Can Overfishing Impact Genes and Fish?

Materials

For the leader:

Computer

Projector

Fish Genetic Diversity Patterns Table

For the activity:

Graphing paper

Pencils/pens

Fish Genetic Diversity Data Table

Fish Genetic Diversity Figure

Fish Genetic Diversity Cards

Overview

When we look at evolution, at the base level, we are investigating and observing changes in the allele frequency in a population over time. Alleles are different versions of a gene, in which are the sequences that codes for a trait (…ATTCGAA…) on a chromosome. A population naturally has a range of alleles that occur in different frequencies. Therefore, when scientists are interested in looking at changes in the genetic diversity of a population (and potential evolutionary changes that have or are occurring), they too look at the allele frequency within a population.

Greater genetic diversity within a population enables the population to adapt to a changing environment. If there are greater numbers of alleles in the population, then there is a higher chance that multiple individuals of that population will have the allele(s) that are suited for the new environmental conditions. Therefore, more individuals of the population would survive to produce offspring that also have the allele(s). Conversely, a loss in genetic diversity would mean that the population would be less likely to survive in the changing environment, as there would be a smaller chance of individuals having the allele(s) suited for the new environment. Thus a loss in genetic diversity can leave a population more vulnerable to a changing environment.

There are a number of factors that impact the genetic diversity of a population. The size of a population has a large influence on the amount of genetic diversity that exists within the population. The larger the population size, the greater there is a chance of different alleles developing and being passed along to offspring. This is also why a population bottleneck (a sharp reduction in the size of a population due to environmental events or human activities) can have such a dramatic impact on the genetic diversity of a population. For example, the large decline in the number of cheetahs due to changing climates ~10,000 years ago reduced the population size initially and then over-hunting in Africa reduced the population size further over the past few centuries. Cheetahs now have some of the lowest genetic diversity of organisms on Earth today; approximately 99% of genes are the same in related Cheetahs as opposed to on average 80% for other organisms.

Because we know that human activities can produce a population bottleneck, scientists became interested in looking at whether overfishing was having an impact on the genetic diversity of fish. A fish population is considered "overfished" when the size of the fish population is too low, aka it is below a predetermined threshold that is necessary to maintain for the future health and success of the fish population (a good resource about overfishing is: http://www.fishwatch.gov/features/overfishing_overfished_same_thing.htm). Overfishing could result in a population bottleneck as large numbers of individuals are removed from the population. However, fish populations are so large to begin with, even those populations that are being overfished still have millions of individuals within the population.

Early studies used a Before-After approach to investigate the question of a relationship between genetic diversity and overfishing. Some studies found a decrease in genetic diversity after overfishing, while other studies found no change in the genetic diversity of fish populations after overfishing. Unfortunately, the way the early studies were conducted was poor, their experimental design meant that they had low statistical power and thus would not able to see an effect even if one existed. Therefore, Pinsky & Palumbi (2013) used a Control-Impact approach to look at 11,000+ genes (rather than 5-10) across 140 species (rather than 1) to determine if there was a relationship between overfishing and genetic diversity. They demonstrated that overfished fish populations had lower genetic diversity than fish populations that have not been overfished.

This lesson has been developed to compliment the work published in: Pinsky, M.L. and S.P. Palumbi. 2013. Meta-analysis reveals lower genetic diversity in overfished populations. Molecular Ecology 23: 29-39.

Motivating Questions:

- **How do bottlenecks impact genetic diversity of organisms?**
- **Is there evidence that overfishing is impacting the genetic diversity of fish? If so, what is the evidence?**

Take Home Message

A bottleneck lowers the genetic diversity in a population and this can potentially harm the population or individuals within a population. Overfishing a fish population creates a bottleneck, which results in a lower amount of genetic diversity in fish populations that have been overfished.

NOTE – This lesson assumes that your students have an understanding of DNA, genes, and alleles.

Structure

Through a hands-on demonstration and real fish genetic diversity data, students will be exposed to the relationship between genetic diversity and overfishing for a variety of fish groups as well as think through the potential consequences of this relationship.

Time Required

One 45-minute class period

Activity Outline

Engage: Students will participate in a hands-on demonstration that presents the impacts of bottlenecks on genetic diversity.	20 minutes
Explore: Students will interpret data from multiple fish groupings to explore the relationship between overfishing and genetic diversity.	15 minutes
Make Sense: Through small group and class discussions students will reflect on what they have learned and brainstorm potential impacts to the characteristics of fish from the loss of genetic diversity due to overfishing.	10 minutes
Total:	**45 minutes**

Audience

Middle school students (6th-8th grade).

New Jersey Core Curriculum Content Standards - Science

Content Area	Content Statement	CPI#
Science Practices: Understand Scientific Explanations	Results of observation and measurement can be used to build conceptual-base models and to search for core explanations.	5.1.8.A.2
Science Practices:	Mathematics and technology are used to gather, analyze, and	5.1.8.B.2

Generate Scientific Evidence Through Active Investigations	communicate results.	5.1.8.B.2
	Scientific reasoning is used to support scientific conclusions.	5.1.8.B.4
Science Practices: Reflect on Scientific Knowledge	Scientific models and understandings of fundamental concepts and principles are refined as new evidence is considered.	5.1.8.C.1
Science Practices: Participate Productively in Science	Science involves practicing productive social interactions with peers, such as partner talk, whole-group discussions, and small-group work.	5.1.8.D.1
	In order to determine which arguments and explanations are most persuasive, communities of learners work collaboratively to pose, refine, and evaluate questions, investigations, models, and theories (e.g., argumentation, representation, visualization, etc.).	5.1.8.D.2
Life Science: Heredity and Reproduction	Characteristics of organisms are influenced by heredity and/or their environment.	5.3.8.D.3
Life Science: Interdependence	Various human activities have changed the capacity of the environment to support some life forms.	5.3.6.C.1

Preparation (20-40 minutes)

1. Write the motivating questions up on the board:

   Q. How do bottlenecks impact genetic diversity of organisms?

   Q. Is there evidence that overfishing is impacting the genetic diversity of fish? If so, what is the evidence?

2. Write (or project) the Engage demonstration reflection questions on the board.
   a. What happened to the number of colors of beads at the end of the taking?
   b. What happened to the number of beads of each color at the end of the taking?
   c. If you were to make an analogy or give a title for what happened to the number of alleles in the fish population throughout the demonstration, what would it be?
3. Prepare the seven pie-pans of beads (6 for the students and 1 for you). Make sure each pie pan has 150 beads of at least 10 different colors. The number of beads of each color does not need to be the same; in fact it is better if they are not the same to be a more accurate representation of allele frequency in nature within a population.

   Note – Depending on how you would like to run the demonstration you can either randomly count out 150 beads in each pie pan (and thus the number of each color would vary across the groups, would take much less time to prepare) or you can have the same number of specific colors across the pie pans (longer time to prepare).

4. Write (or project) the not completed Fish Genetic Diversity Patterns Table on the board.
5. Make a copy of the Genetic Diversity Demonstration Worksheet for each student (or group).
6. Make a copy of the Fish Genetic Diversity Data Cards and cut out the individual fish groupings to pass out to each small group.

Engage (20 minutes)

1. Tell the students that they will be starting class with a demonstration. They will work in six groups. Each group will be given a pan of beads, which will represent the different alleles within a fish population.

2. First the students need to count how many different colors of beads are in the pan. This will provide the students with data on how many different alleles are in the population (an estimate of the genetic diversity through calculating allelic richness). They should record their data on the "Genetic Diversity Demonstration Worksheet."
3. Then the students need to count how many beads of each color are in the pan. This will provide the students with data on how frequent the different alleles are in the population.
4. The students should designate a "taker" who will be the only person able to remove beads from the pan.
5. Then when you say go, the "taker" should try to take all but 10 beads from the pan as quickly as possible. The beads removed from the pan should be put into the cup. When they are done the whole group should raise their hands so you can mark down their speed.
6. Afterwards, the students again need to count how many colors of beads are in the pan and how many beads of each color are in the pan. Tell the students that they should leave the beads in the pan and cup exactly as they are, as they will be using them again later in class.
7. Once the students have collected their data, give them a few minutes to analyze the data as a group. Have the students think about:
    a. What happened to the number of colors of beads at the end of the taking?
    b. What happened to the number of beads of each color at the end of the taking?
    c. If you were to make an analogy or give a title for what happened to the number of alleles in the fish population throughout the demonstration, what would it be and why?
8. After a few minutes ask for volunteers to share about the discussions they were having in their small groups. Be accepting of all responses and questions, as this is reflection activity to get the students thinking about what the demonstration was illustrating.
9. Once the conversation slows down, hold a plastic bottle upside down and point to the bottleneck. Inform the students that scientists use the term "bottleneck" to refer to the extreme loss of alleles or genetic diversity due to an environmental event or human activities, similar to what the students witnessed in the "taking" race of their demonstration.

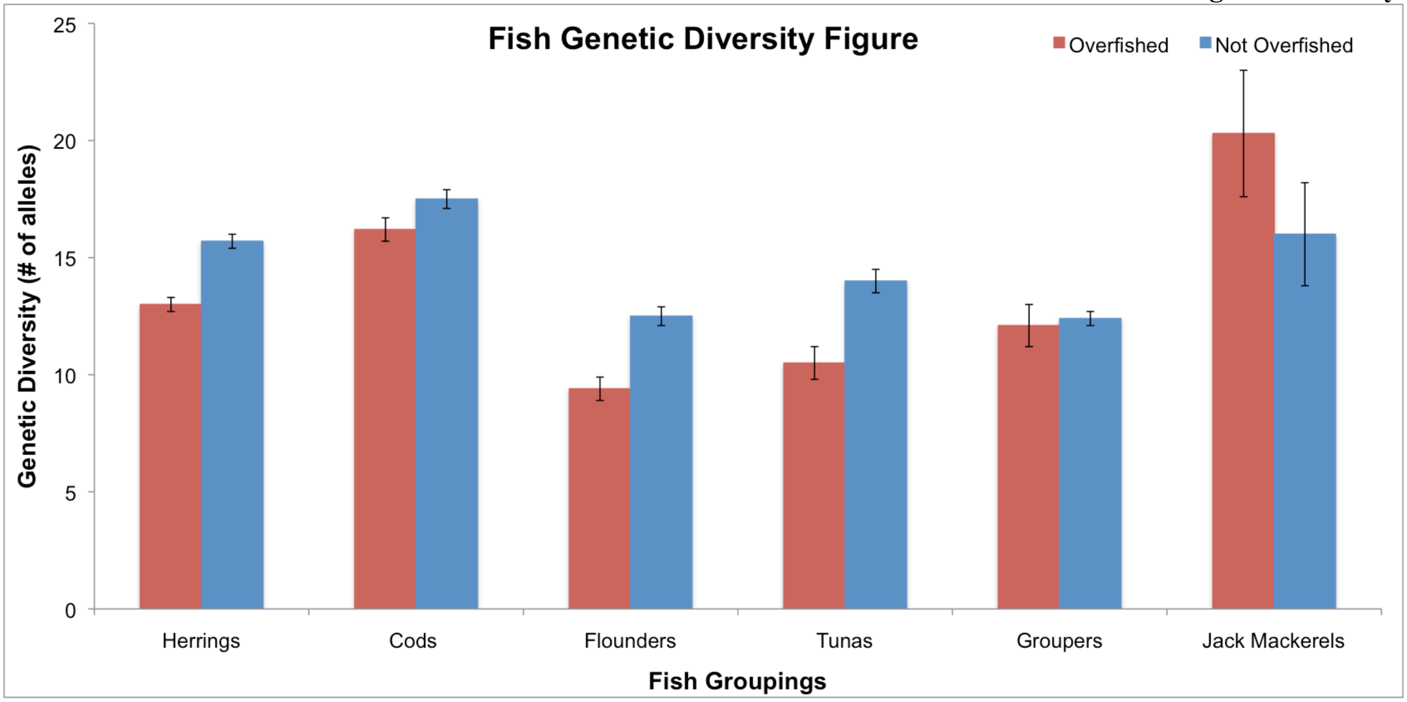
Explore (15 minutes)

1. Tell the students that they just completed what is called a Before-After experiment or model. In that they counted the genetic diversity and frequency before an event, again after the event, and then compared the data to draw conclusions about the impact of the event.
2. Another way to look at changes in the genetic diversity and frequency within a population is called a Control-Impact experiment or model. In this case, scientists have two groups of the same or similar individuals and keep one as is (control group) and change something within the second group (impact group). Then scientists compare the data to draw conclusions about the consequence of the change.
3. Scientists at Rutgers and Stanford Universities were interested if overfishing a fish population would produce a bottleneck and therefore a loss in genetic diversity within the fish population. Because they could not go back in time to sample the fish populations before fishing, instead they look at not overfished populations and overfished populations to compare the genetic diversity. Explain to the students that when a fish population is labeled as "overfished" that means that the size of the fish population is too low, aka it is below a predetermined threshold that is necessary to maintain for the future health and success of the fish population (a good resource about overfishing is: http://www.fishwatch.gov/features/overfishing_overfished_same_thing.htm).

4. First, the students will work in small groups to interpret their data. Each group will be given a different grouping of fish. For each grouping of fish they will have data from overfished population in the grouping and not overfished population in the grouping. The students need to work together to draw conclusions from their data about to the relationship between overfishing and genetic diversity. The students will present their data to the class at the end of their 3 minutes. Encourage the students to think about:
    a. What conclusions can they draw from the data? Was there less genetic diversity in the overfished or the not overfished populations?
    b. What does their data tell them about the relationship between overfishing and genetic diversity?
5. Pass out the "Fish Genetic Diversity Data Cards" so that each small group receives one. Use the six small groups from the Genetic Diversity Demonstration.
6. As the students are talking through their data, circulate and answer questions as needed.
7. After three minutes have passed (or as the students begin to wrap-up their work), have each group report to the class what they were interpreting in their data:
    a. What conclusions did you draw from the data? Was there less genetic diversity in the overfished or the not overfished populations?
    b. What does your data tell us about the relationship between overfishing and genetic diversity?
8. As the students are presenting, complete the "Fish Genetic Diversity Patterns Table." In the end, it should resemble the table below:

	Less Diversity in Overfished than Not Overfished	**No Difference in Diversity between Overfished and Not Overfished**	**Less Diversity in Not Overfished than Overfished**
Herrings	X		
Cods	X		
Flounders	X		
Tunas	X		
Groupers	X		
Jack Mackerels			X

9. Once all of the groups have reported out, project the Fish Genetic Diversity Figure for the students to look at. Ask the students if they see similar or different patterns in the figure to what they helped you create in the Fish Genetic Diversity Patterns Table. (They should be able to see similar patterns, as it is the same data they are just looking at a visual representation of the data rather than in a table.)



10. As you talk with your students through the Fish Genetic Diversity Figure, if you would like you can point out the standard error bars that are plotted onto the figure. You could lead a discussion with your students about how scientists would begin to investigate whether the values are statistically different or not, which is different than the absolute difference that they can easily see on the figure. If the error bars of two data points do not overlap (i.e., Herrings) it is likely that the difference is statistically different. However, if the error bars of two data points do overlap (i.e., Jack Mackerels) it is unlikely that the difference is statistically different. Only by running statistical analyses can scientists determine which of these differences are significant and which are not. Therefore, you may amend the Fish Genetic Diversity Patterns Table to resemble the table below:

	Less Diversity in Overfished than Not Overfished	**No Difference in Diversity between Overfished and Not Overfished**	**Less Diversity in Not Overfished than Overfished**
Herrings	X		
Cods	X		
Flounders	X		
Tunas	X		
Groupers	?	?	
Jack Mackerels		?	?

11. After a few minutes, ask the students to share what patterns they observed with respect to overfishing and genetic diversity overall. Does overfishing cause a bottleneck, and thus a loss in genetic diversity in fish populations? Encourage the students to site what data/evidence they used to draw their conclusions.

Make Sense (10 minutes)

1. Ask the students to work with a partner to brainstorm:
    a. Why would scientists be interested in learning if overfishing lowers the genetic diversity in a fish population?
    b. Or asked another way, why is genetic diversity important to a population?

2. After a few minutes pull the class back together and have volunteers share their brainstorming. As the students share what they were talking about, capture their points on the board. Be accepting of all responses, as this is a brainstorming activity.
3. Once the conversation slows down, have the students look at their pans of beads again. Tell the students that the water temperature in the ocean is extremely high this year and only fish with the pink and purple alleles (or pick two colors from your options) were able to survive.
4. How many groups still have fish? Have the students raise their hands. Show them your pan with all of the original beads still in it, and point of to the students that your pan represents the amount of genetic diversity that the fish population had to start and their pans represent the genetic diversity after a bottleneck.
5. Ask the students to brainstorm in their small groups what this new development could mean for:
    a. The size and health of the fish population in the future?
    b. Specific characteristics of fish within the population?
6. After a few minutes ask for volunteers to share what they discussed about the potential impacts on the fish population and/or characteristics of fish within the population if only two alleles survive. Be accepting of all responses, as this is a brainstorming activity to get the students to think about the potential impacts on the population and characteristics within a population of a loss of genetic diversity. There are no right answers; the point is to have kids use their new knowledge to think creatively about what could happen.
7. Once the discussion slows down, point to the motivating questions and ask:

   Q. How do bottlenecks impact genetic diversity of organisms?

   Q. Is there evidence that overfishing is impacting the genetic diversity of fish? If so, what is the evidence?
8. As a class, have the students review what evidence they used to make conclusions about the relationship between overfishing and genetic diversity. This is your opportunity to make sure the students understand the "take home message" of the section.
9. Ask if the students have any final questions about the activities and concepts of the day.

Genetic Diversity Demonstration Worksheet

Names: ____ Date: _____________

How many colors of beads (alleles) do you have in the pan (fish population) to start?

How many of each color of beads do you have in the pan?

Color of Beads	Before Taking	After Taking

How many colors of beads (alleles) do you have in the pan (fish population) after the taking race?

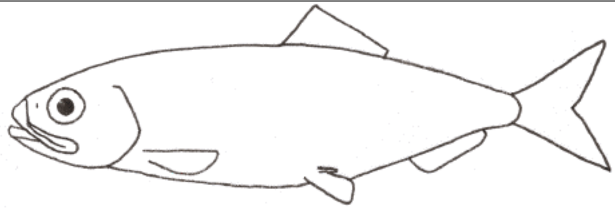
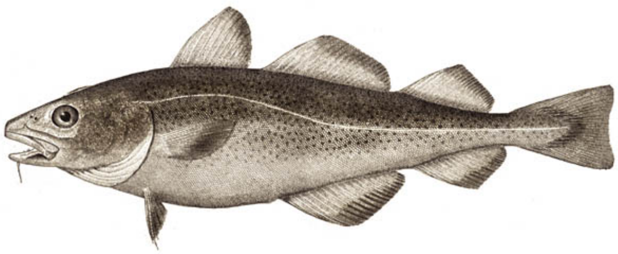
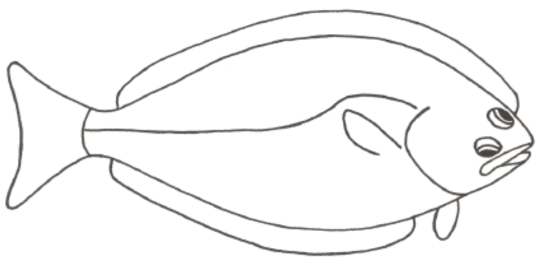
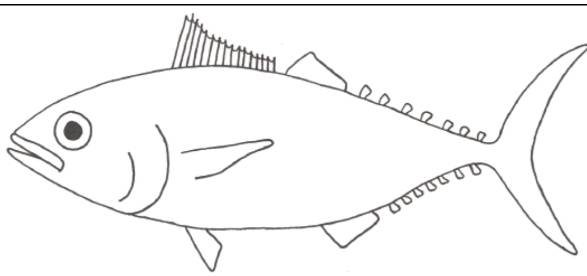
Reflection Questions:

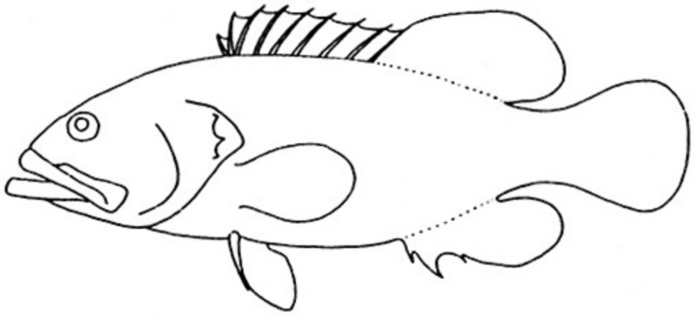
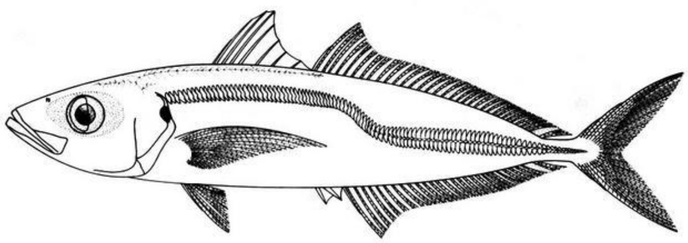
1. What happened to the number of colors of beads at the end of the taking?

2. What happened to the number of beads of each color at the end of the taking?

3. If you were to make an analogy or give a title for what happened to the number of alleles in the fish population throughout the demonstration, what would it be and why?

Fish Genetic Diversity Data Cards

 Burke Museum: http://www.burkemuseum.org/static/FishKey/clup.html	**Herrings (Clupeidae)** Overfished: 13 alleles Not Overfished: 15.7 alleles
 Wikipedia/NOAA: http://commons.wikimedia.org/wiki/File:Atlantic_cod.jpg	**Cods (Gadidae)** Overfished: 16.2 alleles Not Overfished: 17.5 alleles
 Burke Museum: http://www.burkemuseum.org/static/FishKey/pleuro.html	**Flounders (Plueronectidae)** Overfished: 9.4 alleles Not Overfished: 12.5 alleles
 Burke Museum: http://www.burkemuseum.org/static/FishKey/tuna.html	**Tunas (Scombridae)** Overfished: 10.5 alleles Not Overfished: 14 alleles

 Online Keys: http://www.online-keys.net/infusions/keys/keys_print.php?key_no=25	**Groupers (Serranidae)** Overfished: 12.1 alleles Not Overfished: 12.4 alleles
 Discover Life: http://www.discoverlife.org/mp/20p?see=I_RR993&res=640	**Jack Mackerels (*Trachurus*)** Overfished: 20.3 alleles Not Overfished: 16 alleles

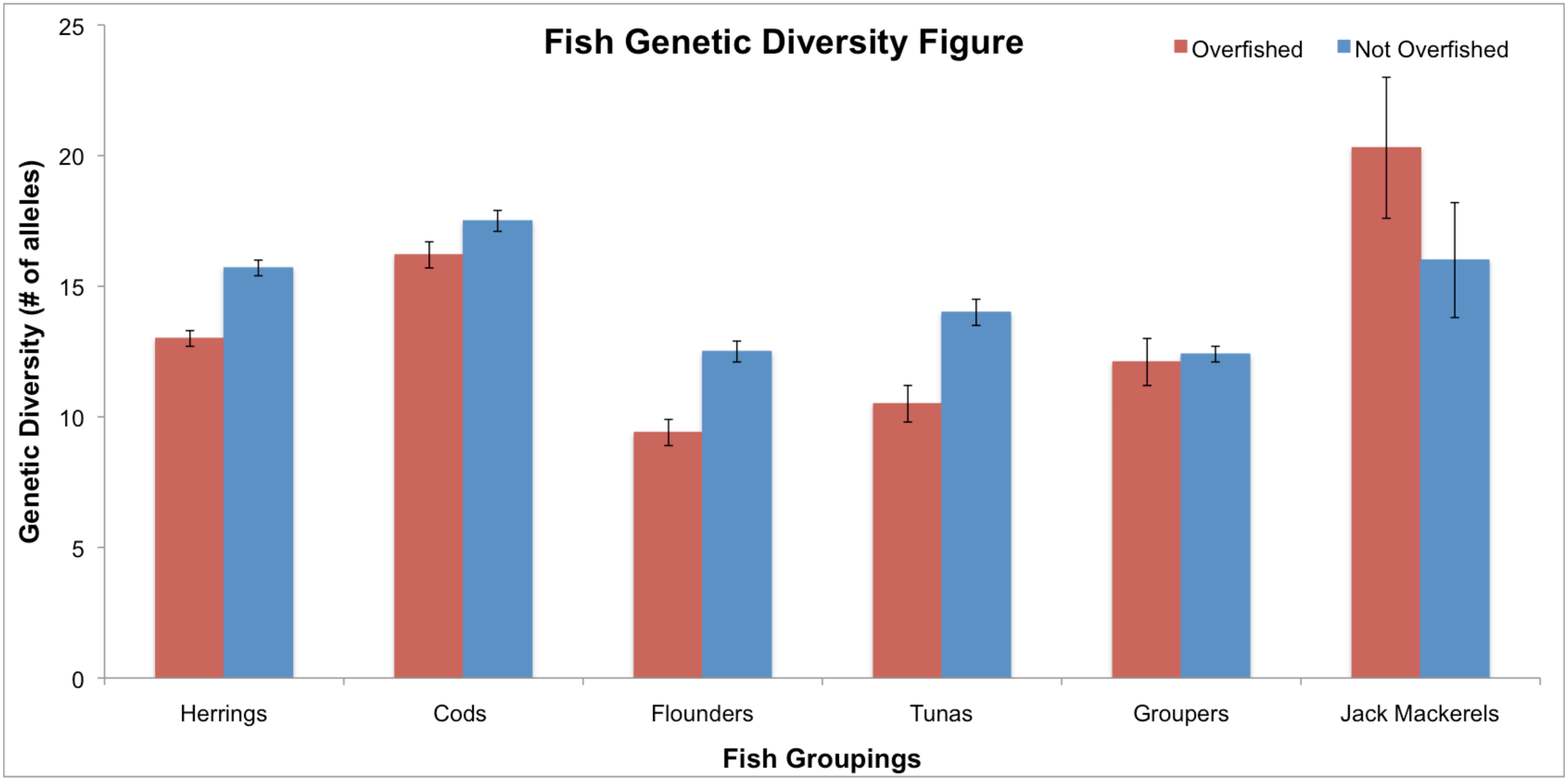
Fish Genetic Diversity Patterns Table (not completed)

	Less Diversity in Overfished than Not Overfished	No Difference in Diversity between Overfished and Not Overfished	Less Diversity in Not Overfished than Overfished
Herrings			
Cods			
Flounders			
Tunas			
Groupers			
Jack Mackerels			

Fish Genetic Diversity Patterns Table (completed)

	Less Diversity in Overfished than Not Overfished	No Difference in Diversity between Overfished and Not Overfished	Less Diversity in Not Overfished than Overfished
Herrings	X		
Cods	X		
Flounders	X		
Tunas	X		
Groupers	?	?	
Jack Mackerels		?	?

Fish Genetic Diversity Figure



Common Core State Standards Connections: ELA/Literacy and/or Math

English Language Arts

WHST.6-8.1	Write arguments to support claims with clear reasons and relevant evidence.
WHST.6-8.9	Draw evidence from literary or informational texts to support analysis, reflection, and research.
SL.8.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.
SL.8.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.
SL.8.5	Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points.

Mathematics

MP.2	Reason abstractly and quantitatively.
6.RP.A.1	Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities.
6.SP.B.5	Summarize numerical data sets in relation to their context.
6.EE.B.6	Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set.
7.RP.A.2	Recognize and represent proportional relationships between quantities.

Next Generation Science Standards

Natural Selection and Adaption, MS-LS4-4 – Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.

Science & Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions - Construct an explanation that includes qualitative or quantitative relationships between variables that describe phenomena.	*LS4.B: Natural Selection* - Natural selection leads to the predominance of certain traits in a population, and the suppression of others.	*Cause and Effect* – Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

Natural Selection and Evolution, MS-LS4-6 – Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.

Science & Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking - Use mathematical representations to support scientific conclusions and design solutions.	*LS4.C: Adaptation* - Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits	*Cause and Effect* – Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

	that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes.	