Supplemental Material

CBE—Life Sciences Education

Hoskins ***et al.***

Supplemental 1:

Table S1. Full models based on optimization of adjusted R^2 for Fall students when all data was used (A) and when only outline and concept map data is used (B). Global model statistics are presented below each model. Bolded items are significant at $p \leq 0.05$.

Variable	d.f.	β	S.E. β	Standardized β	t	p
A)All Data, Full Model						
Intercept	1	-2.02	2.55	0.00	-0.79	0.4330
Lecture Section (C)	**1**	**-6.07**	**2.96**	**-0.31**	**-2.05**	**0.0490**
Outline Content	1	-1.73	1.33	-0.17	-1.30	0.2016
Map Organization	**1**	**5.59**	**2.20**	**0.49**	**2.54**	**0.0162**
Map Content	**1**	**-4.14**	**1.67**	**-0.50**	**-2.48**	**0.0189**
Map Number of Nodes	**1**	**0.66**	**0.20**	**1.33**	**3.23**	**0.0029**
Map Number of Arrows	**1**	**-0.27**	**0.10**	**-0.61**	**-2.78**	**0.0092**
Map Number of Linking Words	1	-0.42	0.24	-0.77	-1.77	0.0859
Map Number of Terminal Nodes	1	18.89	9.50	0.62	1.99	0.0556
Q6a) Outline Use	1	2.09	1.19	0.20	1.75	0.0895
Global Model Statistics: $F_{9, 31} = 5.78$, **$p < 0.0001$**, $R^2 = 0.6267$, Adj. $R^2 = 0.5183$						
B) Survey Data Excluded, Full Model						
Intercept	1	1.46	2.29	0.00	0.64	0.5272
Lecture Section (C)	1	-3.80	3.38	-0.19	-1.13	0.2667
Outline Content	1	-2.48	1.37	-0.24	-1.81	0.0774
Map Organization	1	3.53	2.17	0.31	1.62	0.1120
Map Content	1	-2.70	1.72	-0.32	-1.57	0.1239
Map Number of Nodes	**1**	**0.47**	**0.17**	**0.97**	**2.69**	**0.0100**
Map Number of Arrows	1	-0.15	0.11	-0.33	-1.47	0.1497
Map Number of Linking Words	1	-0.35	0.22	-0.63	-1.61	0.1146
Map Quality of Linking Words	1	-1.90	1.75	-0.17	-1.09	0.2830
Map Number of Terminal Nodes	**1**	**22.49**	**8.79**	**0.71**	**2.56**	**0.0141**
Global Model Statistics: $F_{9,44} = 2.48$, $p = 0.2170$, $R^2 = 0.3369$, Adj. $R^2 = 0.2013$						

Table S2. Summary of multivariate regressions for Spring 2015 data set, where survey data were excluded. Predictors that were significant at $p \leq 0.05$ are bolded. Overall model statistics are provided below each model.

Variable	d.f.	β	S.E. β	Standardized β	t	p
A) Survey Data Excluded, Full Model[1]						
Intercept	**1**	**-0.089**	**0.043**	**0.000**	**-2.05**	**0.0471**
Lecture Section B	**1**	**0.127**	**0.048**	**0.534**	**2.64**	**0.0121**
Lecture Section C	1	0.091	0.052	0.356	1.76	0.0864
Map Number of Nodes	**1**	**-0.005**	**0.002**	**-0.886**	**-2.15**	**0.0383**
Map Number of Linking Words	1	0.003	0.002	0.438	1.87	0.0695
Map Number of Terminal Nodes	1	0.004	0.004	0.392	1.14	0.2634
Global Model Statistics: $F_{5,38} = 2.09$, $p = 0.0876$, $R^2 = 0.2159$, R^2 Adj. = 0.1127						
B) Survey Data Excluded, Best Model[2]						
Intercept	1	-0.074	0.041	0.000	-1.79	0.0812
Lecture Section B	**1**	**0.121**	**0.048**	**0.509**	**2.52**	**0.0161**
Lecture Section C	1	0.090	0.052	0.349	1.72	0.0934
Map Number of Nodes	**1**	**-0.003**	**0.001**	**-0.499**	**-2.13**	**0.0393**
Map Number of Linking Words	1	0.003	0.002	0.396	1.71	0.0961
Global Model Statistics: $F_{4,39} = 2.28$, $p= 0.0784$, $R^2 = 0.1893$, R^2 Adj. = 0.1061						

Supplemental 2: Pre- and Post-surveys administered to students to examine self-reported changes in study habits and techniques in Fall 2014 and Spring 2015.

Study habits pre- survey

Gender __________male___________female

Year in school ______________________________

Major _______________________________

BIO/MBI 115 or 116lecture section (A, B, or C) _____________

Ethnicity _______African American/ Black
_______American Indian/Alaska Native
_______Asian/Pacific Islander
_______Hispanic
_______White/Caucasian
_______Other (please specify)
____

1. What are the last four digits of your cell phone number?
____

2. What is the day of the month in which you were born?
(mm/dd)______________________________

3. How many hours a week do you spend studying for BIO/MBI 116?

4. Please explain how you study now for BIO/MBI 115 or 116 exams (Open)

5. When did you start studying for BIO/MBI 115 or 116 Exam 1?

a. 3 weeks before
b. 2 weeks before
c. 1 week before
e. 2 days before
f. 1 day before

6. Rate each strategy given below based on how often you used it to study.

a. Making outline after class (identifying major/minor topics discussed)

Did not use used few times but not regularly used once a week used after every class

1 2 3 4

b. Reorganizing notes from class

Did not use used few times but not regularly used once a week used after every class

1 2 3 4

c. Drawing pictures, making concept maps while re-organizing notes from class

Did not use used few times but not regularly used once a week used after every class

1 2 3 4

d. Regular reviewing of material from class

Did not use used few times but not regularly used once a week used after every class

1 2 3 4

7. What study strategies other than those listed above did you use to study for BIO/MBI 115 or 116 Exam 1. Explain how often you used them and how efficient they were (Open)

8. Explain in detail the challenges you faced in BIO/MBI 115 or 116 and what did you do to overcome the challenges? (Open)

Study habits post- survey

Gender __________male___________female

Year in school ______________________________

Major _______________________________

BIO/MBI 115 section ________________________________

Ethnicity _______African American/ Black
_______American Indian/Alaska Native
_______Asian/Pacific Islander
_______Hispanic
_______White/Caucasian
_______Other (please specify)
____

1. What are the last four digits of your cell phone number?
____
2. What is the day of the month in which you were born?
(mm/dd)______________________________
3. How many hours a week do you spend studying for BIO/MBI 115 or 116?
4. Please explain how different do you study now for BIO/MBI 115 or 116 exams when compared to before enrolling in the sprint course? (Open)

5. When did you start studying for BIO/MBI 115 or 116 Exam 3?

a. 3 weeks before
b. 2 weeks before
c. 1 week before
e. 2 days before
f. 1 day before

6. Rate each strategy given below based on how often you used it to study.

a. Making outline after class (identifying major/minor topics discussed)
Did not use used few times but not regularly used once a week used after every class

1 2 3 4

b. Reorganizing notes from class
Did not use used few times but not regularly used once a week used after every class
1 2 3 4

c. Drawing pictures, making concept maps while re-organizing notes from class
Did not use used few times but not regularly used once a week used after every class
1 2 3 4

d. Regular reviewing of material from class
Did not use used few times but not regularly used once a week used after every class
1 2 3 4

7. What study strategies other than those listed above did you use to study for BIO/MBI 115 or 116 Exam 3. Explain how often you used them and how efficient they were (Open)

8. Explain in detail the challenges you faced in BIO/MBI 115 or 116 and what did you do to overcome the challenges? (Open)

Supplemental 3: Grading/assessment guide

Guide to Grading of Outlines and Concept Maps in BIO/MBI 104

Grading outlines and concept maps is a fairly subjective procedure. Although there is a rubric provided, much of what we are trying to assess is how students are processing information from lecture, and their ability to highlight the most important features of each topic. By definition, there is no "right way" to execute these assignments; each student will take a different approach and it is the job of the grader to determine how effective that approach is. When grading, it is critical to keep in mind the central goals of each assignment. While equitably assigning scores is part of this process, the most important function of the grader is to provide constructive feedback, such that students can continue to improve the effectiveness of their outlines and concept maps.

Goals for Outlines:

- Identify major and minor topics from the lecture and re-organize material hierarchically

- Create a study guide for later use

- Include sufficient detail as to indicate a full understanding of the topics, including definitions, specific examples, and statements regarding the broad importance of each topic

Goals for Concept Maps:

- Networking Knowledge: the objective of concept maps is to highlight the connections between topics in a visual way, using arrows labeled with questions or linking words that effectively describe said connections

- These are about the process: by asking appropriate questions (when, where, how, but especially WHY), students are forced to engage and think more deeply about the concepts discussed in lecture and their broader meaning

A Step-By-Step Guide

1. Before sitting down to grade, the first step is to become familiar with the material that the students are covering in lecture. There are three lectures sections represented, so this will mean downloading and studying three presentations.

    - In particular, when going through lectures, try to identify what the major topics covered were, and what the broader biological significance of each is

- the biggest mistake students make on outlines/maps (and in general) is to get lost in the details at the expense of missing the take-home message

2. Don't jump right in to grading the first paper in a stack. Rather, take 5 minutes to scan through a subset of the assignments to assess the range of effort/quality of work

    - This is critical: you need to have a sense of what students did before you can set your expectations (your sense of how students *should* perform is not always reality). This will help you avoid a really low or high average score overall, and will increase your ability to be consistent

3. For each assignment, go through and make line-by-line comments as you read

    - for example, if they are missing definitions, statements of why topics are important, or specific examples, highlight these

    - if making a comment about organization, it can be useful to indicate this by starting your comment with "ORG:"

    - be careful with how long you spend on line-by-line comments. This is the #1 way to spend an enormous amount of time grading. The objective here is not to point out every mistake (and you should not), but rather to identify what kinds of mistakes the student is repeatedly making, to highlight examples of these, and to suggest a correction

4. At the end of the assignment, ask yourself: how effectively did the student convey the lecture material? Does this outline/map indicate that they are thinking deeply, or are they simply regurgitating the information that is on the slides (this is the most common problem by far)?

5. Assign a score. Points are broken down into content (out of 5) and organization (out of 5). When assigning points to these categories, the idea is to communicate to the student what they need to improve on. Subtract points from the appropriate categories to indicate this.

    - It is impossible to do this in any completely standardized way, because the assignments are so diverse. I like to decide what overall grade the assignment deserves, then subtract the appropriate number of points from each category (based on where they need to improve)

6. Write a short note highlighting the major issues and justifying deductions and suggesting ways to improve (this is key- we are not punishing students, we are helping them to improve- make sure that your language is helpful, not inflammatory)

    - I like to do this for each section, for example

        ORG: 4/5, mostly well organized, but linking words not descriptive

- use words that describe exactly how topics relate

Content: 3.5/5, Insufficient detail throughout. Define terms, give examples, draw figures when necessary

- Remember to highlight WHY topics are important

- It can sometimes be useful to highlight specific examples to show what you mean (for example, above, I commented on linking words that are too vague). Highlight an example of a vague linking word and suggest a better one

7. Reflect on the performance of the class as a whole. Are there specific problems that most students are struggling with? Write these down somewhere. During class, recapping common mistakes and how to fix them as a group is an excellent exercise.

Some Specific Scenarios:

Lack of effort: do not spend time providing comments on outlines or maps that look like they were thrown together in the hallway before class

- my standard comment for these is: “Insufficient effort, take your time, see me if expectations are not clear”

Unreadable Work: it is hard to provide comments when you can’t read the work. I typically assign a score based on effort, and then write the student a note:

- “Please consider typing or writing legibly- it is difficult to provide feedback when I can’t read your writing!”

Wrong Lecture: sometimes students misunderstand which topic was to be mapped/outlined. Don’t penalize them for this, point-wise. Just grade what they have, but feel free to provide a comment along the lines of “Assigned topic was XX?”

Supplemental 4: Outline and Concept Map Rubric

This is the rubric provided to students for concept maps. We do not provide a specific rubric for outlines, but rather indicate to students in class that the grading scheme is the same as for concept maps, except for formatting. For example, proper hierarchical organization of outlines uses indentation to indicate hierarchy, instead of connecting lines and nodes.

Concept Map Rubric

Points	5	4	3	2	1
Organization	- All concepts included in a hierarchical structure: More general concepts on the top of the map and specific concepts at the lower end -All concepts are connected by a connecting line and words that are valid -Information is presented very clearly and exhibits high level of understanding	-Most concepts included in a hierarchical structure: More general concepts on the top of the map and specific concepts at the lower end. -Most concepts are connected by a connecting line and words that are valid -Information is presented clearly and exhibits good level of understanding	-Adequate number of concepts are included in a hierarchical structure: More general concepts on the top of the map and specific concepts at the lower end. -Adequate concepts are connected by a connecting line and words that are valid -Information is presented well and exhibits adequate level of understanding	-Only few concepts are included in a hierarchical structure: More general concepts on the top of the map and specific concepts at the lower end. -Only few concepts are connected by a connecting line and words that are valid -Information is structured but does not exhibit adequate understanding	-No hierarchical structure -No connections or linking words -Does not exhibit any understanding of the concepts
Contents	-Reveals complex thinking about meaningful relationship between the ideas/concepts -Exhibits more complex facts about the concepts/ideas. Addresses definitions/meaning, structure, function, examples, exceptions, similarities, differences and relationships between concepts. Also addresses more questions such as: why does it happen? how does it happen? What if it does not happen? that implies deeper understanding of the concepts	-Reveals effective thinking but not as complex about meaningful relationship between the ideas/concepts -Exhibits adequate basic and few complex facts about the concepts/ideas. Addresses definitions/meaning, structure, function, examples, exceptions, similarities, differences and relationships between concepts. Also addresses few questions such as: why does it happen? how does it happen? that implies deeper understanding of the concepts.	-Reveals adequate thinking about meaningful relationship between the ideas/concepts -Exhibits adequate basic facts about the concepts/ideas. Addresses definitions/meaning, structure, function, examples, exceptions, similarities, differences and relationships between concepts	-Reveals some thinking about meaningful relationship between the ideas/concepts -Exhibits only few basic facts such as definitions/meaning, structure, function of the concepts/ideas	-No evidence of meaningful relationship -Exhibits only incorrect information

Supplemental 5: Sample Outline on Population Ecology

This is an instructor generated outline, based on the lecture slides for a unit on population ecology in fall 2014. We provide this during week 1 of the supplemental course to guide students in their first attempt at making outlines. Students find this very helpful, as they can open the lecture slides on this topic and see an example of how to reorganize and summarize main ideas.

Sample Outline
Based on Lecture "Population Ecology"
Section A, Fall 2014

Population Ecology

I. Defining Population Ecology

A. Definition: Population Ecology is the study of the factors that influence population size and how they change over time

1. Examples of factors influencing population growth are under "III," below

B. What is a population?

1. Many potential definitions, but at a minimum, a population is a group of individuals of the same species that live in the same area and reproduce with one another

II. Exponential Population Growth

A. Definition: Exponential population growth is a form that occurs in the absence of factors that impose limitations on the population growth rate.

B. Equation: $dN/dt = rN$

1. N = population size at a given moment in time

2. r = intrinsic rate of increase, or sometimes, the "per capita growth rate "

a. r is a CONSTANT in the exponential growth model

i. If r is constant, why is population growth rate not constant in an exponential model? N changes over time!

b. when $r > 0$, population is growing
when $r = 0$, no growth
when $r > 0$, population is growing

3. dN/dt = from calculus, the derivative of population size (N) with respect to time

a. when population size is graphed against time, dN/dt is the slope of the tangent line, or the instantaneous rate of population change

C. Shape: when graphing N against t…

1. Exponential Growth has a J-shaped curve- more units added per unit time as you move from left to right, even though r is unchanged…

2. Exp. Growth is the left curve in the figure below

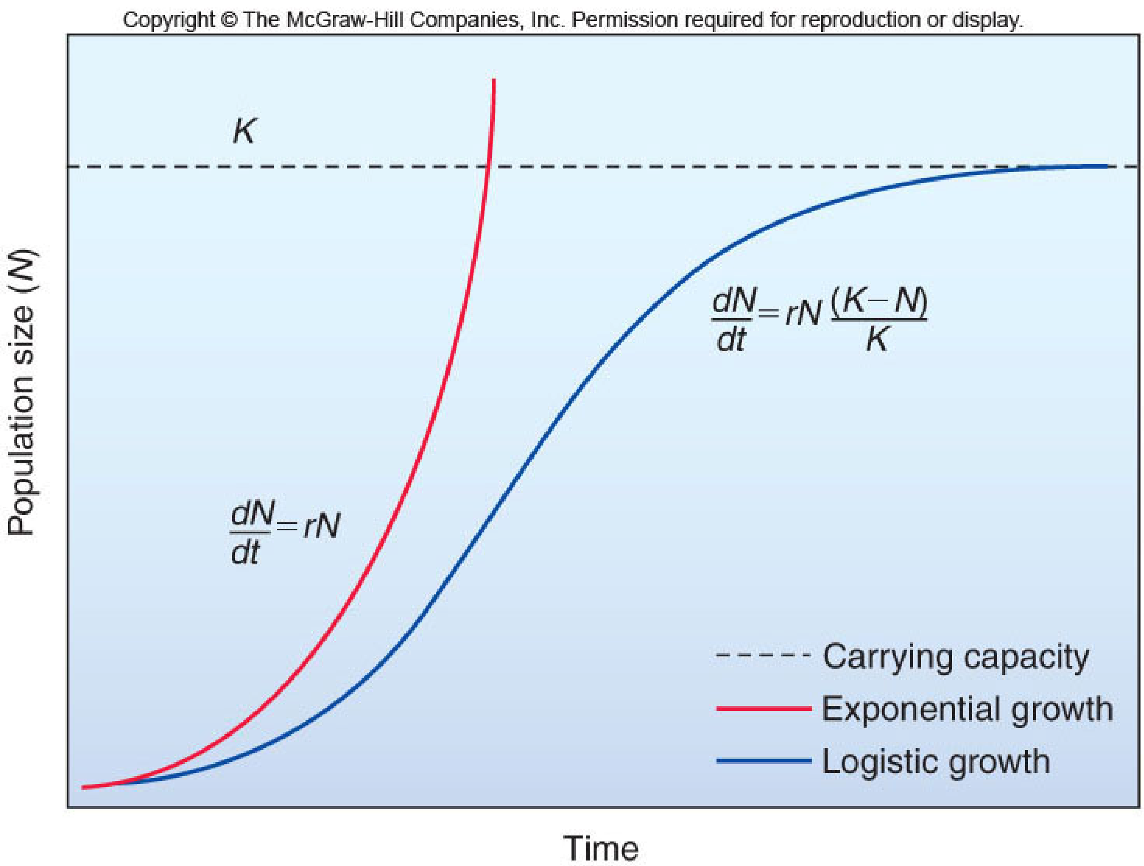

Figure 1. Exponential (J shaped, left), and logistic (S-shaped, right) growth curves and their characteristic equations

D. History and Examples

1. Thomas Malthus published exponential growth model way back in 1798
2. Examples:
   a. Ebola is spreading at an exponential rate
   b. Invasive species often display exponential growth when invading a new range, which enables them to colonize quickly
   c. Bacteria can reproduce very rapidly, often displaying exponential growth rates

E. Realism?: Exponential growth, although sometimes observed, is not always a realistic description of population growth because at some point, growth is usually limited in the real world

1. Example: bacteria on a plate grow exponentially until they eat all the nutrients- growth rate levels off (see logistic growth, below)

III. Logistic Population Growth

A. Definition: logistic population growth is an extension of the exponential model that takes into account density dependence

B. Equation: dN/dt = rN(K-N/K)

1. N = population size at a given moment in time
2. r = intrinsic rate of increase, or sometimes, the "per capita growth rate "
    a. r is a CONSTANT in the exponential growth model
        i. If r is constant, why is population growth rate not constant in an exponential model? N changes over time!
    b. when r > 0, population is growing
       when r = 0, no growth
       when r > 0, population is growing
3. dN/dt = from calculus, the derivative of population size (N) with respect to time
    a. when population size is graphed against time, dN/dt is the slope of the tangent line, or the instantaneous rate of population change
4. K = carrying capacity, or the maximum number of individuals that can be supported under a given set of conditions
    a. Graphically, the horizontal asymptote representing maximum population size
    b. Note that the addition of (K-N/K) is the only difference between logistic and exponential growth equations

C. Factors Regulating Population Growth

1. Ecological Disturbance: any temporary change in environmental conditions that affects the ecosystem in a pronounced manner
    a. Typically, a disturbance kills some individuals, which then frees resources for others
    b. Typically density independent (e.g., hurricane wipes out most of a forest, resulting in a shift in community structure), but can be density dependent, too (e.g., introduction of a pathogen to a novel environment might have different effects depending on the density of available hosts)
2. Density dependent and density independent factors regulate the size and growth of populations
    a. Density Dependent factors are those that affect population growth differentially depending on the size of the population

i. two-types, positive and negative: differ in slope across density gradient- see graph below
ii. happens when either mortality of reproduction rates vary with population size
iii. often the result of biotic interactions
iv. Examples
- competition leads to reduced growth rates at higher N because resource limitation increases with N
- parasitism and disease are density dependent: with higher host N, parasites or disease move through the population more quickly

b. Density independent factors affect population growth as well, but do not depend on the size of populations
i. Examples
- Natural Disasters: a hurricane wipes out a forest, freeing resources and resulting in a very different forest
- Climate cycles: e.g., a bout of extreme cold causes a population to freeze to death- individuals freeze regardless of the number of individuals present

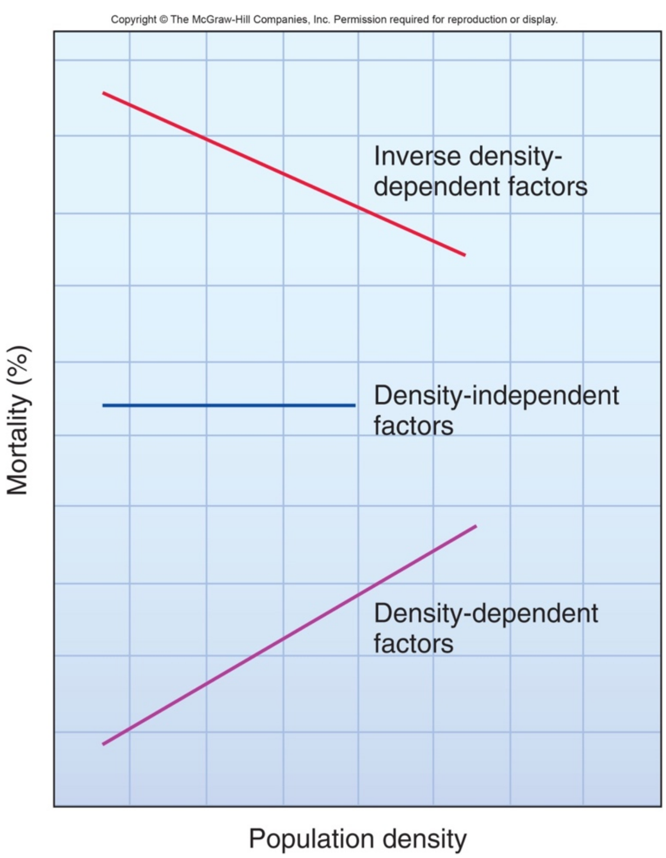

Figure 2. This figure shows the difference between density independent factors and density dependent factors of the two different forms (positive density dependence, inverse density dependence). Note that mortality is on the y axis here, while density dependence can also arise via effects on reproduction that depend on population size.

IV. Life History Strategies

A. Definition: life history is the set of traits associated with the lifecycle of an organism

1. Includes (but NOT limited to) lifespan, age at first reproduction, fecundity (reproductive output, # offspring produced)

B. Life History Strategies are sets of life history characteristics found together in many different species

1. in other words, these are strategies that have been favored by natural selection in a predictable way

2. There are two main patterns

a. r-selected species

i. r-selected because natural selection has favored traits that contribute to high “r,” or per capita growth rate

ii. typically found in colonizing species, or those that make a living by quickly moving into a new area, reproducing rapidly while resources are abundant, and then moving on prior to being outcompeted or remaining resources

- an r-selected species does not do well ith competition, or when population is close to K

iii. Example: dandelions, a weed, produce a ton of small seeds, throw them into the wind, and hope that they colonize a suitable spot

b. K-selected species

i. K-selected because natural selection has favored competitive ability- they are designed to compete well when the population is near K

ii. Example: oak trees are long lived, slow growing, and produce few large seeds, which fall near the parent tree

- once established, oak trees can outcompete other plants for resources (e.g., could shade out dandelions), but establishment doesn’t happen quickly or over great distances

3. Many traits fall into these patterns (memorize table 1)

Table 56.2 Characteristics of *r*- and *K*-Selected Species

Life history feature	*r*-selected species	*K*-selected species
Development	Rapid	Slow
Reproductive rate	High	Low
Reproductive age	Early	Late
Body size	Small	Large
Length of life	Short	Long
Competitive ability	Weak	Strong
Survivorship	High mortality of young	Low mortality of young
Population size	Variable	Fairly constant
Dispersal ability	Good	Poor
Habitat type	Disturbed	Not disturbed
Parental care	Low	High

Table 1. Life history traits typical of r and K-selected organisms

C. Relevance to endangered species

1. Most endangered species are K-selected organisms
   a. With low reproductive rates and long generation times, it takes a long time for these organisms to bounce back from disturbances, man-made or otherwise
   b. Example: Bluefin tuna
      i. long lived, low r, so overharvesting by fishing fleets knocks populations down, but they take a long time to recover

V. Relevance to Human Population Growth
   A. Human population growth has been essentially exponential since the agricultural revolution
      1. We know that Earth has finite resources, so population ecology tells us that we will reach K sometime: human population will have to stabilize or crash
   B. Sustainability issues all come down to what the Earth's carrying capacity is for humans
      1. What is K for planet Earth?
         a. Depends on two factors
            i. what % of Earths resources are for humans versus wildlife
               - increase K by taking more for people, but what about biodiversity?
            ii. per capita resource use: how much of Earth's K is allocated to each person?
               - this is the idea of an ecological footprint, or the resources required to sustain an individual for given lifestyle
               - if we all have smaller footprints, K is larger
                  - industrialized nations tend to have higher K…

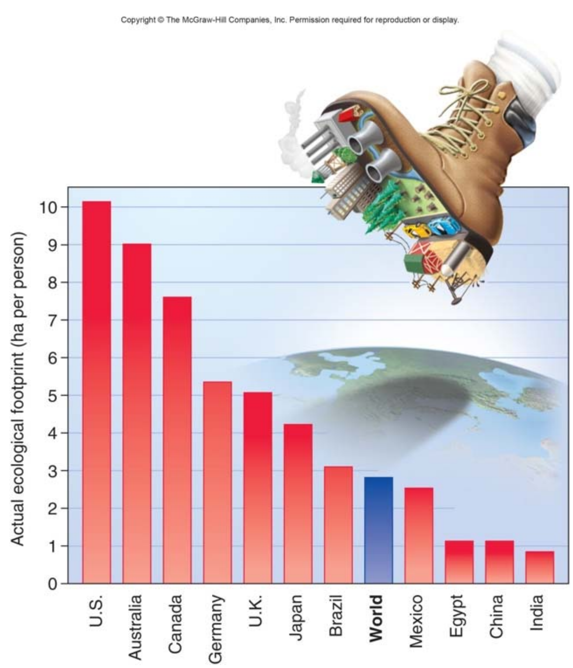

Figure 3. Ecological footprints of various nations. Note that western nations tend to have larger footprints.