Lesson Summary:
Students will examine how limiting factors regulate population growth. They will evaluate historical data from the wildlife management of the deer of the Kaibab Plateau in Arizona and then assess why nature requires flexible and interactive management planning. As an extension activity, students will investigate and evaluate assumptions that have been used in reaching scientific conclusions using the Lotka-Volterra Model on predator-prey interactions. Students also will explore ongoing projects developed by the Ohio Department of Natural Resources for good management recovery plans.

Estimated Duration: Three hours

Commentary:
This lesson allows students to see that if one population is eliminated from an ecosystem, it disrupts other factors in the environment. The complexity and interdependence of natural systems is illustrated in the instructional activities. Students conduct research about early wildlife management plans. Those plans made certain assumptions that later proved to be disastrous for the environment. From this early discovery, wildlife management projects have developed different strategies for wildlife preservation.

Pre-Assessment:
Copy and distributes copies of Attachment A, Pre-Assessment. Have students complete the assignment to the best of their ability. Look for students beginning to form an understanding of how limiting factors affect squirrel populations.

Scoring Guidelines:
Use Attachment B, Pre-Assessment Scoring Guidelines, to evaluate student knowledge of population growth, reproduction rates and graphing analysis technique by having them examine a ground squirrel population in a city park over time. Use student responses to help inform instruction.
Post-Assessment:
Have students in groups of three investigate an ongoing wildlife management project and prepare a presentation for the class using illustrations, graphs, charts, multimedia presentations, etc. The presentations should address the items listed below:
- Life cycle of the organism involved in the management project;
- Include how birth rates, fertility rates and death rates are affected by the environment;
- History of the project;
- Guidelines and implementation of the project;
- Implications of the project on the environment, other populations and society;
- Outcomes of the project;
- Other interesting facts.

Instructional Tip:
If the students are examining a fisheries management project, suggested explorations may include:
- Listing fishing regulations that protect the fish species, including bag and size limits, as well as fishing restrictions during spawning runs.
- Discussing fishing issues such as overharvesting, inadequate environmental quality, invasions and introductions.
- Reporting on some strategies that are currently used in the management of fisheries.

Scoring Guideline:
See Attachment C, Post-Assessment Scoring Guidelines, to assess students.

Instructional Procedures:
Engagement
1. One important aspect of doing a population study is to define appropriate boundaries of the organism under study. One important characteristic of any population is its density. To prepare students for the term “population density,” ask the students to respond to the following preview question in their notebooks. How is the occupancy number in an elevator determined? (Response: The number of people per square meter that the elevator can support.)
2. As a class, have students provide examples of limiting factors that exist in nature. Have students discuss their answers.

Instructional Tip:
Limiting factors are those that limit population growth such as predation, competition, food supply, available land area, parasitism, limited nesting sites, sterility, disproportionate ratios, stress, cold, heat, rain and disease.

3. Have students work in groups of three, to create graphic organizers of all the different factors that can limit a population size.
4. Have students re-examine their data on the squirrel population study and discuss possible outcomes when a population remains unchecked by environmental resistance (limiting factors). Discuss why nature does not allow populations to go unchecked.

**Instructional Tip:**
The squirrel study is a single species model. More interesting dynamics occur with interactions between species. The Lotka-Volterra model is a mathematical model that describes interactions between two species in an ecosystem, a predator and a prey.

5. Investigate and apply the Lotka-Volterra Model to various predator/prey situations. There are several examples of predator/prey population studies where students can apply this model. They include the wolf and moose (Isle of Royale), the snowshoe hare and the lynx (Canada) and the lake trout and lamprey (Great Lakes).

- The Lotka-Volterra model is based on four parameters.
- Consider a forest of lynx and hares. The lynx are the predators and the hare are the prey. Lynx eat the hare, so the more hare, the more food for the lynx and the lynx population increases. Then even more hare are eaten. Are the hare and lynx populations stable, or do the populations have the potential for oscillations?
- Define four parameters:
  - $a$ is the natural growth rate of hare in the absence of predation;
  - $c$ is the natural death rate of lynx in the absence of food (hare);
  - $b$ is the death rate per encounter of hare due to predation;
  - $e$ is the efficiency of turning predated hare into lynx.

If we let $H(n)$ and $L(n)$ represent the number of hare and lynx, respectively, that are alive at time period $n$, then the Lotka-Volterra model involves two equations. The first equation describes how the prey population changes, and the second equation describes how the predator population changes.

$$H(n+1) = H(n) + a*H(n) - b*H(n)*L(n)$$

$$L(n+1) = L(n) + e*b*H(n)*L(n) - c*L(n)$$

The Lotka-Volterra Model is not very realistic because it does not consider competition between prey and predators. However, modifications of this model make it more realistic and are open to further student investigation. If the graphic analysis of this model is done, the predator and prey populations seem to cycle endlessly without settling down quickly. Endless cycling, however, is not common in nature. Using differential equations, this behavior can be observed for any set of values with the four parameters.

6. Examine, from a historical perspective, a real life example of how one limiting factor, predation, affected population size and the management approach that was used.
Population Limiting Factors - Boom or Bust– Grade 11

- One such example is the classic lesson on the deer population of the Kaibab Plateau in Arizona from 1905 to 1939. The Kaibab Plateau is an “island” of forested land at elevations up to 9,000 feet. The story relates to how predators, particularly the mountain lion, were removed to protect the deer population.

- Working in groups of three, have students complete Attachment D, Kaibab Deer Population, by conducting research in the library or Internet.

**Instructional Tip:**
The assumption that was made by the government wildlife management personnel was that removing a predator will help the population of another species. In this simple lesson, the outcome was that the deer with no natural predators now ate most of the vegetation and consequently began to starve by the mid 1920s. The cascading effect from predator to deer to vegetation simply illustrated the balance of nature. If one changes the population of one species, the other species are directly affected. Population ecologists now believe this balance is more complex than originally thought.

7. As an optional activity, research other pieces of this story such as:
   - Using evidence of livestock overgrazing on the plateau prior to the creation of the game reserve by President Theodore Roosevelt.
   - Examining unusual weather data, such as periods of drought, during the time when the deer populations began to plummet.

8. Using the information learned from the Kaibab deer population, and applicable data, have students in each group write a brief description of how one density independent limiting factor (one that is not dependent on population size) such as extreme climate, weather patterns, etc., will limit population growth. Have students share their information with each other and provide corrections and improvements.

**Differentiated Instructional Support:**
Instruction is differentiated according to learner needs to help all learners either meet the intent of the specified indicator(s) or, if the indicator is already met, to advance beyond the specified indicator(s).

- Have students work independently, in pairs or heterogeneous, mixed readiness groups to investigate the Kaibab Plateau deer population and examples of the Lotka-Volterra Model.
- Provide students with a list of key words in this lesson
- Provide students with graph paper with X- and Y-axis established.
- Challenge students to explore ongoing projects developed by the Ohio Department of Natural Resources for good management recovery plans.
Population Limiting Factors - Boom or Bust– Grade 11

Extensions:

- Investigate and apply the Lotka-Volterra Model to a variety of predator/prey situations. There are several examples of predator/prey population studies where students can apply this model. They include the wolf and moose (Isle of Royale), the snowshoe hare and the lynx (Canada), and the lake trout and lamprey (Great Lakes).
- Investigate human disturbances to the ecosystem. Density-independent limiting factors include damming rivers, road construction, filling wetlands and cutting down forests.
- Investigate population problems in the Arctic such as:
  a. Exposure of Arctic populations to higher amounts of radioactive contamination due to the 1986 Chernobyl nuclear disaster and past (1950-1980) atmospheric nuclear testing (e.g., reindeer populations have been severely contaminated and reindeer meat is a major source of food for Arctic people.)
  b. Confirmation of rising death rates of polar bears and falling fertility rates of sea birds caused by pollution from industrial chemicals resulting from the slower degradation of pollutants due to low temperatures in the Arctic.
- Provide students with two world maps, one map illustrating the human population densities and the other global vegetation growth patterns. Vegetation patterns can be shared via satellite images. No distinction is made here between natural and agricultural vegetation. See list of Web sites provided.
- Have students address these questions:
  a. Describe the relationship between human population density and the amount of vegetation in the respective regions;
  b. What characteristics of the region most affect the carrying capacity?
  c. Discuss population growth patterns and the issue of current and future world food supplies.

Homework Options and Home Connections:

- Research the requirements for plants and animals to be on the endangered species list, in their community or the Great Lakes. List possible causes for the dwindling populations. The Fish Habitat Database has extensive information on the habitat requirements and characteristics of 18 selected fish species at five stages of their life and in the six bodies of water of the Great Lakes. Natural resource managers from environmental agencies have developed and implemented fish management laws since these fish are an integral component of the Great Lakes ecosystem.

Materials and Resources:

The inclusion of a specific resource in any lesson formulated by the Ohio Department of Education should not be interpreted as an endorsement of that particular resource, or any of its contents, by the Ohio Department of Education. The Ohio Department of Education does not endorse any particular resource. The Web addresses listed are for a given site’s main page, therefore, it may be necessary to search within that site to find the specific information required for a given lesson. Please note that information published on the Internet changes over time, therefore the links provided may no longer contain the specific information related to a given lesson. Teachers are advised to preview all sites before using them with students.
For the teacher: graphing calculators, population data, and presentation software

For the students: graph paper, graphing calculators, colored markers, population data presentation software

Key Vocabulary:
- birth rates
- carrying capacity
- death rates
- density dependent factors
- density independent factors
- exponential growth
- fertility rates
- limiting factors
- population
- population density
- reproduction rate

Technology Connections:
- Utilize several software programs that model human population growth. Changes can be made in various parameters such as birth rate, death rate and fertility rate to simulate projected populations in countries around the world.

- Simulate populations of organisms in controlled ecosystems.

- Assorted software programs on the Lotka-Volterra model are available on the Internet.

- Population pyramids from the Census Bureau’s International Data Base can be viewed at www.census.gov

- NASA satellite images of vegetation and environmental factors can be viewed at www.gsfc.nasa.gov
  http://observe.arc.nasa.gov
  http://eob.gsfc.nasa.gov
  http://eob.gsfc.nasa.gov

- Wildlife management sites for Ohio and the Great Lakes: http://www.dnr.state.oh.us/
  http://www.glfc.org
Population Limiting Factors - Boom or Bust– Grade 11

Research Connections:


Nonlinguistic representations help students think about and recall knowledge. This includes the following:
- Creating graphic representations (organizers);
- Making physical models;
- Generating mental pictures;
- Drawing pictures and pictographs;
- Engaging in kinesthetic activity.

Generating and testing hypotheses engages students in one of the most powerful and analytic of cognitive operations. It deepens students’ knowledge and understanding. Any of the following structured tasks can guide students through this process:
- Systems analysis;
- Problem solving;
- Historical investigation;
- Invention;
- Experimental inquiry;
- Decision-making.

Attachments:
Attachment A, *Pre-Assessment*
Attachment B, *Pre-Assessment Scoring Guidelines*
Attachment C, *Post-Assessment Scoring Guidelines*
Attachment D, *Kaibab Deer Population*
The average life span of a ground squirrel is five years. Squirrels mate in the spring and late summer. Females mate only one day out of every season. Each squirrel can deliver up to two litters a year of three offspring per litter.

In this scenario, the squirrel population is living under ideal conditions and is constrained only by their life history. Limiting factors such as competition, food availability, predation, climate conditions and exploitation are not considered in this scenario.

Procedure: Address the following by creating a graph and explaining the results in complete sentences.

1. Suppose two ground squirrels mated in the park and produced six offspring annually.
2. Assume all female members of each generation reproduce each year and there are no squirrel deaths. Also assume that half of the population is female. Since there are no limiting factors present, the number of male and female squirrels is equal.
3. Calculate the number of offspring that will be reproduced every year for five consecutive years.
4. List all of the assumptions in this scenario
5. Construct an appropriate graph for your data (Offspring Population Size (N) versus Time in Years).
6. Describe the shape of your graph. Is the growth linear (constant) or exponential?
7. Predict the size of the squirrel population in the park after 10 years.
8. Predict what would happen to the squirrels if they were unable to leave the park. (geographic boundary)
9. Predict what would happen to the plant population (food source) in the park.
10. Hypothesize why the Earth is not overrun with squirrels.
Sample answers include, but are not limited, to the following.

The assumptions for this scenario
- no squirrels die;
- no limiting factors present such as competition, food availability, predation, climate conditions and exploitation;
- the numbers of male and female squirrels produced each year are equal;
- the number of squirrels produced each year are the same.

Year one offspring produced will be 6.
Year two offspring produced will be 18.
Year three offspring produced will be 54.
Year four offspring produced will be 162.
Year five offspring produced will be 486.

Using this data the graph will illustrate exponential growth.

In 10 years the squirrel population could rise to 118,098 if all the assumptions were to hold true.
If squirrels were unable to leave the park, the plant population would be destroyed because all of the squirrels need food and eventually the squirrels would die off because the resources required for their survival would be depleted. The Earth is not overrun with squirrels because limiting factors are in place to keep a balance in an ecosystem.
## Post-Assessment Scoring Guidelines

<table>
<thead>
<tr>
<th></th>
<th>Level 4</th>
<th>Level 3</th>
<th>Level 2</th>
<th>Level 1</th>
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</thead>
<tbody>
<tr>
<td><strong>Depth of Understanding:</strong></td>
<td>Components of the management project are thoughtfully explained.</td>
<td>Components of the management project are accurate.</td>
<td>Components of the management project are simplified.</td>
<td>Components of the management project have major inaccuracies or are oversimplified.</td>
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<tr>
<td><strong>Accuracy</strong></td>
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<tr>
<td><strong>Communication:</strong></td>
<td>Information is communicated clearly and precisely, effectively focused and organized and may also include inventive / expressive dimensions.</td>
<td>Information is communicated clearly, and is focused and organized.</td>
<td>Information has some clarity, focus and organization.</td>
<td>Information is unclear, lacks focus and organization.</td>
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<tr>
<td><strong>Clarity, Focus, Organization</strong></td>
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<tr>
<td><strong>Relevance to Society:</strong></td>
<td>Relevant applications to personal and societal issues are identified and insightfully described.</td>
<td>Applications to personal and societal issues are identified.</td>
<td>Applications to personal and societal issues are suggested or implied.</td>
<td>Applications are unclear or absent.</td>
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<td><strong>Consequences and Alternatives</strong></td>
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<td><strong>Evidence of Inquiry:</strong></td>
<td>Analysis and conclusions of management systems are accurate. Conclusions are valid, detailed and consistent with data.</td>
<td>Analysis of management systems are accurate. Conclusions are valid and related to data</td>
<td>Analysis of management systems are somewhat accurate. Conclusions are related to data.</td>
<td>Analysis of management systems are unclear or inaccurate. Conclusions are not related to the data.</td>
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<tr>
<td><strong>Analysis and Conclusions</strong></td>
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Adapted from Council of Chief State School Officers State Collaborative on Assessment and Student Standards (SCASS) Science Project, April 1997.
Attachment D
Kaibab Deer Population

Name ___________________________

On a separate sheet of paper, complete the following for the Kaibab deer population. Use library resources and the Internet to conduct your research and answer the questions.

1. Investigate and summarize the history of the deer population on Kaibab Plateau in Arizona.

2. Graph the deer population data. (This is approximate historical data.)

<table>
<thead>
<tr>
<th>Year</th>
<th># Deer</th>
<th>Year</th>
<th># Deer</th>
</tr>
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<tbody>
<tr>
<td>1905</td>
<td>4,000</td>
<td>1927</td>
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<td>1925</td>
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<td>1935</td>
<td>18,000</td>
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<tr>
<td>1926</td>
<td>40,000</td>
<td>1939</td>
<td>10,000</td>
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</table>

3. Explain what assumption was made by the wildlife management personnel.
4. List the methods the Forest Service used to protect the Kaibab deer population.
5. List major lessons learned from the Kaibab experience.
6. Investigate how the Arizona Game Commission manages the Kaibab deer today.