

ECOLOGICAL INTERACTIONS: PREDATOR AND PREY DYNAMICS ON THE KAIBAB PLATEAU

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Summary

The relationship between predators and their prey has always occupied a special place in the minds of ecologists, and the great interest in predator-prey systems makes them an ideal case for system dynamics. This article demonstrates how system dynamics may be used to understand the ecological interactions between the deer herd and the predators on the Kaibab Plateau in northern Arizona. This deer herd is widely known because the story of its explosive growth has been told and retold by prominent naturalists. The article begins with a summary of the Kaibab story from the start of the 20th century. A system dynamics model is presented to simulate the deer herd's explosive growth and subsequent collapse.

The article then focuses on the natural control of the deer population through the action of predators. A model is developed to help one understand the dynamic interaction of the deer and predator populations if the predators had not been exterminated in the early years of the 20th century. The simulations illustrate the type of interactions expected in predator prey systems. They also illustrate the use of system dynamics to study oscillatory behavior.

1. Introduction

There has probably been more written on the subject of predator-prey interactions than on any other single topic in ecology. Predation has been described as a clean demographic event that readily lends itself to modeling. It is an intriguing topic, both in the field and in the laboratory. The examples from the field include highly oscillatory behavior which allows populations to coexist indefinitely, as in the famous example of the lynx-hare system in North America. The examples from the laboratory are mainly parasite-host systems designed for controlled experimentation. The experiments have revealed a wide variety of dynamics ranging from stable oscillations to violently unstable behavior.

This article describes an important example from the field: the deer herd that occupied the Kaibab Plateau in northern Arizona at the beginning of the 20th century. This deer population warrants special attention because of its sudden and explosive growth in the early years of the century. (A sudden increase in an animal population is called an *irruption*.) According to Aldo Leopold, the famous naturalist, the Kaibab irruption is the first of a series of irruptions which have since threatened the future productivity of deer herds across the country. Leopold reports having found no record of a deer irruption in North America antequating the removal of predators, and he observed that those parts of the continent which still retain the native predators have reported no irruptions. He interpreted this as circumstantial evidence to support the surmise that removal of predators predisposes a deer herd to irruptive behavior. The Kaibab story has become widely known as other scientists such as Odum, Caughley and Botkin interpret and reinterpret the cause and consequences of the irruption.

2. The Kaibab Deer Herd

The Kaibab deer herd is a Rocky Mountain mule deer, known scientifically as *Odocoileus hemionus*. The deer attain reproductive maturity at about one and a half years of age. They normally mate in November and December; fawning normally occurs in June and July. Twins are very common and occasionally triplets are seen. There is little information available on the total size of the herd at the start of the 20th century, but one expert estimated the population at around three or four thousand.

The Kaibab Plateau is located north of the Colorado River in north-central Arizona. The plateau extends around 60 miles north and south. It is around 45 miles wide at its widest point. The area is bounded on all sides by escarpments and slopes which descend to lower lands. The Kaibab Plateau was occupied by the deer herd and by populations of coyotes, bobcats, mountain lion and wolves. Data on the size of these predator populations is lacking, but there is information on predator kills. During the interval from 1907 to 1923, for example, 3,000 coyotes, 674 lions, 120 bobcats and 11 wolves were killed. It is believed that the wolf was exterminated in these years, and that the mountain lion population was greatly reduced.

Predators were indigenous species. Nevertheless, their removal by hunting and trapping was based on a general consensus that predator control was beneficial. One expert observed that predator removal was in reality a blanket policy that may have grown from an idea of protecting desirable wildlife by eliminating its enemies.

The deer population grew rapidly around this time. By 1918, there was recognition that the large number of deer was beginning to influence the condition of the forage. Continued bad reports in 1920 and 1922 led to the formation of a special committee to investigate the size of the deer population. In August of 1924, committee members spent ten days on the plateau. The reconnaissance party reported that it was common to see over 100 deer in a day's drive. One member reported seeing over a thousand deer along a 26 mile highway leading to the rim of the Grand Canyon. The committee was not sure of the size of the population, but all local witnesses placed the number of deer at not less than 50,000. One expert estimated the deer population at around 100,000.

The reconnaissance party observed that the forage can only be characterized as deplorable, the worst that any member of the Committee had ever seen. The committee observed that white fir, which is commonly eaten by deer only under stress of food shortage, showed effects of recent and heavy use. Skirted trees became a common sight, and the deer were observed in a deplorable condition (in nearly every case the outline of the ribs could be easily seen through the skin). A major die off was observed during the years from 1924-1928. One report estimated that 75% of the previous year's fawns died during the winter. Another describes the deer population falling by around 60% during two successive winters -- by then, the girdling of so much of the vegetation through browsing precluded recovery of the food reserve.

By 1928, government hunters were deployed to reduce the size of the deer population. The hunters were reminiscent of the buffalo hide-hunters. The deer slayers took to the field in December of 1928 and killed over 1,100 deer. The government program was highly controversial and discontinued in the following year. During all this time, the policy of hunting and trapping predators continued. During 1927, predator "control measures" eliminated 403 coyotes, 111 "wildcats" and 11 mountain lions.

The year 1930 was a year of extra summer rainfall, and the deer enjoyed a good growth of weeds, grass, and mushrooms. The deer were reported in good condition throughout the year. By 1932, the deer population was estimated at around 14,000. The range was recorded to be in better condition than observed in many years. One of the Forest Service Game Reports declared that the number of deer appears to be "about right" for the range.

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Biographical Sketches

Andrew Ford was born in 1944 in Lone Pine, California. His research deals with energy and environmental problems in the western United States. He is especially interested in the use of simulation modeling for policy analysis in the electric power industry. Dr. Ford completed his doctoral studies in the Program on Public Policy and Technology at Dartmouth College in 1975. He worked in the Energy Policy Group at the Los Alamos National Laboratory and in the Systems Management Department at the University of Southern California. His research on electric power and conservation was honored with the 1996 Jay W. Forrester Award.

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