Lesson Title:
Contemporary Evolution: Genes & Harvest

Topic:
A lesson on how contemporary evolution can occur through the process of selective harvest.

Content Level:
High School Biology

Time:
Two 50 min class periods

Materials:
15 bean soup (dry), plastic cups, grill topper, Student Handouts

Background:
Humans utilize many different animals across countless taxa for consumption or other commercial purposes. Size selective harvest of fish has become highly efficient in recent decades due to an increase in catch effort, increasing efficiency of equipment, and other advanced technologies. In order for populations to adapt to changing environmental conditions, there must be sufficient genetic variation and enough individuals in which to pass on the adaptive traits.

Fish often mature at a genetically determined size and/or age. These types of traits are called Life History Traits. Growth is highly correlated with age and older individuals are often larger. Generally speaking, the larger the mother, the more offspring she will have with each reproductive event. If she is sufficiently large, her offspring will also be larger. These larger offspring often have higher survival than small offspring. Darwinian fitness is related to the proportion of the parent's genes in the next generation; fitness is generically the number of offspring you have the live to reproduce. Larger female fish have higher fitness than smaller female fish.

If a population of reproducing individuals that breeds a certain age and size becomes harvested at unsustainably high levels, eventually the genetic basis for that age and size will become eroded and contemporary evolution will result in younger and smaller fish breeding and passing on their genes.

Skills:
- Basic counting, categorizing, and data management
- Ability to make Charts and Graphs
- Critical thinking
- Ability to work in groups

Objectives:
- Students will learn about the consequences of selective harvest
- Students will examine genetic concepts of small populations
- Students will test how quickly populations can become genetically constrained
- Students will hypothesize how their results apply to other animals

Standards Addressed:

National Standards

Unifying Concepts and Principles

2 3 4

Science as Inquiry

1 2

Life Science

3 4 5 6

Science in Personal and Social Perspectives

2 3 4 5 6

ND State and West Fargo Public Schools Science Standards & Benchmarks:

10-12.1.1.1	10.1.2.1	10.1.3.1	10.1.3.1
10.2.1-5	11-12.2.1-8	10.4.2	10.4.3.1-4
10.4.4.1-8	10.7.2	11-12.7.3	10.7.5
10-12.7.6			

Procedure:

1. The students should have a basic background in genetics (pedigree charts, heritability, meiosis) and population biology (sociality, population growth, reproduction).
2. Give the class the pretest at least 1 day prior to the activity.
3. Begin with either a short review of some topics given on the teacher outline sheet or tailor introduction to concepts of current unit.
4. Start the activity by pairing the students into groups of 2-4 and give them the materials. Have students read the background information sheet before starting, perhaps as homework the night before they are to begin the lesson.
5. A brief introduction with the students, including the overheads, greatly benefits their progress through the lab. Going through an example of how to harvest, select, and classify the fish/genes also helps.
6. Students should follow the directions on the procedure sheet. Two students should be the unharvested group and two should be the harvested group. The two groups will trade data after completing the gene diversity worksheet.
7. Day one will consist of the introduction and filling out the gene frequency (pedigree) chart. Day two will consist of trading data and completing the questions. Advanced classes will be able to complete in one day and fill out questions as homework.
8. Give the posttest several days after the completion of the activity and have a discussion of the topics covered for the students to debrief what they have learned.

This activity was developed by Joseph Allen, GraSUS graduate fellow. Support was provided by the Center for Science and Math Education and the GraSUS project: GraSUS is funded by a grant to NDSU from the National Science Foundation (DGE-0338128, June 1, 2004 – May 31, 2009, Dogan Comez, PI).

References:

Hutchings, 2005. Can. J. Fish. Aq. Sci. 62: 824-832.

Stockwell et al 2003. Trends in Ecology and Evolution. 18: 94-101.

Conover & Munch. 2002. Science. 297: 94-96.

Symposium: Contemporary evolution in human altered landscapes, UCLA, Feb 2007

Teacher Outline

Suggested Topics to review or cover:

Population Biology

- Growth Curves
- Generation time
- Population = Birth + Death + Emigration + Immigration
- Social versus Solitary Behavior
- Sexual Dimorphism
- Population Density
- Critical Population Size/ Minimum Viable Population
- Other Aspects of Behavior
- Sexual Selection

Genetics

- Mitosis/Meiosis
- DNA
- Genetic Variation
- Epistasis
- Pleiotropy
- Bottlenecks
- Effective Population Size
- Drift
- Inbreeding Depression

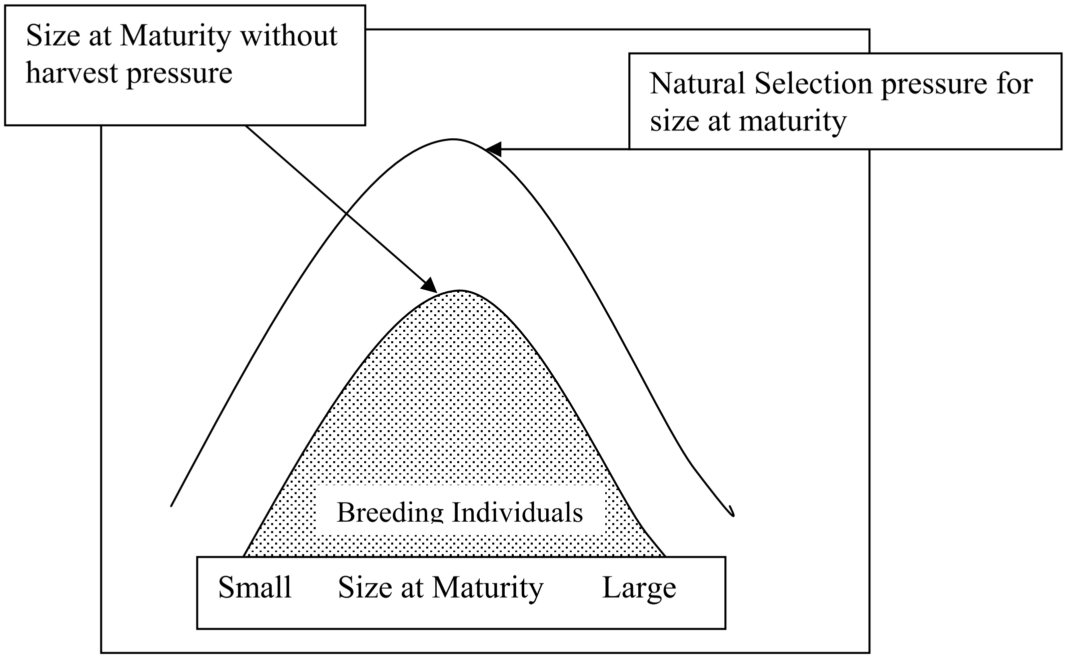
Evolution

- Genotype
- Phenotype
- Natural selection – acts on phenotypes of individuals
- Evolution – acts on genotypes of populations across generations
- Artificial Selection
- Geologic or Evolutionary Time
- Extinction

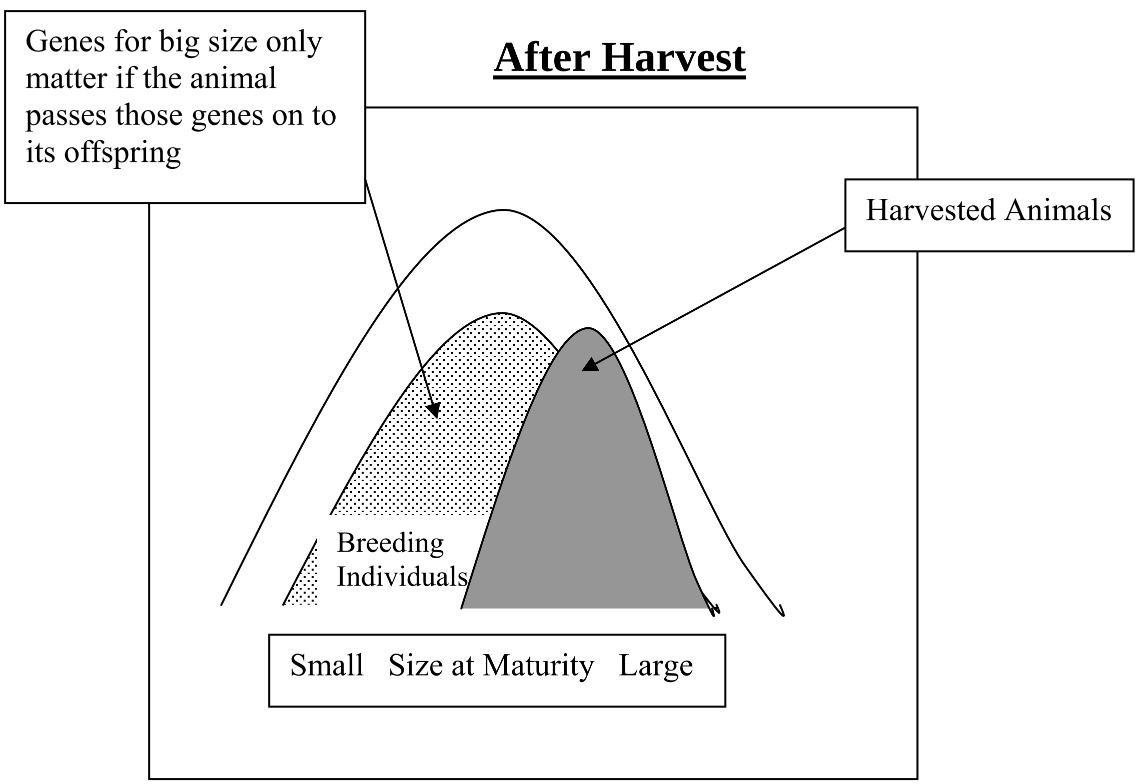
Conservation Biology

- Conservation Genetics
- Captive Breeding
- Exotic Species
- Overharvest
- Pollution/Habitat Degradation and Loss
- Translocation
- Ecology

Before Harvest

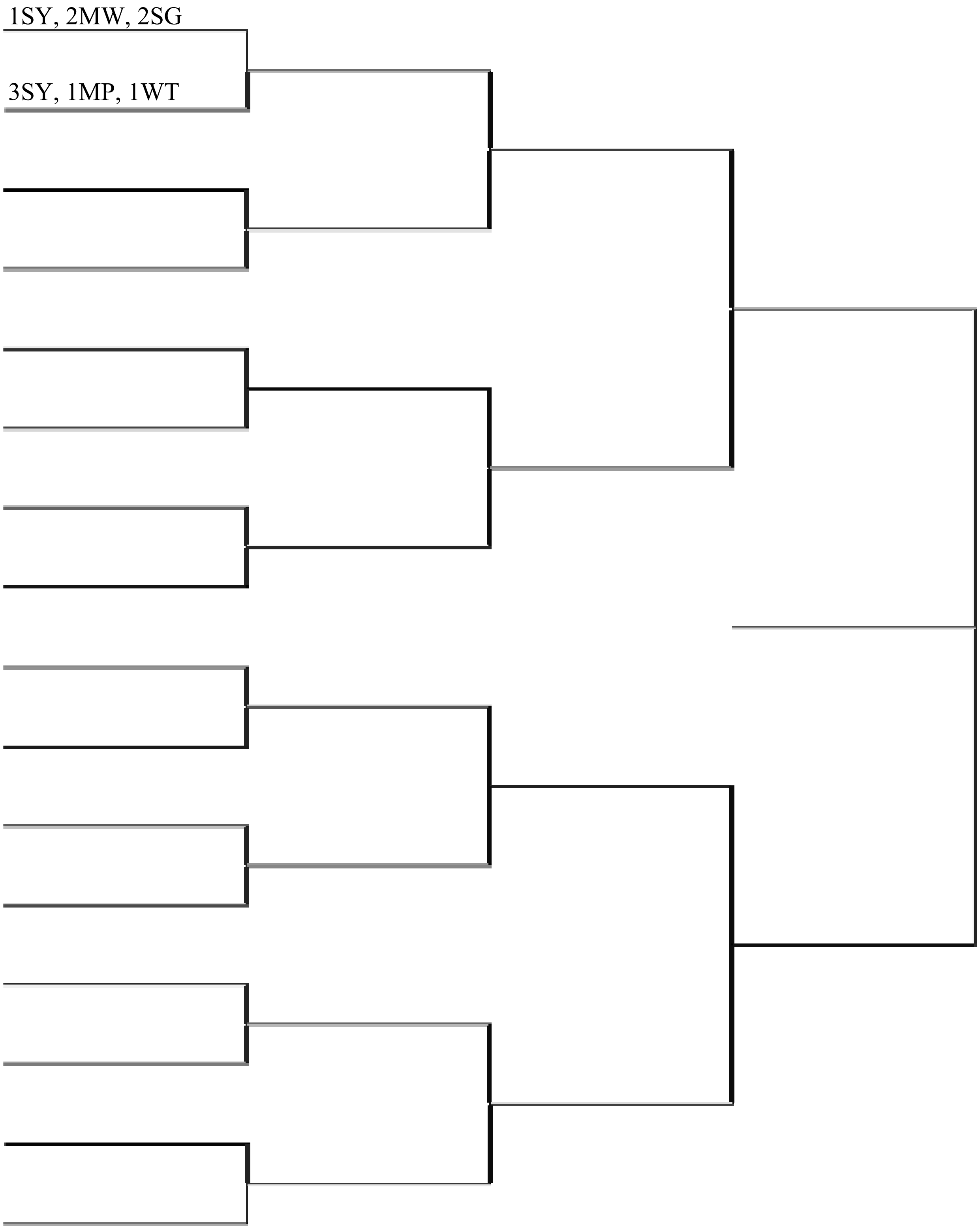


After Harvest



Contemporary Evolution: Unharvested Gene Frequency

GENERATION 1 **GENERATION 2** **GENERATION 3** **GENERATION 4**



Calculation of Diversity Index

Gene type		Number in Generation 4	p	p^2
SY		1	0.06	0.0036
SG		3	0.20	0.0400
MW		5	0.33	0.1089
LW		1	0.06	0.0036
SPR		5	0.33	0.1089
TOTAL		15	~1	0.2650

Diversity $= 1 / \Sigma p^2 = 1 / 0.2650 =$ **3.77**

Gene type – genes present in generation 4.
Number in Generation 4 – how many times particular gene was present in generation 4
p – proportion of a gene in generation 4 (number present divided by total, 1/15 = 0.06)
p^2 – proportion squared for each gene.

Directions: Determine what genes showed up in generation 4 and how many times. Determine the p and p-squared for each gene. Total the p-squared and take the inverse (1 / total p^2), which will yield the diversity index for that population or sample.

Generation 4		
#	p	p^2
1	0.06	0.0036
2	0.13	0.0169
3	0.20	0.0400
4	0.26	0.0676
5	0.33	0.1089
6	0.40	0.1600
7	0.46	0.2116
8	0.53	0.2809
9	0.60	0.3600
10	0.66	0.4356

Contemporary Evolution Pretest **NAME____________________ Period_____**

1. Evolution can occur within a human lifespan. T/F
2. Humans are changing the rate at which evolution occurs. T/F
3. Artificial selection is selection by humans. T/F
4. Evolution cannot occur in small populations. T/F
5. Which of the following are areas of concern for evolutionary research?
   A. Overharvest B. Captive Breeding C. Exotic Species D. All of these E. None of these
6. Which characteristics could increase the natural selection pressures of a population?
   A. Sexual Dimorphism B. Highly Social C. Population Density D. All E. None
7. Population size is a result of (circle all that apply)
   A. Births B. Deaths C. Immigration D. Emigration
8. Define pleiotropy:

9. Define Epistasis:

10. Define contemporary evolution:

Contemporary Evolution Pretest **NAME____________________ Period_____**

1. Evolution can occur within a human lifespan. T/F
2. Humans are changing the rate at which evolution occurs. T/F
3. Artificial selection is selection by humans. T/F
4. Evolution cannot occur in small populations. T/F
5. Which of the following are areas of concern for evolutionary research?
   A. Overharvest B. Captive Breeding C. Exotic Species D. All E. None
6. Which characteristics could increase the natural selection pressures of a population?
   A. Sexual Dimorphism B. Highly Social C. Population Density D. All E. None
7. Population size is a result of (circle all that apply)
   A. Births B. Deaths C. Immigration D. Emigration
8. Define pleiotropy:

9. Define Epistasis:

10. Define contemporary evolution:

Contemporary Evolution Post test NAME____________________ Period_____

1. Evolution can occur within a human lifespan. T/F
2. Humans are changing the rate at which evolution occurs. T/F
3. Artificial selection is selection by humans. T/F
4. Evolution cannot occur in small populations. T/F
5. Which of the following are areas of concern for evolutionary research?

   A. Overharvest B. Captive Breeding C. Exotic Species D. All of these E. None of these
6. Which characteristics could increase the natural selection pressures of a population?

   A. Sexual Dimorphism B. Highly Social C. Population Density D. All E. None
7. Population size is a result of (circle all that apply)

   A. Births B. Deaths C. Immigration D. Emigration
8. Define pleiotropy:

9. Define Epistasis:

10. Define contemporary evolution:

Contemporary Evolution Post test NAME____________________ Period_____

1. Evolution can occur within a human lifespan. T/F
2. Humans are changing the rate at which evolution occurs. T/F
3. Artificial selection is selection by humans. T/F
4. Evolution cannot occur in small populations. T/F
5. Which of the following are areas of concern for evolutionary research?

   A. Overharvest B. Captive Breeding C. Exotic Species D. All E. None
6. Which characteristics could increase the natural selection pressures of a population?

   A. Sexual Dimorphism B. Highly Social C. Population Density D. All E. None
7. Population size is a result of (circle all that apply)

   A. Births B. Deaths C. Immigration D. Emigration
8. Define pleiotropy:

9. Define Epistasis:

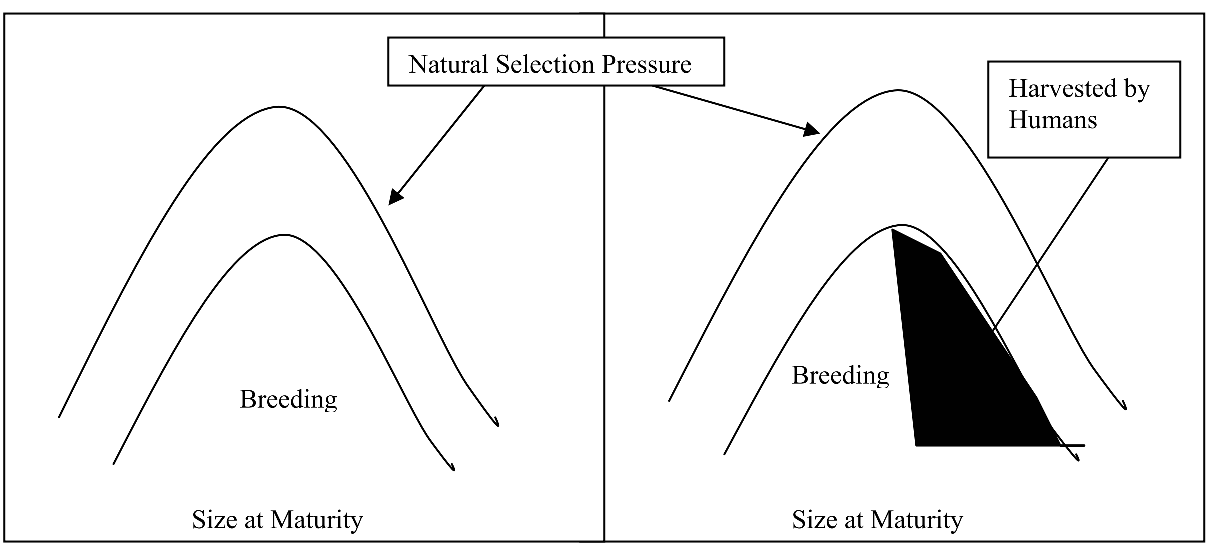
10. Define contemporary evolution:

CONTEMPORARY EVOLUTION
Background

Contemporary Evolution can be defined as rapid evolution due to human influences. Humans utilize many different kinds of animals for consumption or other commercial purposes. Collecting or hunting animals based on a trait of interest is selective harvest. Size selective harvest of fish has become highly efficient in recent decades due to an increase in catch effort, increasing efficiency of equipment, and other advanced technologies. In order for populations to adapt to changing environmental conditions, there must be sufficient genetic variation and enough individuals in which to pass on the adaptive traits.

Fish often mature at a genetically determined size. These types of traits are called Life History Traits. Growth is highly correlated with age and older individuals are often larger. Generally speaking, the larger the mother, the more offspring she will have with each reproductive event. If she is sufficiently large, her offspring will also be larger. These larger offspring often have higher survival than small offspring. Darwinian fitness is related to the proportion of the parent's genes in the next generation; fitness equals the number of offspring you have that live to reproduce. Larger female fish have higher fitness than smaller female fish.

If a population of reproducing individuals that breeds a certain age and size becomes harvested at unsustainably high levels, eventually the genetic basis for that age and size will become eroded and contemporary evolution will result in younger and smaller fish breeding and passing on their genes.



Before Selection After Selection

Background continued

Many species of marine fish are over harvested to the point where they are no longer commercially harvestable. Another possible result of overharvest is that the population may become endangered and some type of harvest limit or all out ban is implemented. Species like the Atlantic cod (*Gadus morha*) are good examples because a moratorium has been placed on the Canadian cod fishery for about the last 15 years. The problem is that the Canadian cod population has still not recovered in numbers and individuals are still small.

In today's activity, we will be modeling **a fish that has 5 genes** that control how size at maturity. The **cups you will use represent an entire population of fish at a particular generation**. The **beans represent the genes** that occur in that population at that generation. Keep in mind the steps of the scientific method as you complete this activity (Observation, Hypothesis, Experiment, and Conclusion). You will calculate a gene diversity index for both the harvested and unharvested groups. This number means nothing by itself and so you use it to compare different groups; the higher the number – the higher the genetic diversity of the group.

How will harvesting affect population genetics (harvested vs. control)?

Hypothesis:

Predictions:

Unharvested	Materials	Harvested
1 cup of beans, 3 empty cups		1 cup of beans, 4 empty cups, 2 mesh screens
Control (no harvest)	**Experiment**	Stack both screens together, place on table and poor cup of beans through. Spread beans out and lightly shake allowing some to fall through screen. Place the beans that fell through the screen back into Generation 1 cup. Place beans that remained in screens into extra cup – do not use for anything else because these represent the genes in the fish that did not breed.

Procedure (everyone)

1 Place your cups in order (G1, G2, G3, G4)

2 Sample a fin clip (5 beans), classify your beans using codes, record on 1 line in gene frequency chart (each line = 1 fish, 1 fish = 5 genes), place genes in the next generations empty cup.
[ex: if sampling generation 1, pull beans out G1 and place them in G2]

3 Repeat step 2 – 16 times for G1, 8 times for G2,
4 times for G3, and 3 times for G4

4 After generation 4 is completed on the gene frequency chart, total your generation 4 genes on the gene diversity worksheet.
MAKE SURE TO USE CORRECT GROUP: HARVESTED OR UNHARVESTED!

5 Finish the diversity calculations following the directions on that page.

6 Trade data (gene diversity chart) with an opposite treatment group. Record the class average gene diversity for both groups on your chart.

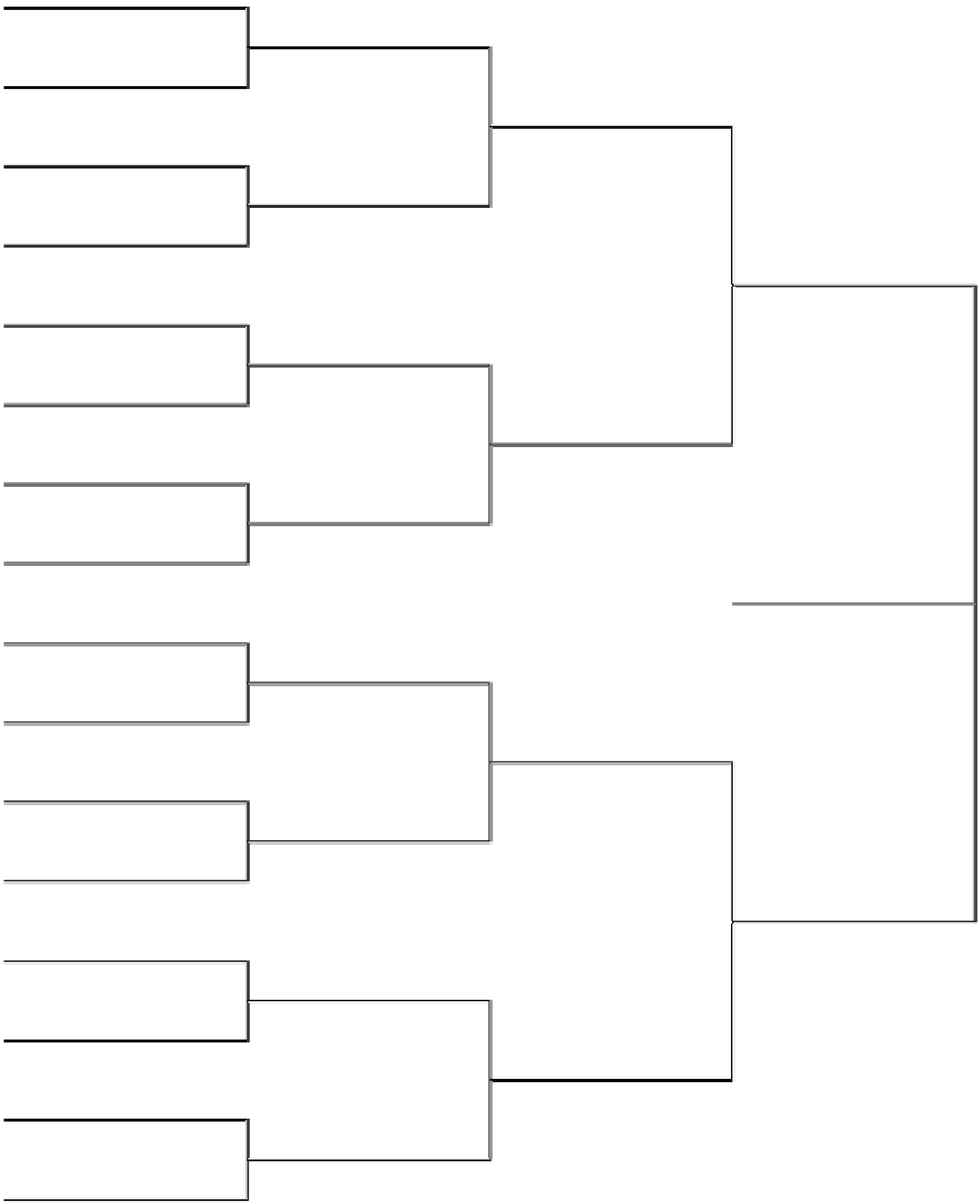
7 Finish by completing the questions on the last page.

Small	**Medium**	**Large**
Yellow (SY)	White (MW)	White (LW)
Green (SG)	Pink (MP)	
Tan (ST)	Brown (MB)	
White (SW)	Red (MR)	
	Speckled Brown (SPB)	
	Speckled Red (SPR)	
	Wrinkled Tan (MWT)	

GENE FREQUENCY CHART

CIRCLE: Unharvested / Harvested

Generation 1 **Generation 2** **Generation 3** **Generation 4**



Unharvested Group NAME________________________ Period _____

Gene type		Number in Generation 4	p	p^2
TOTAL				

Diversity =

Harvested Group

Gene type		Number in Generation 4	p	p^2
TOTAL				

Diversity =

Gene type – genes present in generation 4.
Number in Generation 4 – how many times particular gene was present in generation 4
p – proportion of a gene in generation 4 (number present divided by total, 1/15 = 0.06)
p^2 – proportion squared for each gene.

Directions: Determine what genes showed up in generation 4 and how many times. Determine the proportion and proportion squared for each gene. Total the proportion squared and take the inverse (1 / total p^2), which will yield the diversity index for that population or sample.

DISCUSSION QUESTIONS

Directions: Answer the following questions using what you have learned in this activity and the data you have collected. USE COMPLETE SENTENCES!

1. Explain how contemporary evolution applies to the collapse of the Canadian Atlantic cod.

2. Describe how managing fishing in lakes is different / same from managing oceans. If you state it is different, explain why.

3. Using the lessons learned in this activity, apply the concepts to another harvested animal and explain your reasoning.

4. What characteristics of animals/populations would make them more or less vulnerable to overharvest? Give at least two examples of harvested animals not discussed in class and explain them.

5. What types of government controls to prevent overharvest apply to your examples in Question 4? Are they effective, why or why not?