Supplemental Material

CBE—Life Sciences Education

Hoffman *et al.*

Appendix 1: Example of the layout and supporting/background material for modules. The complete content of all modules is available by request at http://nexus.umbc.edu/:

TOPIC: Do rare males have a mating advantage? Using mathematical modeling to explore sexual selection (Introduction to Mathematical Modeling Evolutionary Ecology Application)

TUTOR GUIDE

MODULE CONTENT: This module contains simple exercises for biology majors taking an introductory course in ecology and evolution to begin applying and interpreting mathematical models of biological problems.

TABLE OF CONTENTS

Alignment to HHMI Competencies for Entering Medical Students:

Competency	Learning Objective	Activity
E1. Apply quantitative reasoning and appropriate mathematics to describe or explain phenomena in the natural world.	E1.1 Demonstrate quantitative numeracy and facility with the language of mathematics	1,5
	E1.2. Interpret data sets and communicate those interpretations using visual and other appropriate tools.	1,2,3
	E1.3. Make statistical inferences from data sets (evaluating best fit linear relationships based on calculating error sums of squares)	2,3,5
	E1.5. Make inferences about natural phenomena using mathematical models	7

Mathematical Concepts covered:
- mathematical modeling in a biological context
- linear models
- regression models

In class activities:
- group discussion
- graphing and interpreting data
- construction of linear models
- using regression approach calculations for determining "best fit" relationships between two variables.

Components of module:
- preparatory assignment to complete and turn in as homework before class
- in class worksheet:
    - discussion questions
    - plotting and interpreting data
    - calculations of sums of squared error values to quantitatively assess the goodness of fit of lines to observed data.
- suggested assessment questions
- guidelines for implementation

Estimated time to complete in class worksheet
- 60 minutes

Targeted students:
- first year-biology majors in introductory biology course covering ecology and evolution

Quantitative Skills Required:
- Basic arithmetic
- Logical reasoning
- Interpreting data from tables
- Graph/Data Interpretation

Suggested Questions for Formative Assessment

Learning Objective	Activity
E1.2. Interpret data sets and communicate those interpretations using visual and other appropriate tools.	1
E1.3. Make statistical inferences from data sets (evaluating best fit linear relationships based on calculating error sums of squares)	3,5
E1.5. Make inferences about natural phenomena using mathematical models	7

Guide for implementation: Discussion

Have students break up into groups of 3 to discuss and come up with answers to the questions. Groups get together to talk about each question – work pauses after 10 minutes or as soon as you think each group has come up with something for both questions (no longer than 15 minutes). The TA should then pick a person from 3 groups chosen at random to share with the class their group's answer to one of the questions. Tell them that everyone in the group should be prepared to share the answer with the class, as you will choose who speaks randomly among the group. Suggested ideas that should emerge from each question are listed below.

An alternative way to run this discussion section of the class would be to run it "Question Time" style where you let them discuss each question in turn for three minutes, then ring a bell or use another method to cut off discussion, then have the whole group report their answer. Then move on to the next question.

TA Guide for Implementation: Lab Activity

Students work in groups. Each group has a computer.

Materials needed: Graph paper for each student

1) TA hands out graph paper to each member of a group and instructs students to open excel spread sheet (**Introduction to Mathematical Modeling.xlsx**). Each individual is instructed to plot the data points and construct a line through the data points based on the two model equations. Each individual will then decide which model (line) more accurately "fits" the data and provide rationale. One or two groups share their decision with the class.
   a) The graph paper should have x and y axes drawn in lower left when held in landscape orientation.
   b) If possible, project the data plot & regression lines for discussion –maybe via instructor's computer & projector or overhead projector.
   c) Discussion of possible data outliers may come up – explain why the data may not fall exactly along the best fit line.

2) Instructor provides brief explanation of least squares method of evaluating regression lines, writing the equation for this calculation on the board. Students then perform these calculations in their groups (can divide up who does computation for which model).

   a) Sample explanation: By plotting the data it looks like y varies with x. The models describe a linear relationship where y varies with x. But the data points don't actually all fall on the line. The distance a point falls from the line is a form of error. The model that best explains, or fits, the data is the one that the data points are closest to, or has the least error (the smallest error sum of squares).

$$ErrorSumOfSquares = \sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2$$

Y_i is a data point at X_i, and Y_{hat} is the value of Y that falls on the line at X_i as defined by the model.

3) Instructor-led discussion (as a class) about which group's model is the "best fit".

Appendix 2: Demographic Assessment

1. Semester
    - Spring
    - Fall
    - Summer

2. Gender
    - Female
    - Male

3. What is your racial origin? (choose one or more of the following)

American Indian or Alaska Native
Black or African American
Hispanic/Latino
Native Hawaiian or other Pacific Islander
Asian
White

4. Age:
    - 19 (or younger)
    - 20
    - 21
    - 22
    - Over 22

5. Class Rank:
    - Freshman
    - Sophomore
    - Junior
    - Senior

6. Student Status:
    - Full-time
    - Part-time

7. What is your current GPA?

Less than 1.0
1.1 to 2.0
2.1 to 3.0
3.1 to 4.0

8. What is your major?

Biology
Biochemistry
Chemistry
Psychology
Other

9. Did you transfer to UMBC from a community college?

Yes
No

10. Which of the following courses did you take in high school? If you did not take a course, check the box "Did not take." For each course you did take, indicate the course level (basic, honors, or AP).

Algebra I	A. Did not take	B. Basic	C. Honors	D. AP
Algebra II	A. Did not take	B. Basic	C. Honors	D. AP
Trigonometry	A. Did not take	B. Basic	C. Honors	D. AP
Geometry	A. Did not take	B. Basic	C. Honors	D. AP
Pre Calculus	A. Did not take	B. Basic	C. Honors	D. AP
Calculus	A. Did not take	B. Basic	C. Honors	D. AP
Physics	A. Did not take	B. Basic	C. Honors	D. AP

11. Did you take the AP exam for calculus?

A. Yes
B. No

12. Did you receive AP credit for pre calculus (Math 150) at UMBC?

A. Yes
B. No

13. Did you receive AP credit for calculus I (Math 151) at UMBC or have you taken, or are you currently taking, calculus (Math 151)?

A. Yes
B. No

14. Did you receive AP credit for calculus II (Math 152) at UMBC or have you taken, or are you currently taking, calculus (Math 152)?

A. Yes
B. No

15. Have you taken, or are you currently taking, Physics 111 (non-calculus based introductory Physics I)?
A. Yes
B. No

16. Have you taken, or are you currently taking, Physics 121 (calculus based introductory Physics I)?
A. Yes
B. No

17. Have you taken, or are you currently taking, Physics 112 (non-calculus based introductory Physics II)?
A. Yes
B. No

18. Have you taken, or are you currently taking, Physics 122 (calculus based Introductort Physics II)?
A. Yes
B. No

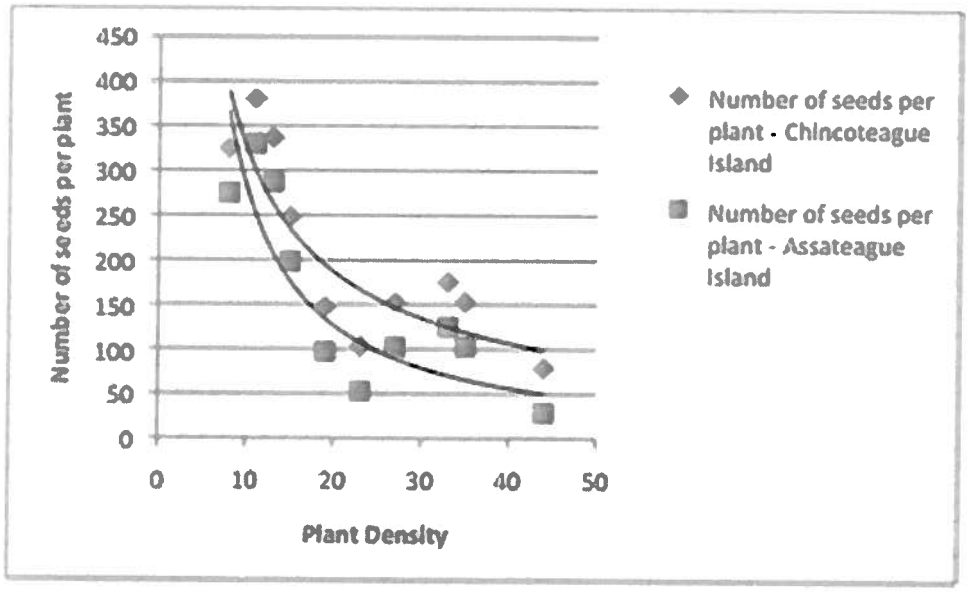
19. Have you taken, or are you currently taking, Statistics 350 (introductory statistics)?
A. Yes
B. No

Appendix 3: Pre-Post Assessment Exam

1. How useful do you think that quantitative approaches (e.g., mathematical modeling, statistical analyses) are to the study of biology?

a. It is impossible to study modern biological problems without such approaches.
b. Such approaches are extremely important for studying modern biological problems.
c. Such approaches are very important for studying modern biological problems.
d. Such approaches are somewhat important for studying modern biological problems.
e. Such approaches are not important for studying modern biological problems.

Population density is a key factor influencing life history traits. American Beachgrass is commonly found growing on the dunes in the coastal areas of the northeast and is often planted to help stabilize sand dunes. In an experiment designed to evaluate the effects of population density on seed production (an important life history trait) the following data were obtained from multiple plants from two populations, one population on Assateague Island and the other on Chincoteague Island. Estimates of plant density were based on counts of the number of individual plants within a 1 meter radius surrounding the plant. Use the graph below to answer the following five questions



2. How many plants were sampled from the Assateague population to produce the graph above?

Competency addressed: Data interpretation

a. 100
b. 1000
c. 10
d. 20
e. 40

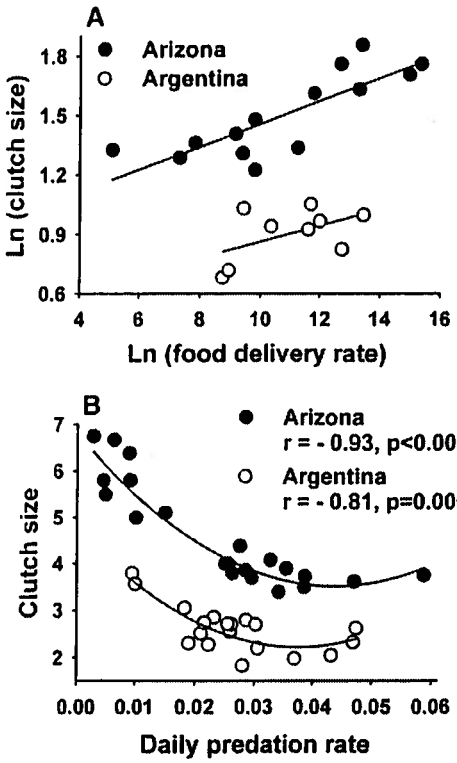
3. What is the best description of the data presented on the above graph?
Competency addressed: Data interpretation
a. There is a positive relationship between plant density and seed number
b. There is a linear relationship between plant density and the number of seeds per plant
c. Increasing density is associated with a increase in the number of seeds per plant
d. There is an exponential relationship between plant density and seed number
e. Plant density depends on the number of seeds per plant

4. From the graph it looks like
Competency addressed: Data interpretation
a. Plant densities are higher in Assateague compared with Chincoteague.
b. Plants on Chicoteague Island are more sensitive to the effects of density
c. Plants on Assateague Island are more sensitive to the effects of density than plants on Chincoteague Island.
d. The average number of seeds per plant is higher in Assateague Island compared to Chincoteague Island.
e. The range of plant densities is comparable on Chincoteague and Assateague islands.

5. If we were to use this information to predict the relationship between plant density and the number of seeds per plant on the Jersey shore, what is the most reasonable hypothesis?
Competency addressed: Data interpretation
a. at a density of 10 plants, plant density has no effect on the number of seeds per plant
the rate of change of seed number per plant as a function of density is highest after the density reaches 30 individuals
b. when density is between 20 and 30 plants we would expect no more than 200 seeds per plant
c. plants producing 350 seeds per individual will lead to a plant population density of around 12 plants
d. when plants get to a density of 50 we expect none of them to produce seeds

6. The lines shown on this graph are lines of "best fit" to each set of data. When evaluating the fit of a line to a set of experimental data, the line of best fit to the data is the one that
Competency addressed: Data interpretation
a. supports the hypothesis being tested
b. has the largest summed distance between the line and each data point
c. has the smallest summed distance between the line and each data point
d. passes through each data point on the graph
e. uses exponential values to describe relationships between variables

7. A commonly observed phenomenon across many bird species is that females typically lay larger clutches (have higher numbers of eggs per nest) when breeding in temperate zones (Arizona in this case) compared to birds in the tropics (Argentina in this case). Looking at the graph to the right which interpretation of the data matches the actual data gathered in figures A and B?



Competency addressed: Data interpretation

a. smaller clutch sizes are favored in the tropics because delivery rates of food by parent birds to the nest are lower. This implies much fewer resources in the tropics (if birds had more offspring in a nest it would require higher delivery rates)

b. smaller clutch sizes are favored in the tropics because they experience higher daily predation rates – larger clutch sizes would require more visits to the nest and so attract more predators

c. the relationship between clutch size and food delivery rate is very different when comparing the birds from Arizona vs. Argentina

d. daily predation rate and food delivery rate don't seem to provide much information to help us explain the different clutch sizes of birds from temperate vs. tropical habitats.

e. the natural log of food delivery rate determines daily predation rate

8. In 2008, the world's population was about 7 billion people. What is the scientific notation for 7 billion people?

Competency addressed: Quantitative numeracy

a. $1x10^7$ b. $1x10^9$ c. $7x10^7$ d. $7x10^9$ e. $7x10^{10}$

9. The Verhulst-Pearl equation of logistic growth ($\Delta N/\Delta t = rN((K-N)/K)$, describes the instantaneous growth rate of a population (the change in population size, ΔN, over a given time interval, Δt) that is influenced by the carrying capacity, K (the maximum number of individuals that can be supported in a given environment. Based on this equation, for small values of r (<1), as N gets larger to approach K, what happens to the population growth rate?

Competency addressed: Mathematical models

a. it increases

b. it decreases

c. it grows until it equals K

d. it doesn't change, r is a constant value

10. Based on the above model, if r equals zero, we expect that
Competency addressed: Mathematical models
a. the population size will decline quickly to zero
b. the population will decline slowly to zero
c. the population will grow until it reaches the carrying capacity
d. there is no change in population size over time
e. the per capita birth rates are slightly lower than the per capita death rates

11. The three main postulates of evolution by natural selection are

a. populations vary; variation is heritable; populations have distinct fitnesses.
b. traits are polygenic; loci are polymorphic; mutations arise randomly.
c. natural selection, sexual selection, kin selection.
d. individuals vary, variation is heritable, that variation correlates with fitness.
e. none of the above.

12. Darwin hypothesized that

a. individuals evolve to adapt to their environment.
b. populations evolve as a response to natural selection.
c. variation in DNA provides the raw material of evolution.
d. all of the above.
e. a & c only.

13. Which of the following best describes the four main reasons that allele frequencies in a population might change over time?

a. point mutation, translocation, inversion, duplication.
b. natural selection, sexual selection, kin selection, drift.
c. common descent, natural selection, convergent evolution, drift.
d. selection, drift, mutation, migration.
e. none of the above.

14. Genetic drift is a random change in allele frequencies. Which of the following situations is/are most likely to result in genetic drift?

a. A large population experiences strong natural selection when a new predator is introduced.
b. In the earliest stages of speciation, just a few individuals found a new population on an island.
c. A large island population experiences a catastrophic tsunami, reducing the population to a few individuals in a high elevation population.
d. BOTH B and C
e. A, B and C

15. Selection acts on _____, to cause change in allele frequencies in _____.

a. individuals, populations
b. species, species
c. populations, individuals
d. species, populations
e. populations, species

16. Choose the best answer: Natural selection acts to...

a. favor those characteristics that preserve the species
b. favor those characteristics that lead to faster population growth
c. increase the reproductive output of individuals
d. increase the life span of populations
e. decrease the chance of species extinctions

17. Speciation is:

a. the divergence of a single lineage into two descendent populations
b. the evolution of new forms due to mutation
c. frequently caused by geographic isolation
d. both A and B
e. both A and C

18. Biological evolution is typically defined as

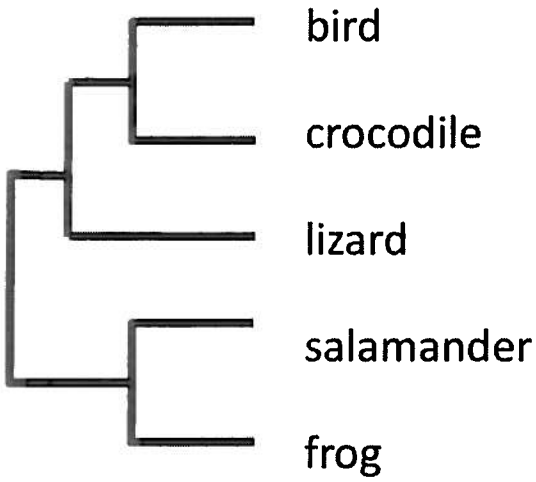
a. changes in the genetic composition of an individual over time
b. changes in the phenotype of an individual over time
c. changes in the genetic composition of a population over time
d. changes in the phenotype of a population over time
e. ontogeny

** 19. According to Hamilton's law of kin selection, a mutation that increases the altruistic behavior of individuals will only be favored by selection if the benefit to a related individual (increasing the reproductive output of the relative, B) times the coefficient of relatedness (r) is greater than the cost in reproduction (C) to the altruistic individual. Consider a mutation that increases altruistic behavior of individuals to help their siblings rear their offspring (r = 0.5 for siblings). If the cost of an altruistic behavior of the individual with this mutation decreases its fitness by 3 offspring, what is the minimum number of offspring that must be produced by the beneficial acts of a sibling (B) to favor the spread of the altruistic mutation in the population?
Competency addressed: Mathematical modeling
(only used on pre/post exams given in Summer 2013, Fall 2013, and Spring 2014)**
a. 1 offspring b. 2.5 offspring c. 3 offspring d. 4.25 offspring
e. 6 offspring

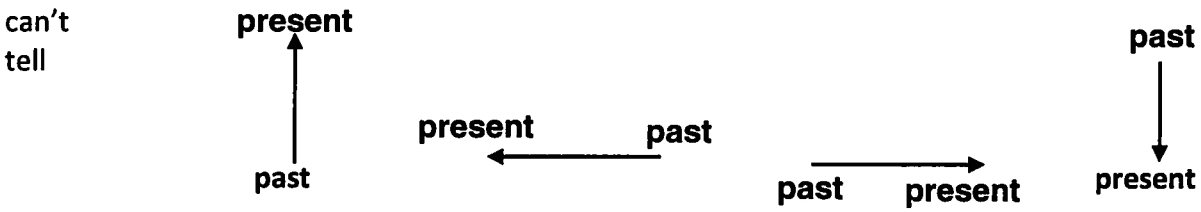
20. A hypothetical locus with two alleles for running speed exists in a population. Individuals with genotype RR are super speedy, Rr are mildly fast, and rr individuals prefer to walk. At another locus, yellow individuals are YY, white individuals are Yy and brown individuals are yy. If a super speedy, yellow individual mates with a mildly fast brown individual and produces offspring, what fraction of their children are likely to be super speedy and yellow?
Competency addressed: Quantitative numeracy
a. 0% b. 25% c. 50% d. 75% e. 100%

21. Referring to the question above, if two " brown walkers" (yyrr) mate and produce offspring, what fraction of their children are likely to be brown walkers?
Competency addressed: Quantitative numeracy
a. 0% b. 25% c. 50% d. 75% e. 100%

22. Below is an evolutionary tree (phylogeny) of five vertebrate species. Which of these species is most closely related to lizards?
a. bird b. salamander c. frog d. can't tell based on the tree.



23. Given the phylogeny above, which of the following "time arrows" is correctly oriented?
a. b. c. d. e.



24. Based DNA sequences from the nuclear genome, which of the following primate species is ancestral to humans?
a. chimpanzees b. orangutans c. baboons d. rhesus monkey
e. none of the above

25. Which of the following taxonomic groupings are humans NOT a member of?

a. Vertebrata b. Chordata c. Mammalia
d. Carnivora e. Humans are members of each of these taxa.

26. Which of the following statements is the best description of human evolutionary history?

a. The human lineage split from the Neanderthal lineage approximately 0.5 million years ago (MYA).
b. Humans evolved from chimpanzees approximately 6 MYA.
c. Our primate ancestors and birds evolved from dinosaurs 65 MYA.
d. The coelacanth is a fish found off South Africa that was our ancestor approximately 100 MYA.

27. Evolutionary biologists now agree that we should recognize and name only "natural groups" or "clades". In other words, we should only use monophyletic groups – groups of species that consist of:

a. a common ancestor and all their descendants.
b. groups of species that can interbreed with each other but not other such groups.
c. species that all share similar overall morphology.
d. pairs of species that are each other's closest relatives.
e. none of the above

28. The cytochrome b mitochondrial gene generally diverges at approximately 2% per million years in apes. If gorillas and chimps differ by 16% in their cyt b sequence, approximately how long ago does that suggest the species diverged?
Competency addressed: Quantitative numeracy
a. 32 million years b. 8 million years c. 6 million years d. 16,000 years
e. 18 million years

29. "SPECIES = a group of organisms that all share a more recent common ancestor with each other than they do with other organisms". This definition of species fits best with the:

a. Biological Species Concept
b. Morphological Species Concept
c. Phylogenetic Species Concept
d. Both A and B
e. The above definition is not a species concept

30. Which of the following fish lineages is the oldest? (IE, which branches off from the main path of evolution the earliest?)

a. sharks & rays b. lungfish c. coelacanths
d. ray-finned fishes e. can't tell

31. Which of the following invertebrate animals is most closely related to humans (as indicated by both developmental plan and DNA sequence based trees)?

a. sea star b. coral c. nematode worms d. blue crabs
e. ALL of the above are equally related to humans

32. As part of a sea turtle recovery project you need to first gather data on the probability that offspring born this year survive to reproduce. You tag 800 baby turtles as they emerge from their nest and then record the number of survivors every 5 years. Five years after you tag the initial cohort of turtles you find 100 survivors. Five years later you find 20 survivors. And five years after that you find 3 surviving turtles. These were all adults so you discover that the age at which turtles become adults (are sexually mature) is 15 years old. If your project successfully estimated the age-specific survival rates of turtles, what percent of newborn turtles are expected to survive to reproductive age?
Competency addressed: Quantitative numeracy
a. less than 1% b. 1 to 2% c. 3 to 5% d. 5 to 10% e. 11-20%

The additional question (below) appeared on the pre/post exam in Spring 2013 and Fall 2013

33. In 2008, the world's population was about 7 billion people. Assuming density independent population growth, given current world population growth rate of 1.2% annually, what will the size of the population be in the year 2048 (when most of you are approaching retirement)?
Competency addressed: Quantitative numeracy
a. 1.13×10^{10} people b. 11.3 million people c. 29 billion people
d. 9×10^{13} billion people e. 7×10^{14}

Summary of Pre-post exam questions aligned with competencies and relevant module activities

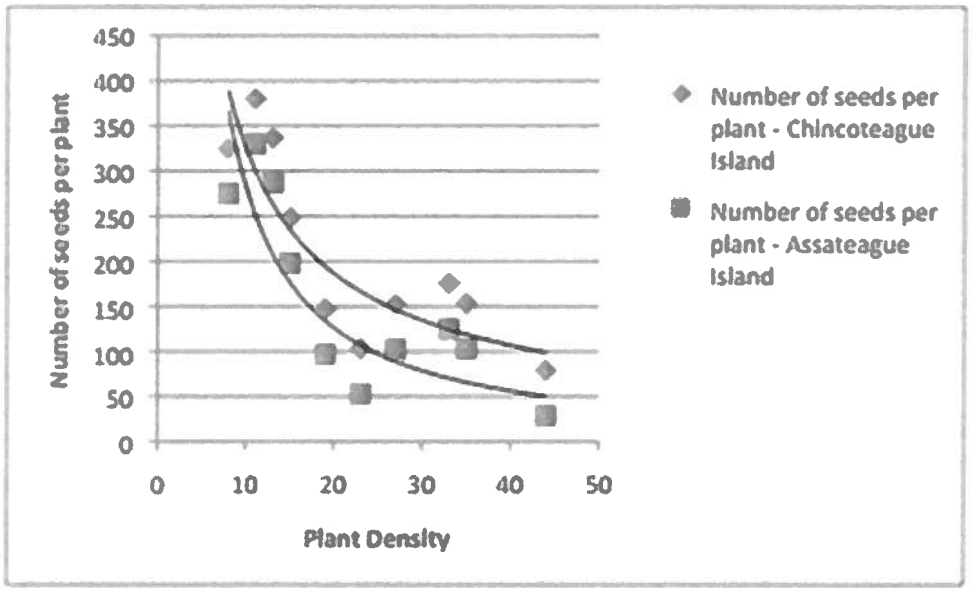
Exam Question	Skill Assessed	Module addressing this learning goal
2,3,4,5,6,7	Data Interpretation	Intro to Mathematical Models Population Genetics I, II
8,20,21,28,32,33	Quantitative Numeracy	Mendelian Genetics Intro to Mathematical Models Population Genetics I, II
9,10,19	Mathematical models	Intro to Mathematical Models

Appendix 4: Interview Protocol

1. Could you describe for me, how did you go about solving this problem? How did you figure it out? What were you thinking about as you read the problem and the answers?
2. (If the student says they guessed): On what basis did you guess? Did you eliminate any of the answers? Were there any clues in the wording of the question?
3. (If the student refers to the data in the graph but doesn't fully articulate how they used it): What were you looking at in the graph? How did you make use of it?
4. (If the student has the right answer but doesn't fully articulate their reasoning): Assume that you're teaching a novice—someone with little to no background in biology. Explain to me in a way that I can learn it from you.

Assessment Questions for Interview

Use the following information and graph to answer questions 1-4.
Population density is a key factor influencing life history traits. American Beachgrass is commonly found growing on the dunes in the coastal areas of the northeast and is often planted to help stabilize sand dunes. In an experiment designed to evaluate the effects of population density on seed production (an important life history trait) the following data were obtained from multiple plants from two populations, one population on Assateague Island and the other on Chincoteague Island. Estimates of plant density were based on counts of the number of individual plants within a 1 meter radius surrounding the plant. Use the graph below to answer the following four questions.



1. How many plants were sampled from the Assateague population to produce the graph above?

a. 100
b. 1000
c. 10
d. 20
e. 40

2. What is the best description of the data presented on the above graph?

a. There is a positive relationship between plant density and seed number
b. There is a linear relationship between plant density and the number of seeds per plant
c. Increasing density is associated with a increase in the number of seeds per plant
d. Plants tend to have fewer seeds when they are in high density
e. Plant density depends on the number of seeds per plant

3. From the graph it looks like

a. Plant densities are higher in Assateague compared with Chincoteague.
b. Plants on Chicoteague Island are more sensitive to the effects of density
c. Plants on Assateague Island are more sensitive to the effects of density
d. The average number of seeds per plant is higher in Assateague Island compared to Chincoteague Island.
e. The range of plant densities is comparable on Chincoteague and Assateague islands.

4. If we were to use this information to predict the relationship between plant density and the number of seeds per plant on the Jersey shore, what is the most reasonable hypothesis?

a. at a density of 10 plants, plant density has no effect on the number of seeds per plant
b. the rate of change of seed number per plant as a function of density is highest after the density reaches 30 individuals
c. when density is between 20 and 30 plants we would expect no more than 200 seeds per plant
d. plants producing 350 seeds per individual will lead to a plant population density of around 12 plants
e. when plants get to a density of 50 we expect none of them to produce seeds

Appendix 5: Results of multiple regression analyses on Student Scores on Post Assessment

		A. Skill: Quantitative Numeracy								
Characteristic	Description	Spring 2013 (R^2=0.190, F=4.447, p=0.000)			Summer 2013 (R^2=0.340, F=1.548, p=0.182			Spring 2014 (R^2=0.430, F=18.639,p=0.000		
		Coefficient	*t* value	*p* value	Coefficient	*t* value	*p* value	Coefficient	*t* value	*p* value
Pre-test score	Student's score on the pre-test	0.273	4.001	**0.000**	0.444	2.881	**0.008**	0.384	7.110	**0.000**
Transfer status	Whether or not student transferred from a community college	-8.072	-2.079	**0.039**	2.503	0.286	0.777	-11.493	-4.484	**0.000**
Algebra 1	Whether or not student took algebra 1 in high school	-5.443	-1.517	0.131	-4.749	-0.924	0.364	-5.708	-2.065	**0.040**
Algebra 2	Whether or not student took algebra 2 in high school	5.916	1.025	0.307	-1.120	-0.201	0.842	6.961	1.818	0.070
Pre-calculus	Whether or not student took pre-calculus in high school	-9.853	-2.429	**0.016**	5.198	0.726	0.474	-1.674	-0.499	0.618
Calculus	Whether or not student took calculus in high school	5.681	1.821	0.070	1.297	0.303	0.764	-3.108	-1.072	0.285
Calculus 1 at UMBC	Whether or not student received AP credit for calculus 1 or was currently taking or had already taken calculus 1	-1.652	0.565	0.573	-9.922	-1.034	0.310	8.736	3.350	**0.001**
Calculus 2 at UMBC	Whether or not student received AP credit for calculus 2 or was currently taking or had already taken calculus 2	3.937	1.369	0.173	11.624	1.190	0.244	1.191	0.496	0.621
Stat 350	Whether or not student took or was currently taking STAT 350 (statistics for biology majors at UMBC)	-4.732	-1.4121	0.157	-1.814	-0.206	0.838	1.109	0.415	0.678

Appendix 5: Results of multiple regression analyses on Student Scores on Post Assessment

		B. Skill: Data Interpretation								
Characteristic	Description	Spring 2013 (R^2=0.169, F=3.858, p=0.000			Summer 2013 (R^2=0.473, F=2.693, p=0.022)			Spring 2014 (R^2=0.249, F=8.189, p=0.000		
		Coefficient	*t* value	*p* value	Coefficient	*t* value	*p* value	Coefficient	*t* value	*p* value
Pre-test score	Student's score on the pre-test	0.390	5.398	**0.000**	0.754	4.585	**0.000**	0.356	5.390	**0.000**
Transfer status	Whether or not student transferred from a community college	-6.154	-1.131	0.260	12.922	1.473	0.152	-6.455	-1.698	0.091
Algebra 1	Whether or not student took algebra 1 in high school	-3.890	-0.775	0.439	0.695	0.129	0.899	-3.263	-0.789	0.431
Algebra 2	Whether or not student took algebra 2 in high school	2.969	0.374	0.709	-1.313	-0.224	0.824	-0.617	-0.108	0.914
Pre-calculus	Whether or not student took pre-calculus in high school	-0.063	-0.011	0.991	7.416	0.984	0.334	-3.453	-0.689	0.492
Calculus	Whether or not student took calculus in high school	0.667	0.152	0.879	-3.605	-0.815	0.422	-0.527	-0.122	0.903
Calculus 1 at UMBC	Whether or not student received AP credit for calculus 1 or was currently taking or had already taken calculus 1	0.569	0.139	0.890	5.566	0.555	0.583	14.520	3.750	**0.000**
Calculus 2 at UMBC	Whether or not student received AP credit for calculus 2 or was currently taking or had already taken calculus 2	-1.561	-0.390	0.697	-14.728	-1.298	0.205	0.028	0.008	0.994
Stat 350	Whether or not student already took or was currently taking STAT 350 (statistics for biology majors)	3.618	0.781	0.436	-2.861	-0.309	0.760	-6.123	-1.535	0.126

Appendix 5: Results of multiple regression analyses on Student Scores on Post Assessment

		C. Skill: Mathematical Modeling								
Characteristic	Description	Spring 2013 (R^2=0.163, F=3.698, p=0.000)			Summer 2013 (R^2=0.330, F=1.475, p=0.207)			Spring 2014 (R^2=0.243, F=7.910, p=0.000)		
		Coefficient	*t* value	*p* value	Coefficient	*t* value	*p* value	Coefficient	*t* value	*p* value
Pre-test score	Student's score on the pre-test	0.257	3.679	**0.000**	0.198	1.378	0.179	0.240	3.836	**0.000**
Transfer status	Whether or not student transferred from a community college	0.537	0.067	0.946	-20.217	-1.494	0.147	-12.684	-2.343	**0.020**
Algebra 1	Whether or not student took algebra 1 in high school	6.409	0.866	0.388	-9.191	-1.114	0.275	-10.185	-1.738	0.084
Algebra 2	Whether or not student took algebra 2 in high school	-0.634	-0.054	0.957	5.695	0.641	0.572	12.124	1.491	0.137
Pre-calculus	Whether or not student took pre-calculus in high school	-5.532	-0.665	0.507	-2.317	-0.201	0.842	-7.208	-1.011	0.313
Calculus	Whether or not student took calculus in high school	4.529	0.705	0.482	-11.929	-1.766	0.089	-0.514	-0.083	0.934
Calculus 1 at UMBC	Whether or not student received AP credit for calculus 1 or was currently taking or had already taken calculus 1	16.447	2.733	**0.007**	6.075	0.390	0.700	12.081	2.193	**0.029**
Calculus 2 at UMBC	Whether or not student received AP credit for calculus 2 or was currently taking or had already taken calculus 2	2.942	0.497	0.620	19.405	1.234	0.224	9.766	1.935	0.054
Stat 350	Whether or not student already took or was currently taking STAT 350 (statistics for biology majors)	-5.722	-0.836	0.405	7.139	0.507	0.616	-6.453	-1.140	0.256