9 Student will investigate and understand how organisms adapt to biotic and abiotic factors in an ecosystem

- Adaptations that enable organisms to survive

LS.10 The student will investigate and understand that ecosystems, communities, populations, and organisms are dynamic, change over time, and respond to daily, seasonal, and long-term changes in their environment

Learning Objectives

- ✓ Students will make observations about teeth
- ✓ Students will plot observations and compare plots to determine which variable(s) are most important
- ✓ Students will discuss the importance of sample size and how this can limit our understanding of conclusions
- ✓ Students will use data to develop a hypothesis

Total length of time required for the lesson

60-80 minutes total; Advance preparation of lab materials – 15 minutes, Lab setup – 5 minutes, Introduction – 10 minutes, Activity – 30 to 45 minutes, Discussion – 15 minutes, Breakdown and clean-up – 5 minutes.

Key words, vocabulary:

- **Ecology**: the study of how organisms interact with one another and with their environment.
- **Specimen**: an animal or part of an animal preserved for scientific use and kept in a natural history collection.
- **Dentition**: the number, type and arrangement of teeth in an animal.
- **Anterior:** situated near or toward the head.
- **Posterior:** situated behind or at the rear.

Background information

Tooth replacement. Humans only have two tooth generations (i.e., our baby teeth and our adult teeth), but most non-mammalian vertebrates like reptiles and fishes have multiple generations and lifelong tooth replacement. Bony fishes continuously replace teeth throughout their life, yet there is still a poor understanding of the diversity of tooth replacement patterns (Berkovitz and Shellis, 2017). Understanding cycles of tooth replacement can help us understand fish ecology – such as annual feeding cycles and, ultimately, growth of fish over the year.

Diet of Atlantic Wolffish. Adult Atlantic Wolffish, *Anarhichas lupus*, have a dentition consisting of long fang-like teeth in the anterior, and large, round molar-like teeth posteriorly on the upper and lower jaws. Atlantic Wolffish use the large fang-like teeth to capture hard-shelled prey and then use their round, molar-like teeth to crush prey. Diets vary based on location and prey availability, but commonly include bivalves (e.g., sea scallops, ocean quahogs, and surf clams), echinoids (e.g., green sea urchins and sand dollars), brittle stars, gastropods (e.g., whelks and Atlantic moon snails), as well as crustaceans (e.g., hermit and Jonah crabs, and pandalid shrimp). Rarely, fishes such as Atlantic Cod or Cunner occur in stomach contents (Nelson and Ross, 1992). Teeth of Atlantic Wolffish are heavily worn by their diet of hard-shelled organisms. Because of this tooth wear, teeth must be periodically replaced.

Atlantic Wolffish Tooth Replacement. Fishes do not have hands to help them process their food, so teeth play a very important role. Imagine if when we ate clams we chewed them with their shells on?!

This would result in a lot of wear and tear on our teeth. It is no wonder Atlantic Wolffish need to replace their teeth. The unusual part, however, is that Atlantic Wolffish replace their teeth all at once, a pattern known as simultaneous tooth replacement. As far as we know, simultaneous tooth replacement like this occurs only in wolffishes even though there are >30,000 other living species of fishes. Atlantic Wolffish lose the old set of teeth and regenerate them during the winter (Bemis and Bemis, 2015).

Our hypothesis for why simultaneous tooth replacement occurs is that when new teeth are developing they are sensitive and, because the food that they chew is so hard, Atlantic Wolffish have evolved to only replace teeth during one period of the year. This way, an Atlantic Wolffish can stop feeding or switch to soft prey during its tooth replacement period to avoid damaging the new teeth. This hypothesis is supported by stomach contents of Atlantic Wolffish collected without teeth: they have no hard-shelled food in their stomachs. We also know that Atlantic Wolffish reduce their growth rate during winter when they are toothless, which suggests that they are feeding less overall.

Museum Collections. The images of Atlantic Wolffish are from specimens in the Cornell University Museum of Vertebrates. The jaws were dissected out of specimens collected as bycatch (= the unwanted fish caught during fishing), which means that no fish were killed for this study. The Cornell Museum of Vertebrates, like many other collections around the world, allows Ichthyologists (= scientists who study fishes) to borrow specimens for studies. Museums work like a library and each specimen has a unique number assigned to them so they are easy to find and store data with each specimen (e.g., where and when the fish was caught), and so researchers can borrow them to be studied.

Student handouts

- Atlantic Wolffish Specimen Photos 1
- Atlantic Wolffish Specimen Photos 2
- Atlantic Wolffish Worksheet (key provided for instructor)
- Atlantic Wolffish Graph Templates (set of 4 graphs; completed graphs provided for instructor)
    - Location Caught Graph
    - Season Caught Graph
    - Length of Fish Graph
    - Sex of Fish Graph

Materials & Supplies

- Calculator to calculate percentage of present teeth
- Computer and projector for accompanying PowerPoint
- Dry erase board/easel
- Scrap paper and pencils

Classroom Set up

- Students should work in groups of three-four students; set up however best for this

Procedure

Advance preparation of lab materials – 15 minutes

Prepare lesson activity by printing photographs and worksheet for the Atlantic Wolffish teeth in advance.

Each group should have a copy of:

Atlantic Wolffish specimen photos Page 1

Atlantic Wolffish specimen photos Page 2

Ideally photographs should be printed in color, but are usable in black and white; instructor may choose to laminate the Specimen Photos to ensure their longevity.

Each student should have their own copy of:

Atlantic Wolffish worksheet

Atlantic Wolffish graph templates (set of 4 graphs)

- Location Caught Graph
- Season Caught Graph
- Length of Fish Graph
- Sex of Fish Graph

These are not designed to be reusable; print in black and white.

Engagement

Begin the PowerPoint, *Atlantic Wolffish: A Tale of Missing Teeth*

- See slides for specific notes with suggested dialog and discussion

- Start by focusing on slides 2 & 3 which highlight the comparison between tooth replacement in people and sharks
- Ask students:
    - What do you know about shark teeth?
    - Presumably some will say that "sharks replace their teeth are replaced throughout life" and this will begin the discussion of tooth replacement
    - If students are unfamiliar with this, point out the replacement teeth in the shark image on slide 2 in the PowerPoint

Exploration

- Discuss Atlantic Wolffish, where they live, and what they eat
- Watch video by Jonathan Bird in the PowerPoint that shows an Atlantic Wolffish feeding on hard shelled prey that wears their teeth
    - Introduce the concept that fishes, like sharks, also replace their teeth throughout their life
    - Ask questions to get students thinking about tooth replacement in fishes:
        - Why might a fish that eats hard prey replace its teeth?
            - Possible answer: because they wear down their teeth because they are crushing the hard prey which breaks and damages their teeth
        - When a fish replaces their teeth, how do you think they do it?
            - Possible answers: loose one tooth or a few teeth at a time like we do when we lose our baby teeth, or all at once
        - Why might a fish evolve to only loose some teeth at once?
            - Possible answer: so that they can continue to feed while they are replacing their teeth
- Talk about what an Ichthyologist is and discuss ichthyology as a career option
    - Ichthyology is the study of fishes and an ichthyologist is someone who studies fishes as a career (see slides for more details)
- Talk about what a fish collection is and explain that the photographs of fish specimens students will be examining are housed in a fish collection
    - Make comparison to a library, but for natural history specimens (see slides for more details)

Explanation

- Split the class into four groups
- Explain to the class that each group will receive a set of Atlantic Wolffish specimen photos (Atlantic Wolffish specimen photos 1 and Atlantic Wolffish specimen photos 2)
- Hand out Atlantic Wolffish specimen photos 1 and Atlantic Wolffish specimen photos 2 to each group

- Explain that the Specimen Number (the CUMV #, this number is a real catalog number at the Cornell University Museum of Vertebrates) on each Atlantic Wolffish image matches a line in the table.
- Walk through the example Atlantic Wolffish in the PowerPoint to help students see which are present teeth and which are absent teeth
    - This is the hardest part but most important part – teaching students to make the observations about which teeth to call present, and which teeth to call absent
    - Project an image of an Atlantic Wolffish or direct student's attention to the first image and have students try to score the specimen
        - Highlight which teeth are absent and which are present
        - Ask students how they would count the teeth
        - There will likely be variation in the numbers of teeth students come up with from the answer key; this is okay, the teeth are hard to count. However, even a rough count will give them the "correct" answers if students try to do a good job
- Review how to calculate percentages if necessary and discuss why percentages are a better measure than absolute number of teeth here (if individuals have a different number of total teeth, the patterns in tooth loss will still be highlighted) so that students are comfortable filling in the percentages column in the table

Elaboration

- Have students score the rest of the data for Atlantic Wolffish in the table and calculate percentages for the number of teeth present
- Assign each group a variable to graph (i.e., Location Caught, Season Caught, Length of Fish or Sex of Fish)
- Have students complete the plot for their assigned variable
- The only relationship students should find is between Season and percent of teeth present (see answer keys for completed graphs)
- Once each group has a draft of their graph, have the students participate in a gallery walk to see what results from other groups studying other variables found

Differentiate for different skill sets and time available

- Consider the following as modifications based on classroom and time for activity:
    - Graphing can be done in a group to speed up the graphing where only one set of graphs is produced, or as individuals where each student graphs each variable
    - Have each group prepare graphs for all variables in their own groups and eliminate the gallery walk

Evaluation

- Suggested wrap up questions and answers:
    - What variable(s) determines when Atlantic Wolffish are missing their teeth?
        - Answer: Season
    - How did the specimens we had access to affect our conclusions? For example, we only had a few samples from Summer and Fall seasons, and not all Atlantic Wolffish had sex provided in the data
        - Answer: we might consider collecting more data on fish collected in Summer and Fall months, as well as reexamine Sex with more data
    - Ask students to brainstorm why Atlantic Wolffish have evolved to replace all their teeth at once
        - Answer: This is open ended, and we do not know the answer to this question, so encourage students to think broadly
            - One hypothesis we have suggested (Bemis and Bemis, 2015) is that developing teeth are sensitive and because the prey Atlantic Wolfish are chewing is so hard, they have evolved to only replace them during one period of the year. During this period, they stop feeding or switch to soft prey so that the new, incoming teeth are not damaged
- Have students work through the questions at the end of the worksheet either in class or as homework

13. Assessment

Students will be assessed based on their performance on the data table, graphs, and follow up worksheet questions.

14. Acknowledgments

G. Nelson and M. Ross (Nelson and Ross, 1992), and J. Galbraith NOAA Northeast Fisheries Science Center, provided the Atlantic Wolffish specimens now deposited at the Cornell University Museum of Vertebrates (CUMV) that were photographed for this lesson plan. The specimens were accessioned by J. Friel and C. Dardia, CUMV. J. Bird provided access to the video used in the PowerPoint. W. E. Bemis worked together with K. E. Bemis together to develop the research (K. E. Bemis and W. E. Bemis, 2015) that resulted in the data and conclusions presented here as a VA Sea Lesson Plan. Suggestions from A. Markwith and S. McGuire, VIMS, and M. Pfeifer improved the lesson plan. Support for the lesson plan was provided by Virginia Scientists & Educators Alliance.

Atlantic Wolffish: A Tale of Missing Teeth Worksheet

Name_____

Date_____

Introduction. Unlike humans who only replace their teeth once, fishes loose and replace their teeth continuously over their lifetime as the teeth are worn through use. For example, continuous tooth replacement allows fishes like piranhas and sharks to maintain sharp cutting edges on their teeth because these teeth are constantly being replaced.

Atlantic Wolffish, *Anarhichas lupus*, live in the Gulf of Maine in the western North Atlantic Ocean, and feed on hard shelled prey including clams, crabs, snails, and sea urchins. To catch and chew hard prey, Atlantic Wolffish have large fang-like teeth in the front of their mouth and round, molar-like teeth in the back of their mouth used to crush food. However, feeding on hard-shelled prey damages their teeth and so Atlantic Wolffish have evolved to replace their teeth.

The class has received a report of an Atlantic Wolffish that was caught off Stellwagen Bank in the winter with no teeth. Having no teeth (meaning that the Atlantic Wolffish is replacing all its teeth at once) is very unusual and has not been reported for other species of fishes. To study why this specimen of Atlantic Wolffish might not have any teeth, we need to examine more specimens to see what the data suggest.

For our study, we have photographs of Atlantic Wolffish caught at different locations during different times of the year (Spring, Summer, Fall, and Winter). For most individuals, we have data on the size (total length in cm) and sex (Male or Female) of the individual, but sometimes these data are missing. All data available are the Data Table.

Instructions

- With your group, study the images of the lower jaws and teeth of Atlantic Wolffish
- Complete tooth counts:
    - Count the number of teeth present in an individual
    - Count the number of missing teeth in an individual
    - Add these numbers together to get the total number of teeth
    - Calculate the percentage of present teeth by dividing the number of teeth present by the total number of teeth (# teeth present / # of total teeth = % of teeth present)
- Complete the four graphs (Location caught, Season caught, Length of fish, Sex of fish) once you have finished filling out the data table
- Compare the four graphs together and look for patterns in the data. Which graph(s) show(s) a trend?
- Determine which variable(s) are influencing tooth loss, which variables show no patterns, and which you might need more data to confirm your observations
- Discuss your findings with the class about before finishing worksheet

Fill out the Data Table after studying the images of Atlantic Wolffish.

Specimen Number	Location Caught	Season Caught	Length of Fish (cm)	Sex of Fish	# teeth present	# of total teeth	# teeth present / # of total teeth = % of teeth present
CUMV 95987	Great South Channel	Summer	83	F			
CUMV 95988	Great South Channel	Winter	83	M			
CUMV 95989	Great South Channel	Spring	79	F			
CUMV 95990	Brown's Bank	Spring	88	?			
CUMV 95991	Brown's Bank	Fall	70	?			
CUMV 95992	Brown's Bank	Winter	107	?			
CUMV 95993	Cashes Ledge	Spring	82	M			
CUMV 95995	Cashes Ledge	Fall	79	M			
CUMV 95996	Cashes Ledge	Spring	100	M			
CUMV 95998	Stellwagen Bank	Winter	74	?			
CUMV 95999	Stellwagen Bank	Spring	75	?			
CUMV 96000	Stellwagen Bank	Winter	110	F			

Graph the data after you have finished filling out the data table.

Complete the questions below after graphing.

1. If someone showed you a picture of an Atlantic Wolffish without teeth, what would you know about it based on our study?

2. What is one limiting factor the study?

3. How do you think the Atlantic Wolffish might change its diet during times when it has no teeth?

4. Develop a hypothesis for why Atlantic Wolfish replace all their teeth simultaneously. What evidence supports your hypothesis or what data would you need to collect to support it?

Atlantic Wolffish: A Tale of Missing Teeth Worksheet

Name__ Instructor Key_

Date_____

Introduction. Unlike humans who only replace their teeth once, fishes loose and replace their teeth continuously over their lifetime as the teeth are worn through use. For example, continuous tooth replacement allows fishes like piranhas and sharks to maintain sharp cutting edges on their teeth because these teeth are constantly being replaced.

Atlantic Wolffish, *Anarhichas lupus*, live in the Gulf of Maine in the western North Atlantic Ocean, and feed on hard shelled prey including clams, crabs, snails, and sea urchins. To catch and chew hard prey, Atlantic Wolffish have large fang-like teeth in the front of their mouth and round, molar-like teeth in the back of their mouth used to crush food. However, feeding on hard shelled prey damages their teeth and so Atlantic Wolffish have evolved to replace their teeth.

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Instructions.

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- Complete tooth counts:
    - Count the number of teeth present in an individual
    - Count the number of missing teeth in an individual
    - Add these numbers together to get the total number of teeth
    - Calculate the percentage of present teeth by dividing the number of teeth present by the total number of teeth (# teeth present / # of total teeth = % of teeth present)
- Complete the four graphs (Location caught, Season caught, Length of fish, Sex of fish) once you have finished filling out the data table
- Compare the four graphs together and look for patterns in the data. Which graph(s) show(s) a trend?
- Determine which variable(s) are influencing tooth loss, which variables show no patterns, and which you might need more data to confirm your observations
- Discuss your findings with the class about before finishing worksheet

Fill out the Data Table after studying the images of Atlantic Wolffish.

Specimen Number	Location caught	Season caught	Length of fish (cm)	Sex of fish	# teeth present	# of total teeth	# teeth present / # of total teeth = % of teeth present
CUMV 95987	Great South Channel	Summer	83	F	32	32	32/32 = 100%
CUMV 95988	Great South Channel	Winter	83	M	7	44	7/44 = 15%
CUMV 95989	Great South Channel	Spring	79	F	36	37	36/37 = 97%
CUMV 95990	Brown's Bank	Spring	88	?	41	41	41/41 = 100%
CUMV 95991	Brown's Bank	Fall	70	?	15	33	15/33 = 45%
CUMV 95992	Brown's Bank	Winter	107	?	1	36	1/36 = 3%
CUMV 95993	Cashes Ledge	Spring	82	M	33	36	33/33 = 100%
CUMV 95995	Cashes Ledge	Fall	79	M	31	42	31/42 = 74%
CUMV 95996	Cashes Ledge	Spring	100	M	40	40	40/40 = 100%
CUMV 95998	Stellwagen Bank	Winter	74	?	0	36	0/36 = 0%
CUMV 95999	Stellwagen Bank	Spring	75	?	37	37	37/37 = 100%
CUMV 96000	Stellwagen Bank	Winter	110	F	6	36	6/36 = 17%

Graph the data after you have finished filling out the data table.

Complete the questions below after graphing.

5. If someone showed you a picture of an Atlantic Wolffish without teeth, what would you know about it based on our study?
    a. It was caught in the winter.

6. What is one limiting factor of the study?
    a. Limited data for sex of fish
    b. Not as much data for fall or summer fish

7. How do you think the Atlantic Wolffish might change its diet during times when it has no teeth?
    a. Feed on softer foods like fishes, reduce feeding, or not feed at all.

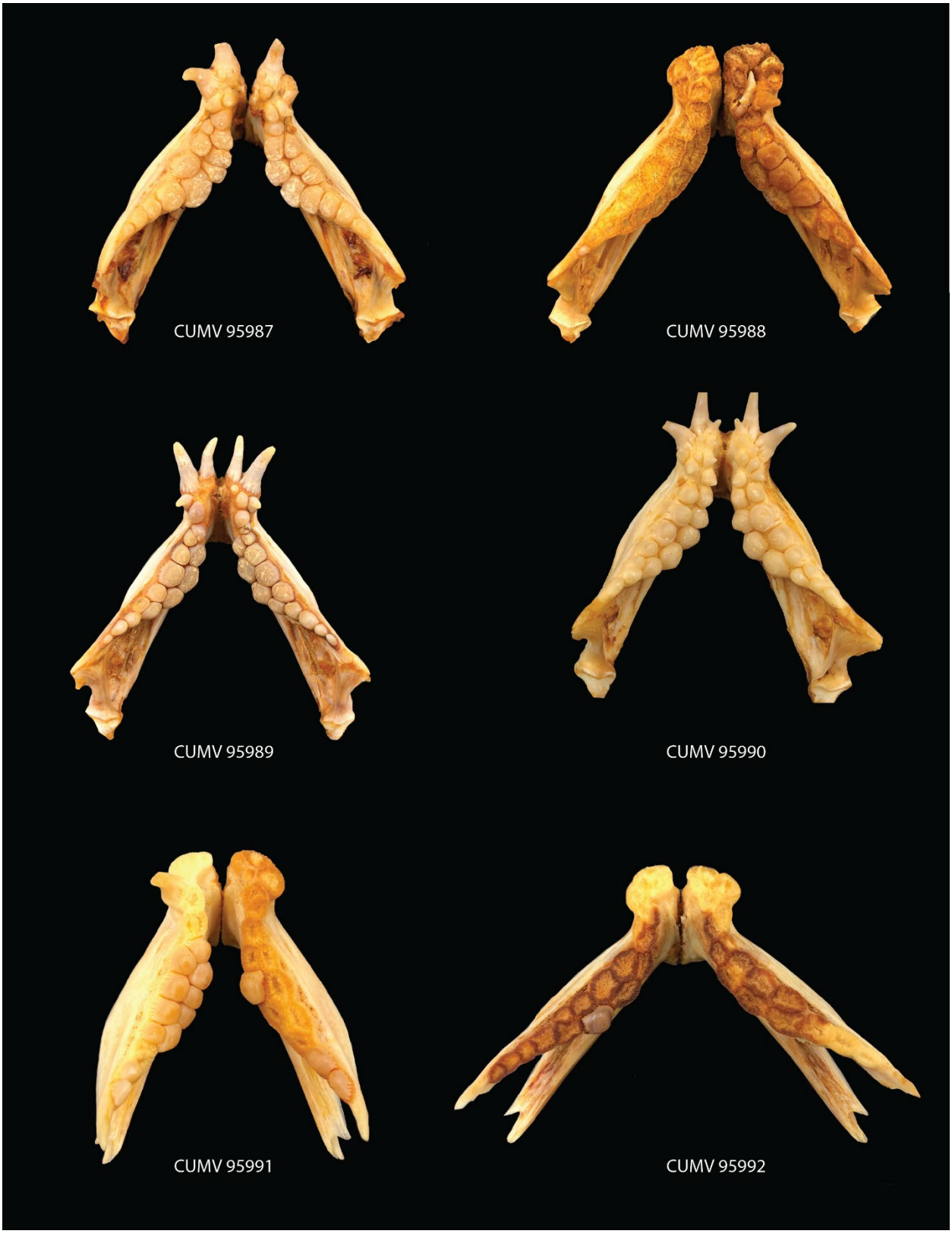
8. Develop a hypothesis for why Atlantic Wolfish replace all their teeth simultaneously. What evidence supports your hypothesis or what data would you need to collect to support it?
    a. This is open ended, and we do not know the answer to this question, so encourage students to think broadly
    b. One hypothesis we suggested (Bemis and Bemis, 2015) is that developing teeth are sensitive and because the prey Atlantic Wolfish are chewing is so hard, they have evolved to only replace them during one period of the year. During this period, Atlantic Wolfish stop feeding or switch to soft prey so that the new, incoming teeth are not damaged.

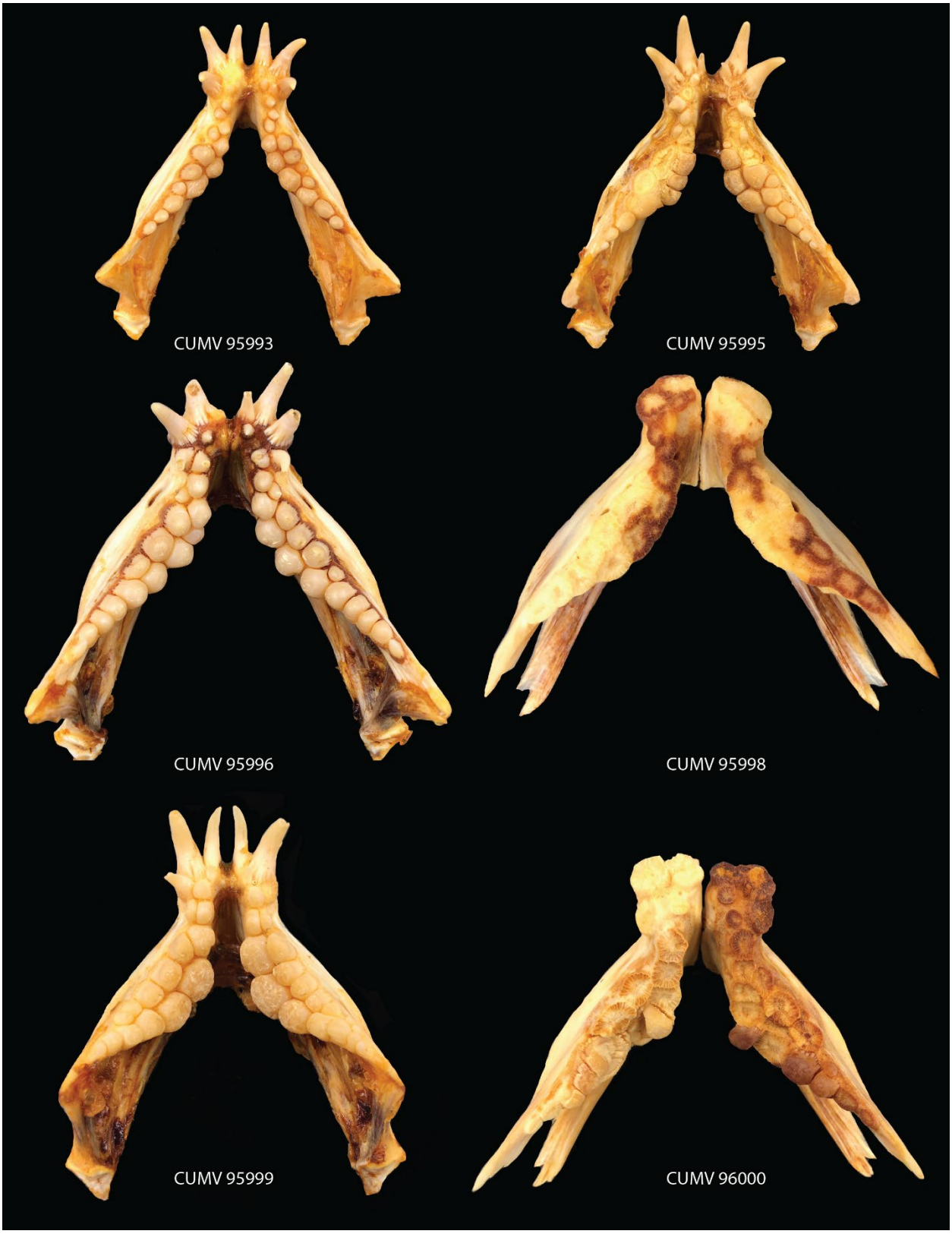
References and further reading:

Bemis, K. E., and W. E. Bemis. 2015. Functional and developmental morphology of tooth replacement in the Atlantic Wolffish, *Anarhichas lupus* (Teleostei: Zoarcoidei: Anarhichadidae). Copeia 103: 886-901.

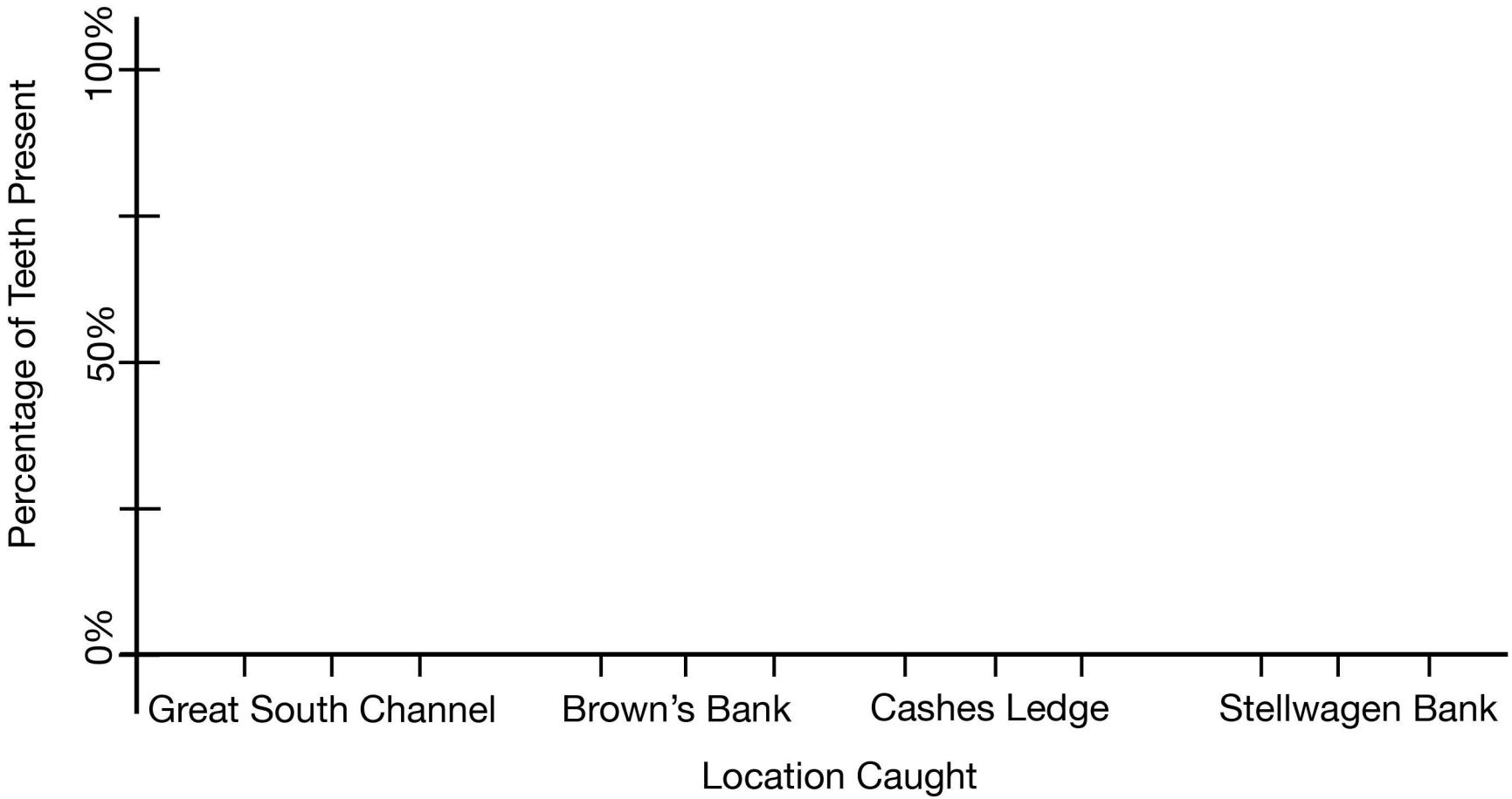
Berkovitz, B. K. B. and R. P. Shellis. 2017. The Teeth of Non-Mammalian Vertebrates, 1st edition. Academic Press, 354 pg.

Nelson, G. A., and M. R. Ross. 1992. Distribution, growth and food habits of the Atlantic Wolffish (*Anarhichas lupus*) from the Gulf of Maine-Georges Bank region. Journal of Northwest Atlantic Fishery Science 13:53–61.

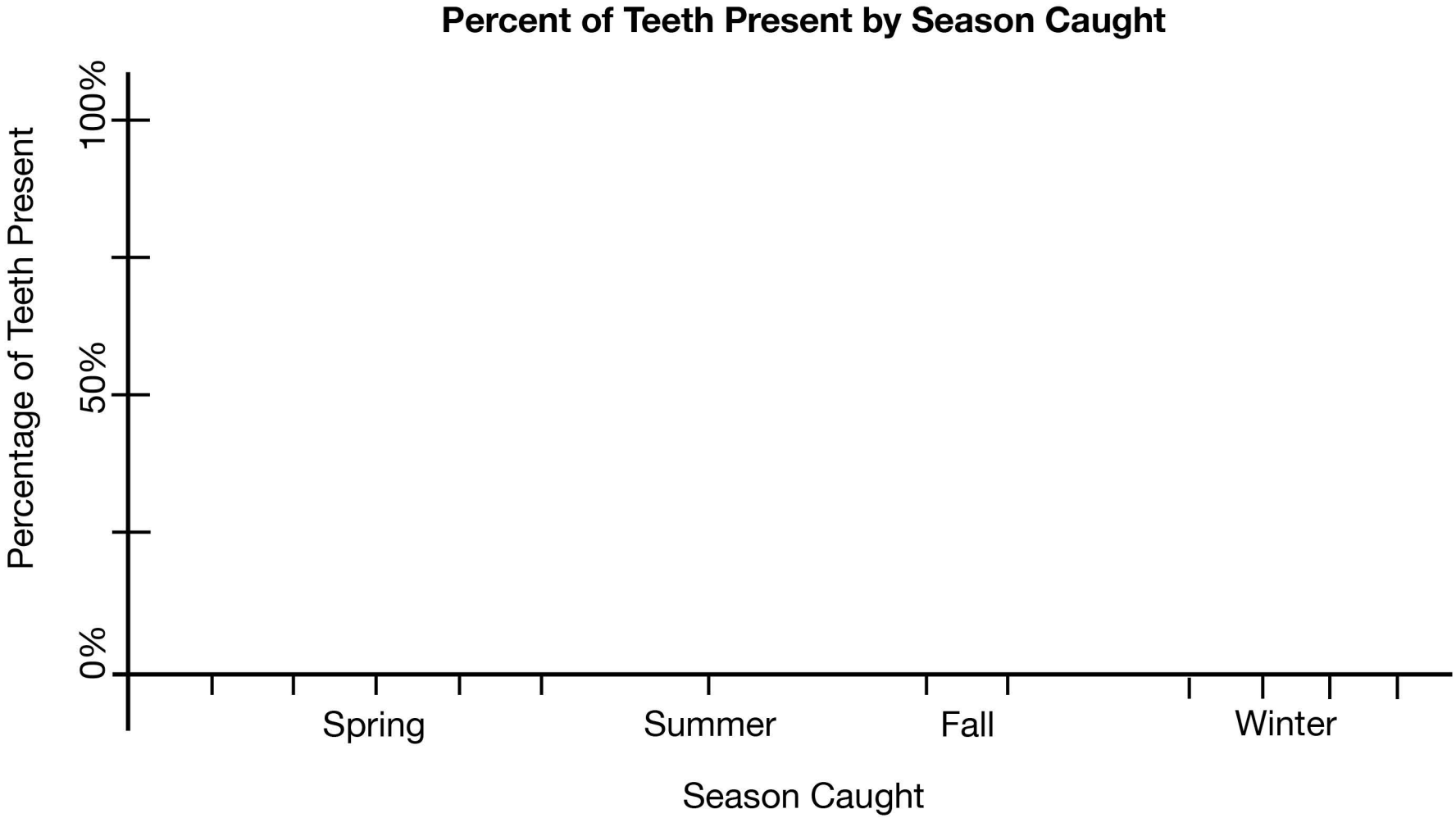

CUMV 95987
CUMV 95988
CUMV 95989
CUMV 95990
CUMV 95991
CUMV 95992


CUMV 95993
CUMV 95995
CUMV 95996
CUMV 95998
CUMV 95999
CUMV 96000

Percent of Teeth Present by Location Caught

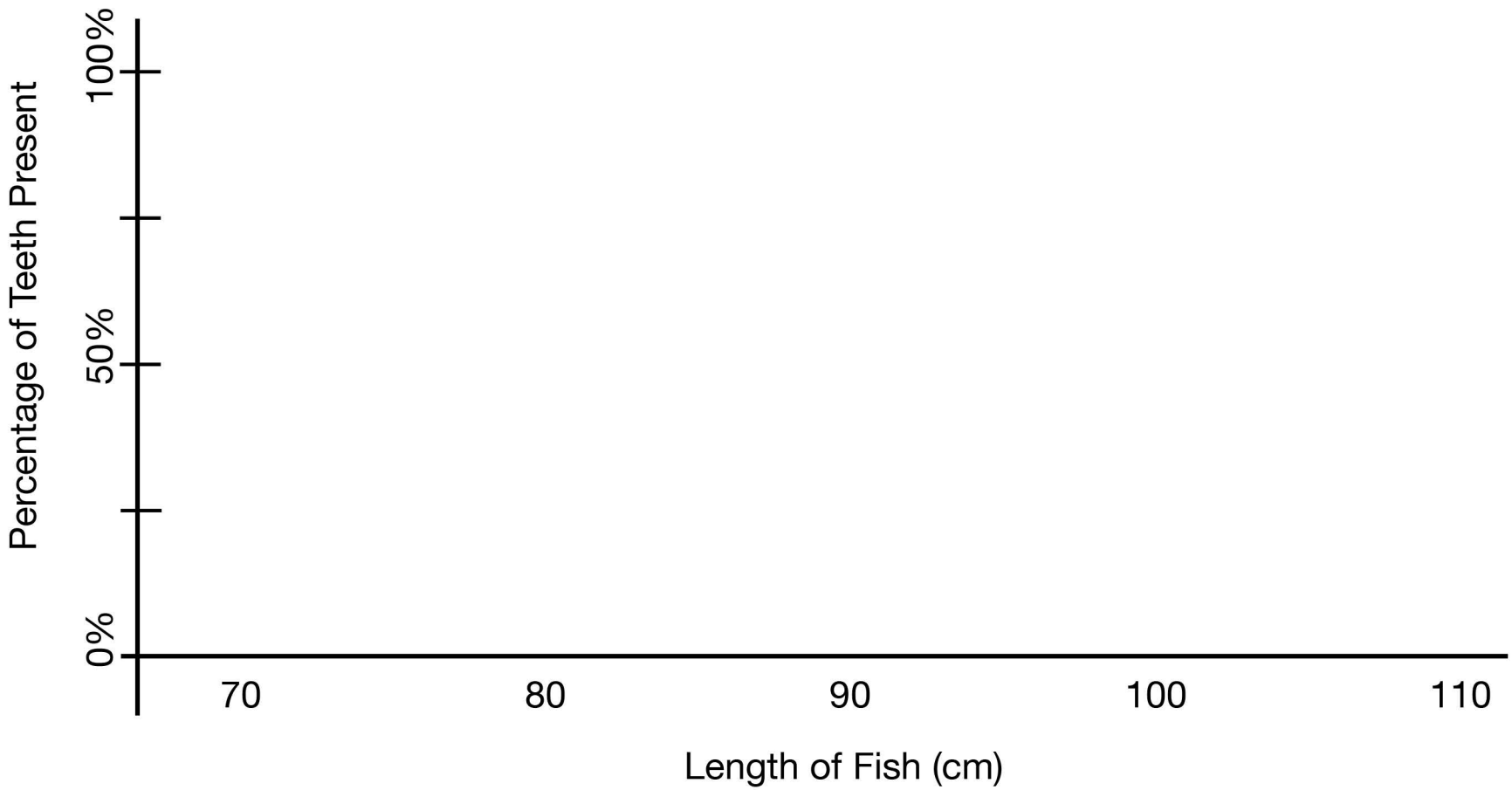


- Use a bar graph to plot the data from the percentages of present teeth from the data table by Location Caught.
- The hash marks on the x-axis will help you place your bars.
- Is there an observable trend that suggests Location Caught influences the Percent of Teeth Present? It is okay if there is no trend.



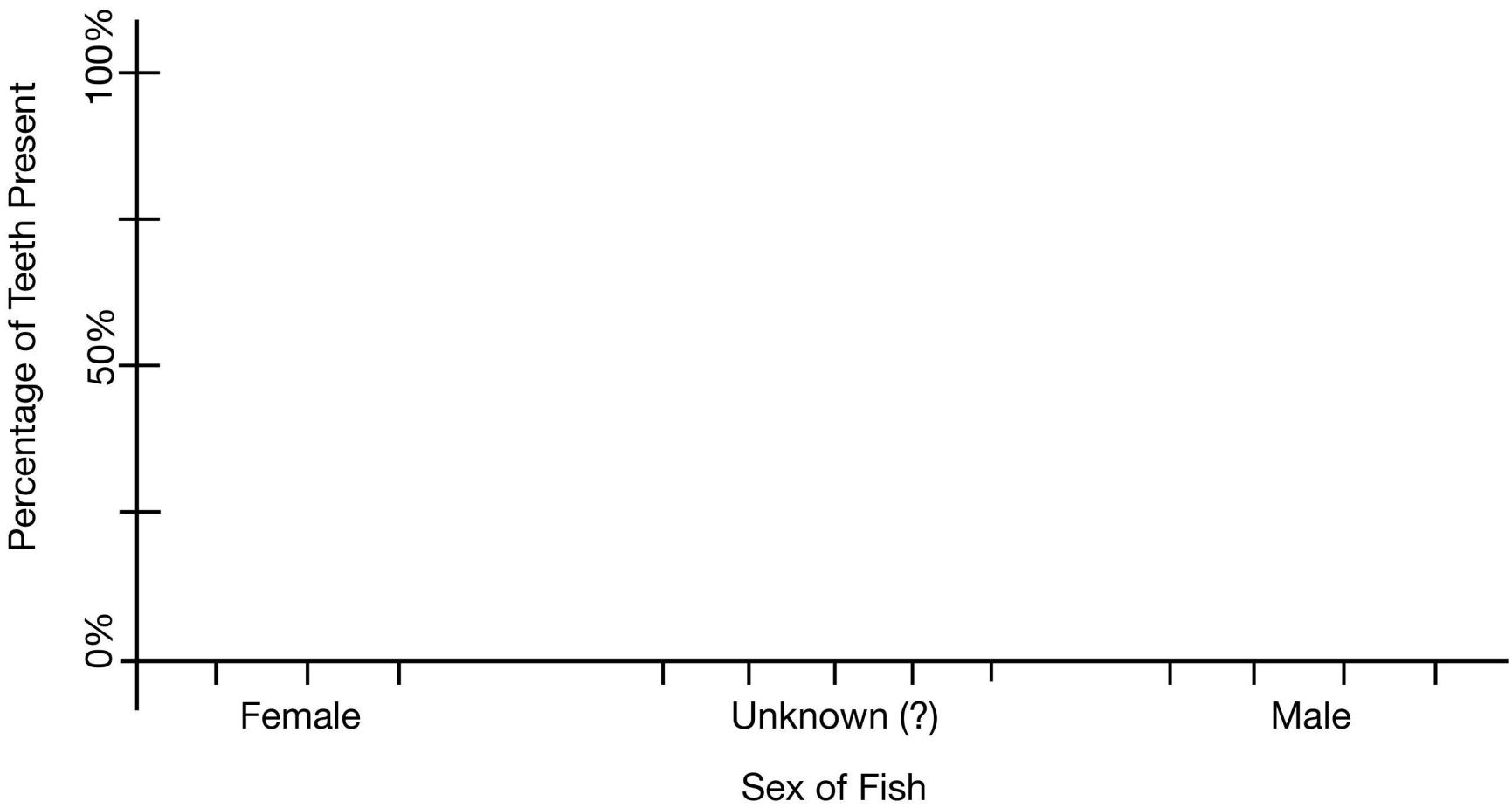
- Use a bar graph to plot the data from the percentage of present teeth from the data table by Season Caught.
- The hash marks on the x-axis will help you place your bars.
- Is there an observable trend that suggests Season Caught influences the Percent of Teeth Present? It is okay if there is no trend.

Percent of Teeth Present by Length of Fish (cm)

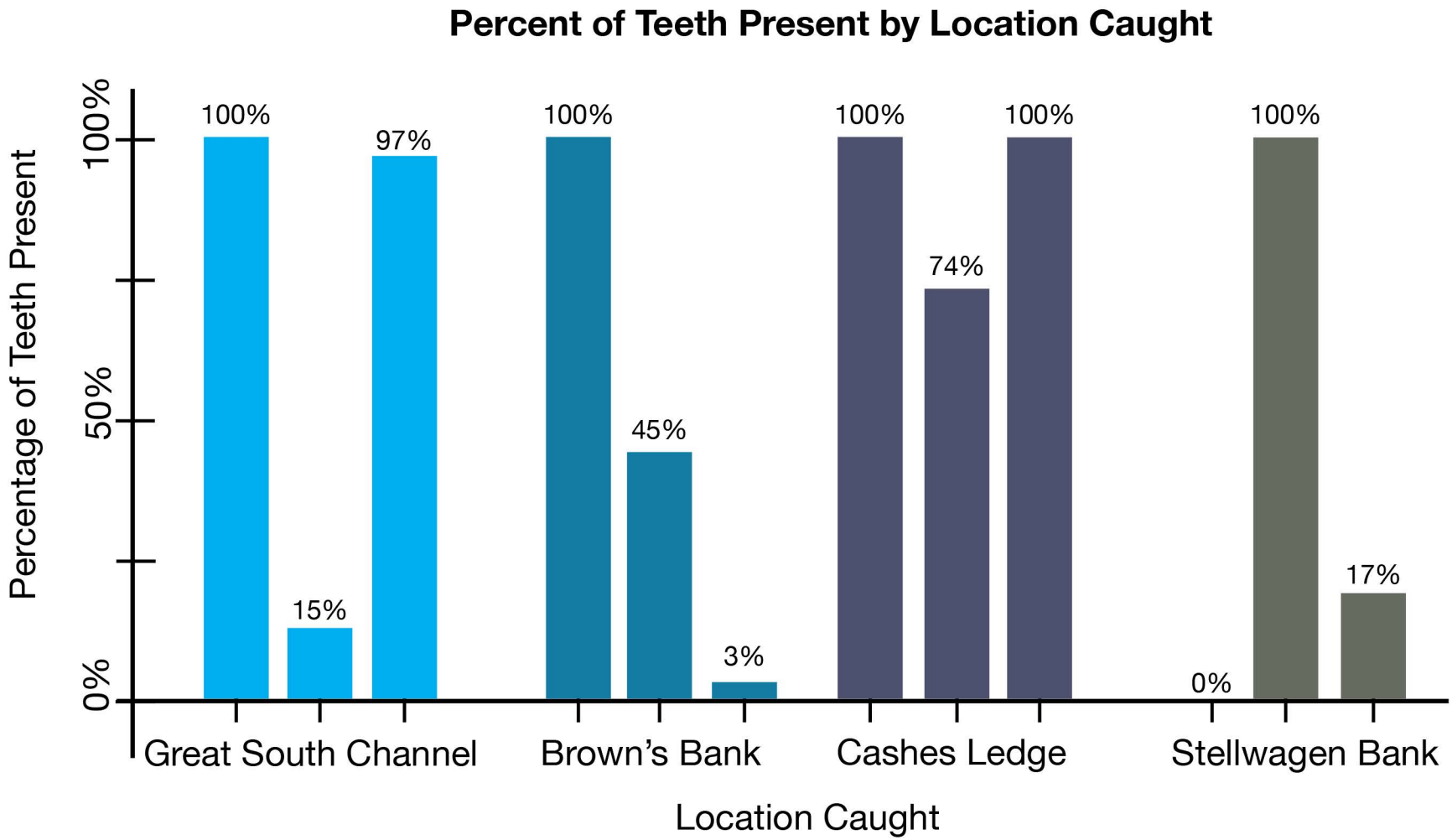


- Use a scatter plot graph the data from the percentages of present teeth from the data table by Length of Fish.
- Place an X for each individual fish on the graph.
- Is there an observable trend that suggests Length of Fish influences the Percent of Teeth Present? It is okay if there is no trend.

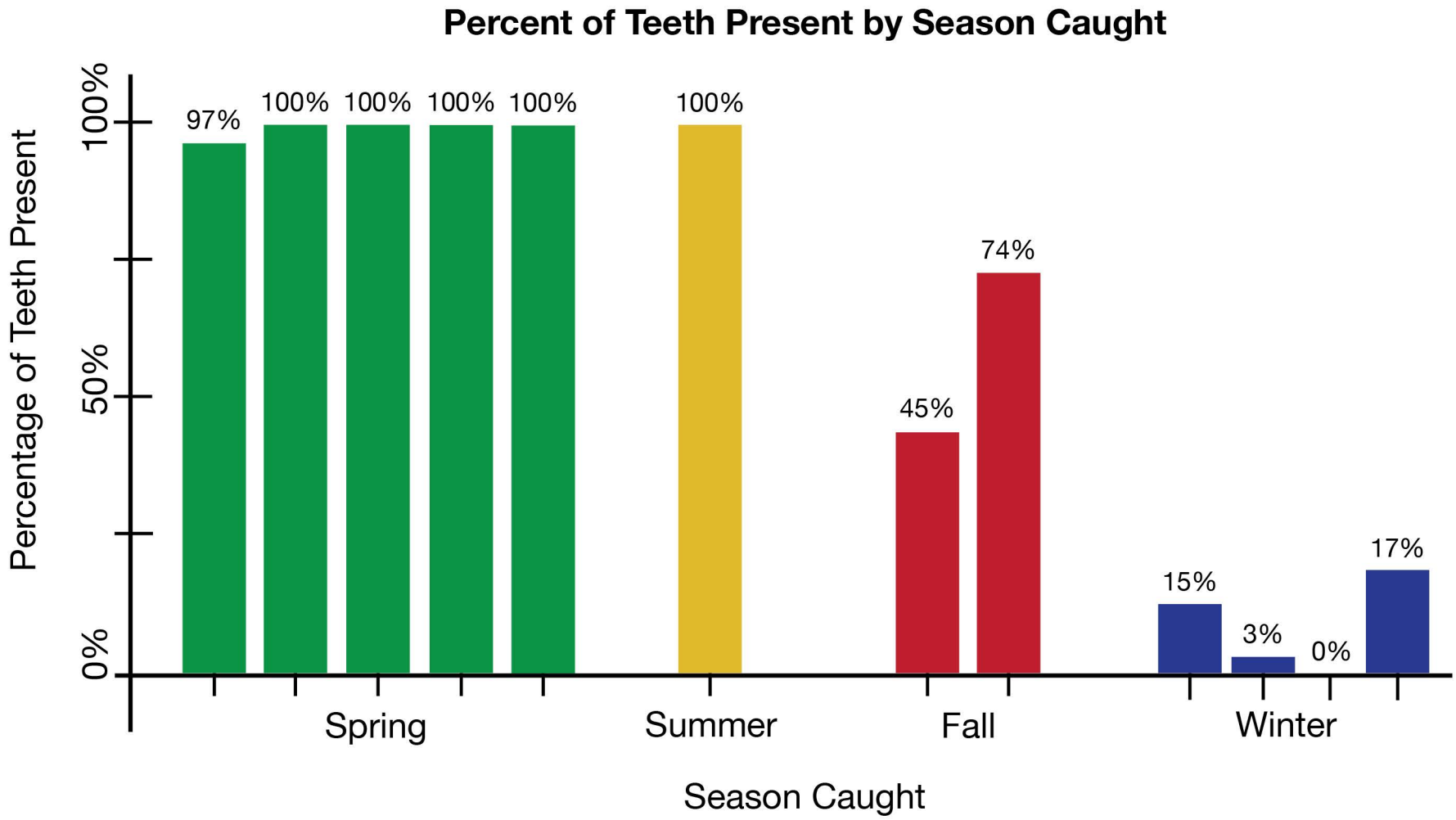
Percent of Teeth Present by Sex of Fish



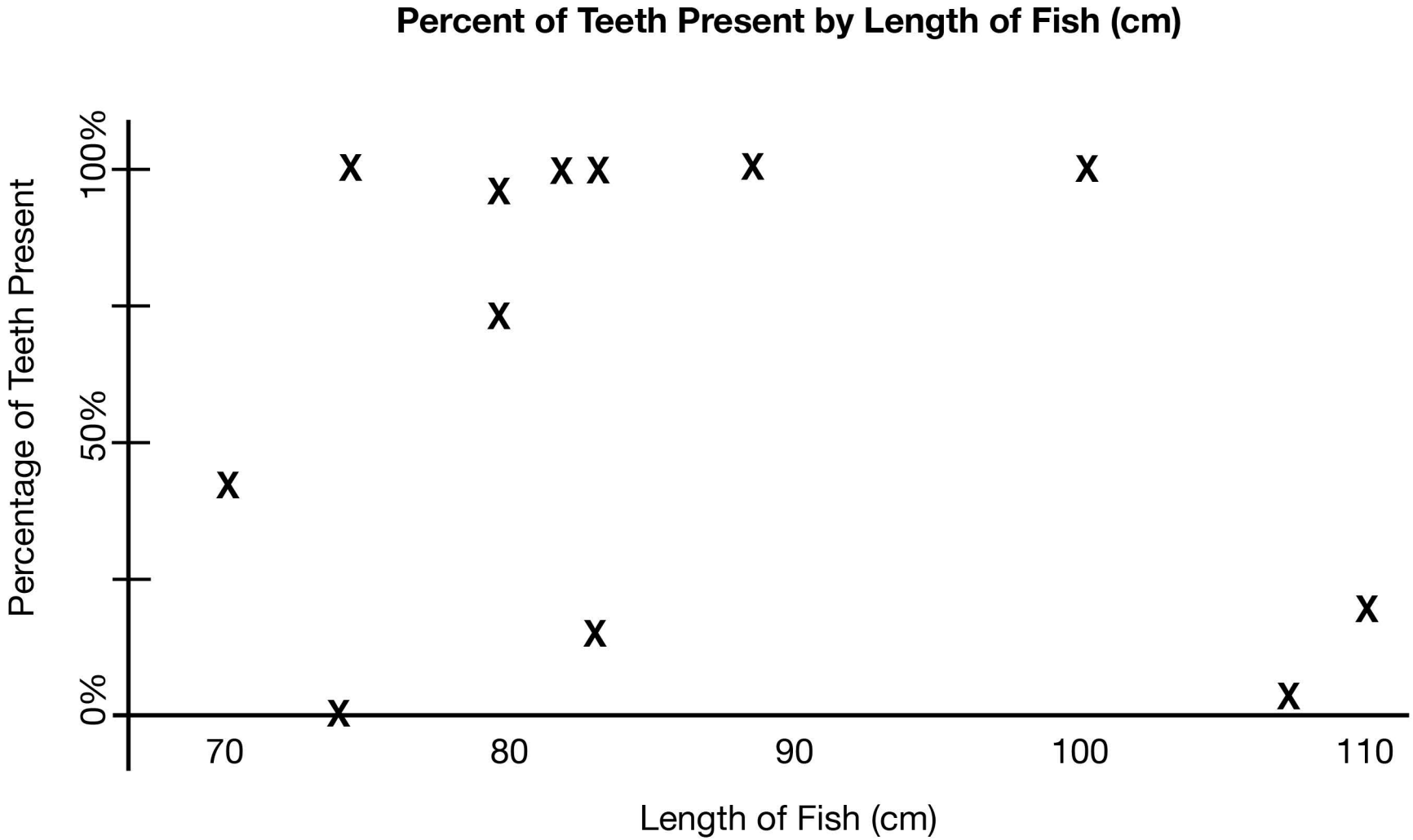
- Use a bar graph to plot the data from the percentages of present teeth from the data table by Sex of Fish.
- The hash marks on the x-axis will help you place your bars.
- Is there an observable trend that suggests Sex of Fish influences the Percent of Teeth Present? It is okay if there is no trend.



- Use a bar graph to plot the data from the percentages of present teeth from the data table by Location Caught.
- The hash marks on the x-axis will help you place your bars.
- Is there an observable trend that suggests Location Caught influences the Percent of Teeth Present? It is okay if there is no trend.

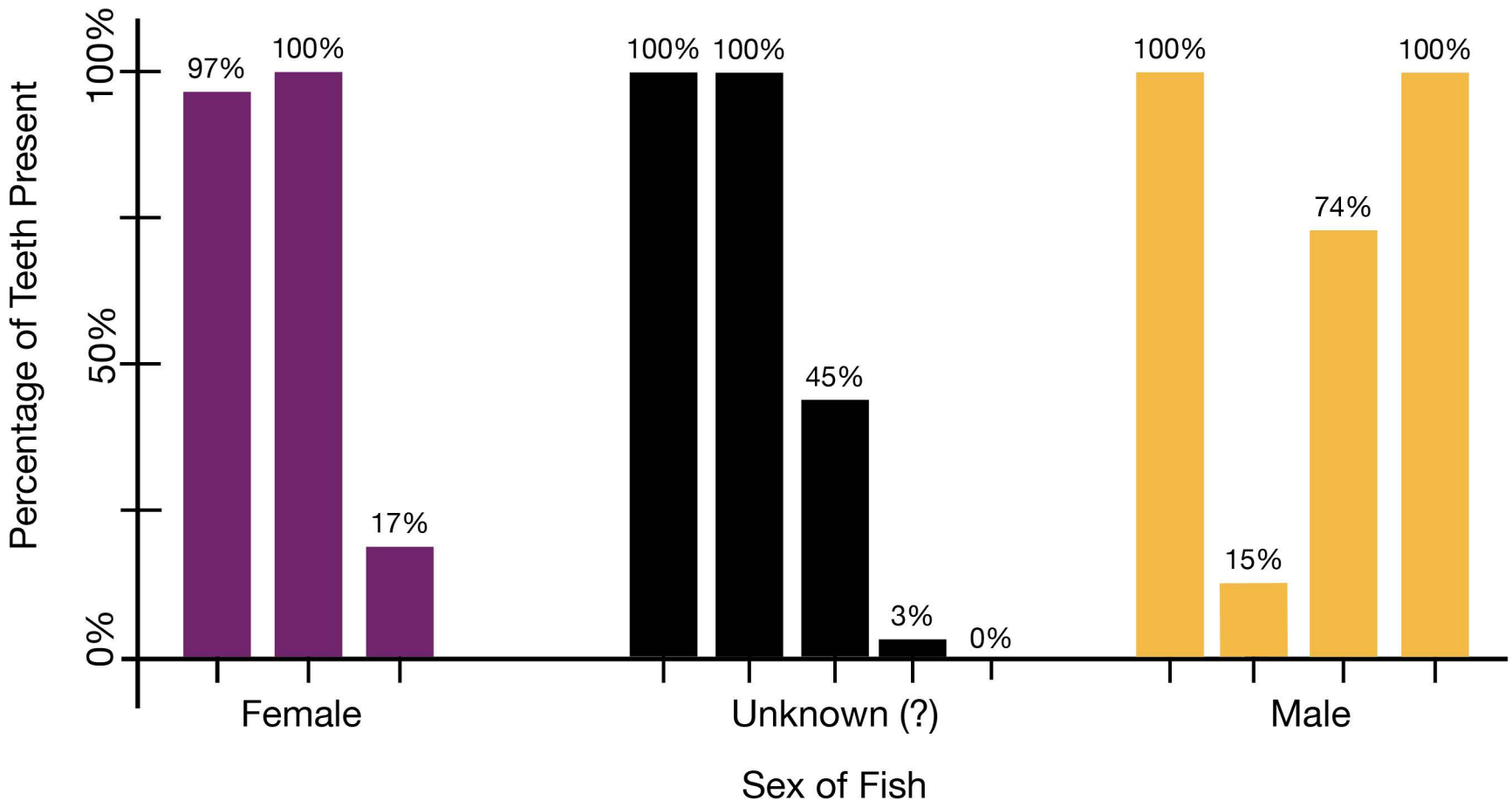


- Use a bar graph to plot the data from the percentage of present teeth from the data table by Season Caught.
- The hash marks on the x-axis will help you place your bars.
- Is there an observable trend that suggests Season Caught influences the Percent of Teeth Present? It is okay if there is no trend.



- Use a scatter plot graph the data from the percentages of present teeth from the data table by Length of Fish.
- Place an X for each individual fish on the graph.
- Is there an observable trend that suggests Length of Fish influences the Percent of Teeth Present? It is okay if there is no trend.

Percent of Teeth Present by Sex of Fish



- Use a bar graph to plot the data from the percentages of present teeth from the data table by Sex of Fish.
- The hash marks on the x-axis will help you place your bars.
- Is there an observable trend that suggests Sex of Fish influences the Percent of Teeth Present? It is okay if there is no trend.