

STEPHANIE LESSARD-PILON,
JAMES MCNEIL



ABSTRACT

A challenge for introductory students in conservation biology is to understand how different environmental and human factors – in particular, density-dependent and density-independent factors – can interact to increase extinction risk in species. To enhance students' processing of sometimes dry and challenging material, we use a kinetic exercise in which students become an endangered animal, move around their environment, and act out a series of scenarios that highlight how species can be driven down a path toward extinction.

Key Words: games; simulations; extirpation; density-dependent; density-independent; conservation; extinction.

○ Introduction

Current rates of species extinction around the world are greater than at any time over the past million years (Wake & Vredenburg, 2008). In addition to the direct and indirect effects of human activities (Primack, 2014), species are threatened by the loss of genetic diversity as populations shrink, become fragmented, or become locally extinct (extirpated), and unique traits are lost. These threats manifest as both density-dependent and density-independent processes. Density-dependent processes are regulated by the number of individuals in the existing population and include factors like interspecific and intraspecific competition for resources, and the spread of diseases between individuals. Density-independent processes influence the birth and death rates of populations regardless of density. For example, weather, pollution, or natural disasters may kill individuals regardless of how many individuals occur in a particular habitat (Primack, 2014). These processes can also interact, thus increasing the risk of extirpation and, eventually, species extinction. These concepts

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are central to our understanding of species conservation, since mitigating these effects is one of the goals of conservation biology. Helping students understand how these stressors affect populations creates a foundation for future discussions of conservation. While there are quantitative models that help describe the ways that factors interact to drive species toward extinction, these are difficult to interpret for beginning students or have significant learning curves to apply in a classroom setting. As an alternative, we present a simulation game that introduces these concepts in a fun and informative way.

Active learning approaches, including games, help students effectively retain information, as demonstrated by improved exam scores and reduced failure rates (Freeman et al., 2014). High levels of engagement are positively correlated with increased understanding and retention of the material, as well as with students' ability to link their conceptual understanding to their daily lives (Heddy & Sinatra, 2013). Our game helps students engage with the factors that lead to increased risk of extirpation in populations and is easily modifiable to fit different class lengths, classroom setups, and learning objectives.

○ Activity

Sneebles are fictional mammals that live within forested, undisturbed habitats adjacent to human communities. Male Sneebles display beautiful, distinctive coats, while the females are more difficult to see in the wild. To begin, students are assigned to be either male or female Sneebles by receiving differently colored cards of construction paper (males one color, females another). Before distributing the cards, we mark some cards randomly with stars to indicate special characteristics of individuals. Students are told that we will assess the impact of various disturbances on individuals and the population at the end

of the activity, so they should retain their cards, even if they are removed as a result of one of the disturbances. The nature of the special characteristics and disturbances is intentionally left vague so that student behavior in the simulation is not influenced by trying to anticipate a particular outcome.

In small classes, each student participates, but in large classes, a subset of volunteers (10–20 individuals) can also work. Using tables or lines of tape on the floor to define a habitat range (an approximately 15' × 15' area), students are told to “sneeble” within their habitat – meaning, move randomly throughout the defined space. Sneebles are nonterritorial, solitary mammals. It can be important to remind students not to bunch up in groups as the exercise progresses; it works best when Sneebles are truly moving independently of each other.

A series of disturbances ensues, causing impacts to the population (Figure 1). Before each disturbance, faculty tell students to “freeze.”

Disturbance 1

The Sneeble habitat is divided by the creation of a road. The road is indicated by physically placing a table in the middle of the habitat or by adding a new tape line to the floor. Any Sneebles on the “road” are immediately removed from the scenario. We time the appearance of the road such that the population of Sneebles is divided approximately in half (Figure 1). The students are then released to move freely around their newly shrunken habitat, but are warned that they cannot cross the road. If students attempt to cross the road, they are removed from the exercise (due to Sneeble-car collisions).

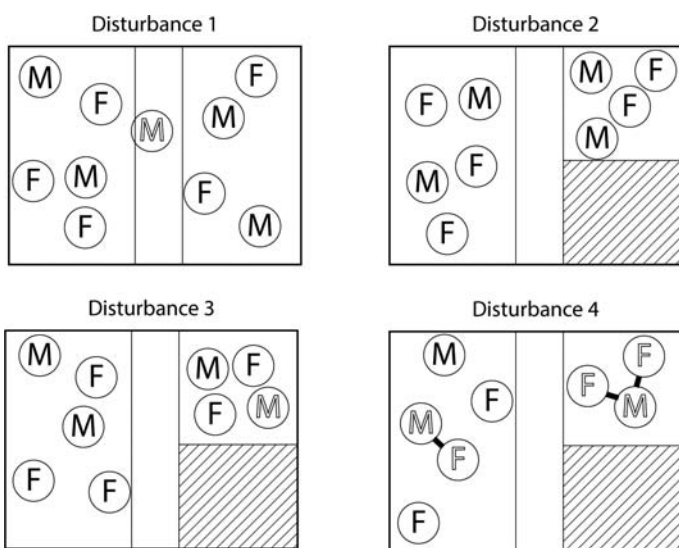


Figure 1. Layout for Sneeble activity. The positions of male (M) and female (F) Sneebles within their habitat (the bounding rectangle) are marked. Sneebles killed as a result of a disturbance are represented by hollow letters. In successive disturbances, the figure demonstrates modifications to the overall Sneeble habitat, including the addition of a road (two thin lines) and a housing development (striped box). Sneebles found close enough together to be killed in disturbance 4 are denoted by connecting lines.

Disturbance 2

Students are informed that a housing development has been constructed in their habitat and the area available to one of the subpopulations is further reduced by half (Figure 1). However, instead of being eliminated, as they were by the road construction, Sneebles are compressed into the remaining territory. The students resume sneebling.

Disturbance 3

The next threat is presented: trophy hunters from the housing development have started eliminating male Sneebles to satisfy a market for their distinctive coats, and half the male Sneebles in the compressed population created by Disturbance 2 are removed (Figure 1). This action models the removal of part of a population due to a desirable trait, such as antlers on male deer or brightly colored male birds. Even with the removal of some of the males, at this point, the Sneebles in the compressed subpopulation are at a higher density (more Sneebles per unit area) than those in the uncompressed subpopulation on the other side of the road. After the males are removed, the students resume sneebling.

Disturbance 4

A disease has been introduced into the entire Sneeble population and any individuals that are within a hand’s span of each other have become infected and are removed (Figure 1). This disturbance usually has a stronger effect on the compressed Sneeble subpopulation, often resulting in the total extirpation of that group. Several individuals in the uncompressed population are usually also affected, but they are not typically all eliminated.

○ Guiding Students through the Post-exercise Discussion

At this point, we halt the exercise and have the students compare the subpopulations of Sneebles. This exercise emphasizes how density-independent factors (e.g., the road, the housing development) can reduce habitat and stress populations, allowing density-dependent factors (e.g., hunting, disease) to have an enhanced effect and potentially drive a species to extinction. Also at this point, we reveal that Sneebles with marked cards had special traits (e.g., cures for human diseases, inspiration for famous artists, climate change adaptability) that could be randomly and irretrievably lost from the population if the population faces too much pressure.

This activity can easily be modified to show the impact of disturbances on many aspects of population dynamics, evolution, and life history. For example, the activity could include a discussion of genetic drift (a change in allele frequency due to random events). By labeling the cards with symbols to represent different alleles in the population, and by examining the frequency of these alleles after each disturbance, it would be easy to model the way these events can have significant effects on the genetic diversity of the population.

Additionally, Allee effects could be explored in the context of this activity. Allee effects occur when population growth rates decrease as population density decreases (Stephens et al., 1999). For example, once there are too few Sneebles in a population, there could also be insufficient opportunity to find mates in the population. This factor could be demonstrated – at the end of each round, before the students begin sneebling again – by having one male and one female

Sneeble pair up to choose another student to join their subpopulation from the pool of either previously removed Sneebles or the classroom at large, mimicking a new Sneeble being born into that population.

This simulation works best as a jumping-off point for discussions of case studies from the natural world. There are several examples of real-life organisms across all taxa that are similarly impacted by multiple stressors. For example, the highly charismatic golden lion tamarins (*Leontopithecus rosalia*) of Atlantic coastal forests in Brazil are threatened by density-independent factors like habitat loss due to agricultural encroachment and increased human development. These endangered primates are also threatened by density-dependent factors, including hunting, the pet trade, and disease (Save the Golden Lion Tamarin, 2018). For example, a recent outbreak of yellow fever affected first human populations, then howler monkey populations. In 2018, the first death of a golden lion tamarin due to yellow fever was documented. Yellow fever is not endemic to Brazil; as a result, golden lion tamarins have not evolved resistance to the disease, and their susceptibility to it is heightened by the increased proximity of tamarins with human communities. The African painted dog (*Lycan pictus*) is another example of a highly charismatic animal threatened by a combination of habitat loss due to increased agricultural and industrial pressure; tourism; and diseases, including canine distemper (Woodroffe & Sillero-Zubiri, 2012). Discussing these examples, after having gone through the exercise with the Sneebles, helps students visualize how multiple factors combine to drive a species toward extinction. Addressing these factors also helps students begin to recognize where conservation actions can be taken to protect species.

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STEPHANIE LESSARD-PILON (slessar2@gmu.edu) and JAMES McNEIL (jmcneil@gmu.edu) are members of the Undergraduate Faculty, Smithsonian-Mason School of Conservation, George Mason University, Front Royal, VA 22630.

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