TwoOldGuys™ Study Guides
BI114 Biological Concepts for Teachers
Chapter 5. Ecology, Basics
5.1. Population Growth

Based on Indiana's Academic Standards, Science, as adopted by the Indiana State Board of Education, Nov 2000.

Numbers refer to the age-appropriate grade-level for the content.

Review

We have now completed our examination of the species. We saw the definition of the species and its place in the classification scheme. We have summarized the more important of the higher taxa. We looked into the genetic mechanisms that allow the species to remain unchanged over several generations, as well as the evolutionary mechanisms believed to be involved in allowing the species to change over many generations. We also noted the controversy between the scientific concept of evolution and the religious belief in creation, because it may affect your ability to present these concepts in your classroom.

We now wish to move to the concepts of ecology. These concepts seek to explain the nature of groups of different species and their roles in the environment.

Population Growth

In Section 1.3, The Species Concept and Phylogeny, it was stated that there are considered to be four fundamental units in Biology: the species as the fundamental unit of classification and evolution, the population as the fundamental unit of ecology, the individual as the fundamental unit of living organisms, and the cell as the fundamental unit of life. We defined the population to be all individuals of the species occupying a defined geographic area, interacting with each other, potentially interbreeding, and sharing the same gene pool.

Population growth potential far exceeds actual populations

grades 4: to 6:

Numbers of wild animals stay fairly constant year to year

If you watch animals (or plants) in reasonably natural settings; such as parks (National, State, or local), school yards, suburban lawns, or even pigeons around the town square or city hall; you may have noticed that the number of individuals of each kind (species) tends to remain fairly steady over several years. In part, this observation is based on estimates with extremely low precision [remember, we defined precision as repeatability], but you could improve the precision by counting the numbers of some species at about the same time each year for several years. Not only would your 4th through 6th grade students find these counts to be very boring, but you would probably find that the numbers change only slightly from year to year. More importantly, the changes are random – sometimes going up and other times going down.

For the data collection efforts in which I have been personally involved (dealing with plants, not animals) the numbers of individuals of each species has remained “reasonably constant” only if we define reasonably constant to a rather low precision. Many of the species I (alone or as a member of a field team) have tracked tended to vary considerably year to year, yet frequently, the common species remain common, and the rare species remain rare.

The only exceptions to the idea that the numbers of animals remains approximately constant are cases of pest species which sporadically increase dramatically and become a major pest, then return to their normal lower numbers. We cannot explain why this happens in most cases, and certainly cannot predict accurately when it will happen.

grades 6: to 8:

Similar species may compete for resources to survive

Anyone who has ever set up a bird feeder has had an opportunity to observe this competition. Frequently there will be more than one kind of birds at the feeder. As you watch them, you will eventually see one bird chase off a bird of a different kind. For example, bluejays may chase sparrows away from the feeder. We believe that the same thing happens (more subtly) in the wild. Most field biologists have actually observed instances of such contests involving nearly every possible group of animals. I have seen fish challenge each other for a feeding territory, birds chase each other out of their territory, chipmunks and squirrels exchanging vocalizations over potential food, and a black bear challenge me for access to a raspberry patch [the bear won!].

The idea that competition occurs between ‘similar’ species may be a bit misleading. The fox squirrels that live in my neighborhood have become very skilled at displacing various birds from my bird feeder.

There is no doubt in the minds of professional ecologists that squirrels and sparrows are not 'similar' species. Yet, compete they do, but only in a limited way. The animals share a portion of their eating habits, but not all of their diet. Both squirrels and sparrows are willing to eat at the "convenience store" called a bird feeder. Sparrows will not eat nuts and acorns, while squirrels do not normally eat seeds of non-woody weeds. So their diets overlap only in the artificial reality of the bird feeder.

It is important to note that the subtitle above refers not to food but to resources. All animals require physical space for a nest or den where they can sleep and raise offspring [or at least lay eggs], space with vague boundaries in which to seek food and a mate. Food comes in two concepts: preferred foods and foods that provide specific nutrients, which may or may not be the same foods. Ducks and Geese exhibit a surprising fondness for the bread crumbs that humans are so fond of offering to the fowl creatures. This is surprising because white bread is no more nutritious for water fowl than it is for humans; and humans derive little nutrient value from soft white bread [even those which claim to be enriched with x% of daily vitamin requirements]. Any requirement that any species makes on its environment is fair game for competition, as some other species may wish to share that very requirement..

grades secondary: to college:

Exponential growth

(for example, mice with litter size = 6; non-overlapping generations)

We use the simplifying assumption of non-overlapping generations, because dealing with overlapping generations requires way to much algebra for this early on a Monday morning [I assume most, if not all, of my readers considered High School algebra to be something they would never use again after the school year ended. In addition, I am suggesting that many students may be less inclined to accept intellectual challenges on Monday morning than at any other time during the week]. The assumption of non-overlapping generations assumes that the animals reproduce only once a lifetime, then promptly die. Otherwise, you have to recognize that the age of the mother has a lot to do with the litter size. Young mothers have few in their litter, then that number creeps up to some maximum, then drops off. This suggests that many animals may live long enough to reproduce more than once. You would have to add the number of offspring in each litter to the number of adults, and then subtract the number of individuals dying during the time interval. So, we merely wave our magic wand and all these complications go away. We are left with a model that is sufficiently simple that we can almost understand it:

generation	n	reproducing pairs
0	2	1
1	6	3
2	18	9
3	54	27
4	162	81
5	486	243
6	1,458	729
7	4,374	2,187
8	13,122	6,561
9	39,366	19,683
10	118,098	59,049

This simple model suggests that a single pair of mice who sneak into your house in the fall can, in a mere 10 generations, become over 59,000 pairs of mice in your house. At three generations a year for indoor mice, this requires just over 3 years to produce 118,098 offspring by reproducing only once then dying.

Yet, natural populations do not continue such growth indefinitely.

Rather, the growth of the population slows, perhaps reaching a stable density. Remember, back in 4th to 6th grade, we suggested that the number of animals in nature tends to change little from year to year, although the population growth potential, here in secondary to college, predicts that the numbers ought to increase dramatically each year. Therefore, something must happen to prevent the numbers from increasing.

Perhaps the most famous of the papers written on this subject, was *Essay on Population*, by Malthus (1798). For Biologists, this essay is famous, not because we actually read it, but because Charles Darwin did, and referred to it in developing his hypothesis, the "struggle for existence," which is part of his Theory of Evolution. Most non-biologists are familiar with a reference to Malthus, without knowing to whom the reference is. In *A Christmas Carol*, when Charles Dickens has Ebenezer Scrooge arguing with the gentlemen soliciting donations for the poor, who state, concerning the poor and the poor houses, that "Many can't go there, and many would prefer to die." The reply is "'If they would rather die,' said Scrooge 'they had better do it, and decrease the surplus population.'" (Dickens, Stave 1: Marley's Ghost) Here the expression 'decrease the surplus population' is a reference to Malthus. Beyond the portion of the *Essay on Population* to which Darwin referred, Malthus argues that unless something is done to control the growth of the human population [of early Industrial Revolution Europe], the population will "soon" exceed the ability of agriculture to feed them.

Carrying Capacity

grade secondary: to college:

Carrying Capacity = "ability of the environment to support the population
- of the species, or
- of all comparable species in the community."

This is the mechanism which we believe explains how the population numbers of wild animals can reach a stable density. It is not a characteristic of the animal [or plant] populations, but a characteristic of the environment in which the animals live. The environment, and all of the resources that it supplies to the animals, has a limited capacity to support the animals. For example, when the resource involved is bird territories: if Bobolink nesting pairs defend a territory that is about 30 meters square [98 feet], then a field that is about 150 meters square [492 feet] will be able to support only 25 [5 X 5] nesting pairs of Bobolinks.

In the real world, the resources of the environment must be shared by more than one species. For example, the same field described in the previous paragraph also supports Redwing Blackbirds which compete with Bobolinks for nesting territories and maintain territories of about the same size as Bobolinks do. Both Redwing Blackbirds and Bobolinks will chase other birds from their territories whether the other birds are Redwing Blackbirds or Bobolinks. The field can support only 25 nesting pairs, so if 10 pairs of Redwing Blackbirds live in the field, the capacity to support Bobolinks drops to only 15 nesting pairs. [This example is based on actual estimated field data from a patch of wet prairie in Marshall County, Indiana].

You should have noticed that the explanation offered in this subsection contradicts the explanation in section 3.3 “Selection, artificial and natural." Under the heading Selection, it was argued that if (a) populations are capable of growth too ridiculously large numbers, and (b) actual populations do not exhibit this growth but remain reasonably stable, then (c) there must be competition among siblings to be the survivors. If this competition occurs, then any individual which has a genetic advantage will have a better chance of surviving, which in turn would lead to "natural selection" and then to evolution. The natural selection hypothesis suggests that the regulation of population size is internal to the species, and genetic (inheritable). On the other hand, the carrying capacity hypothesis suggests that the regulation of population size is external to the species as a characteristic of the environment.

In the ordinary conduct of science, given two competing hypotheses, we should set up an experiment to determine which hypothesis better describes reality. Unfortunately, these are not 'simpler' questions, and we have yet to figure out what observable events ought to occur should either hypothesis be true. This makes it far too difficult to observe the predicted event(s) [the first step in which is predicting the events].

"Boom & Crash" cycles

grade secondary: to college:

Some species do not ever reach stable densities, but fluctuate between very high and very low abundances or densities. Such fluctuations are called Boom and Crash Cycles:

- *boom* phase = growth to excessively high densities
- *crash* phase = rapid decline to excessively low densities

The terms "boom" and "crash" are borrowed from the stock market: Periods of 'rapid' increase in the values of stocks is called a boom market; while periods of rapid decline are referred to as market crashes. During the boom phase [in ecological systems], the population grows beyond the capacity of the environment to support the individuals. This results in a degradation of the environment, so the capacity of the environment becomes even smaller relative to the population size. The reduction in capacity of the environment then drives the crash phase. Often the crash phase drops the population size down to near local extinction. Sometimes, the crash will actually cause a local extinction, usually followed by re-invasion from some nearby population.

In normal usage, the term "cycle" refers to events which recur at fairly regular intervals. The daily temperature cycle, for example, involves the temperature going up then down every 24 hours. As you may have noticed, however, there will be some days when this cycle does not occur. Sometimes during the winter, as a cold front passes through, the temperature may drop for up to about 40 hours. A number of 'cycles' in nature have variability in the length of the cycle. Since we have found 'cycles' which vary by more than 50% of their average length, we have modified our usage of the term 'cycle' to include these rather irregular processes.

If you have read anything in the relatively recent past concerning the crash portion of the boom and crash cycles, you will have read that humans are somehow responsible for the decline in numbers of any 'interesting' species, where 'interesting' is defined as whatever the author thinks is interesting. The hypotheses of ecology [over the last half Century or so] provide a sufficient explanation of many near extinctions without having to assume that humans, as a species, are so powerful that they can change the "natural laws" governing the universe. It seems a bit curious that "environmentalists," who declare that we ought to learn to live within the limits of our natural environment lest we drive our own species to extinction, advance arguments that seem to be based on the assumption that we, as a species, are capable of altering the "natural laws'" in ways that should allow us to ignore those natural laws which impose limitations on us. After all, if we are capable of changing the "laws of nature," we ought to be able to change any natural law which restricts us in any way. Alternatively, if we are obligated to obey the laws of nature, then we must be unable to alter the laws of nature to meet our needs.

Works Cited

Dickens, Charles. *A Christmas Carol.* 1996-2006. STORMFAX, Inc (www.stormfax.com/dickens.htm). Text, spelling and punctuation as published by Elliot Stock, 62, Paternoster Row, E.C., London, 1890.