

# Investigating factors controlling population size. (WJEC A2)



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# Investigating factors controlling population size.

## *Teachers' Notes*

The "Survival Exercise" illustrates through practical role play, how population size is controlled, how organisms fit into food webs and how behaviour and adaptation play a role in this. It raises discussion after the exercise about the role of density dependent and independent mortality factors. The game also includes an actual case study of a reintroduced species in the Cevennes National Park, the capercaillie. This activity is suitable for a light evening after the work for the day has been completed.

## *Key Syllabus Areas*

### 4.5 Factors controlling population size.

Factors affecting population growth: competition, carrying capacity.

Regulation by density dependent and independent factors.

## *Reference List*

Adds, J., Larkcom, E., Miller, R. (1997) *The Organism and the Environment*. Nelson.

Chenn, P. (1999) *Ecology. Advanced Biology Readers*. John Murray.

Sunderland, W. J. (Ed.) (1996). *Ecological Census Techniques*. Cambridge.

## *The Survival Exercise.*

### *Introduction*

This is an active role play exercise which fits well into a light evening in the summer.

Population size is controlled by a range of factors. These can be broadly categorised as density dependent or density independent mortality factors. Density dependent mortality factors are those which control a population relative to its density - the denser the population becomes, the more these factors become important in controlling population size. Factors which would fall into this category include food availability, availability of nest sites and of mates, predation, **competition** (both **inter-specific** and **intra-specific**) and disease. These factors contain a population within the environmental **carrying capacity** and can be seen as a type of biotic environmental resistance.

Density independent mortality factors reduce or increase population size irrespective of the population density. Natural events fall into this category - earthquakes, flooding, drought, forest fire, the coming of the rainy season - all control population size irrespective of its overall density. These events will affect survivorship and ultimately food supply, therefore acting as a limiting factor on the carrying capacity of the environment.

Populations which increase according to the S-shaped-curve-model of population growth (ie. The population size increases exponentially after an initial lag phase, before reaching and fluctuating around the environmental carrying capacity) tend to be limited most strongly by density-dependent mortality factors. Organisms that fit this

model tend to be longer-lived, relatively large in body size and have fewer young in which they invest more parental care. Examples include elephants, oak trees and humans.

Populations which increase according to the J-shaped-curve-model of population growth (ie. The population size increases exponentially after an initial lag phase, until it is checked dramatically, and the population drops to a low number) tend to be limited most strongly by density-independent mortality factors. Organisms that fit this model tend to be short-lived, relatively small in body size and have many young in which they invest little or no parental care. Examples include most terrestrial invertebrates and annual weed species such as dandelions.

Of course, it is not really this clear cut. The life strategy of the vast majority of organisms lies somewhere on a continuum between these extremes.

### ***Specific Information***

The role play exercise models in a hands-on way some of the density dependent and independent mortality factors which control population size. Students assume a role in a woodland food web - herbivore, small carnivore or large carnivore - and each has to feed and avoid becoming a meal for the other, according to their position in the food web. Each student is a named species - there are two of each species in the scenario, and when they find each other, they are able to collect an extra life, representing population growth. Disease plays a part in the exercise, one student is nominated to infect the population. Finally, hunters are let loose in the woods to gradually pick off any students who remain alive at the end of the exercise. A density independent disaster occurs during the exercise, and at the end of the exercise, the population size is reassessed. The exercise takes approximately two hours, including the briefing, the game and the de-brief.

### ***Aims***

To reach an understanding of the effects of density dependent and density independent mortality factors on a small community.

### ***Equipment***

The "Survival Exercise" role play kit.

### ***The Exercise.***

Divide the class into three groups - herbivores, small carnivores and large carnivores. Each receives 'lives' (tiddlywinks in a 'stomach pot') according to their position on the trophic pyramid. To correctly model Lindeman's Law of energy transfer between trophic levels, there need to be approximately ten times as many lives in total held at each trophic level. Remember that approximately 90% of energy is lost between each trophic level, so each animal effectively needs ten below it on the trophic pyramid to support it. Therefore for example, with a group of 50 students, one would need two large carnivores with 2 lives each (4 lives in total), ten small carnivores with 4 lives each (40 lives in total) and 38 herbivores with 10 lives each (380 lives in total). One student plays disease. Give each student an animal to be - two of each species.

### **The herbivores:**

Herbivores feed by visiting one of ten feeding stations scattered around the wood. These stations have unique orienteering markers on them, which they use to stamp their feeding card to prove they have been there. The herbivore is only guaranteed to survive if they find and stamp all ten feeding stations.

### **The small carnivores:**

Small carnivores are identified by a blue bib. Small carnivores feed by hunting for herbivores. Prey is caught by tagging (lightly!) on the shoulder. The herbivore must then surrender a life to the small carnivore.

### **The large carnivores:**

Large carnivores are identified by a red bandana. Large carnivores feed by hunting for herbivores and small carnivores. Prey is caught by tagging (lightly!) on the shoulder. The herbivore or small carnivore must then surrender a life to the small carnivore. The small carnivores must give their own lives to the large carnivores, not one from a herbivore that they have taken.

### **Disease:**

Disease is identified by a hat. Disease can catch everyone once only. They may only take lives that belong to their prey - not lives they have taken from others as food.

### **The game:**

Release the animals into the woods - each trophic level at 2 minute intervals, and disease last of all. Leave the game to run for 20 to 45 minutes, you decide.

After 15 minutes of the allotted period, blow a whistle once. All animals must return to the 'Graveyard' and give up one life. This represents a natural disaster and so a density independent mortality factor.

Five minutes from the end, hunters enter the woods - one or two members of staff. An alarm call will be given: 'Humans are coming!'. If the hunters spot the animals and can see them well enough to name them, they must shout the student's name. The student must then give one of their lives to the hunter.

At any point during the exercise, if an animal pair is able to find one another, they may return to base together and receive another life each, representing population growth through births.

Agree a whistle signal that can end the game at any time if necessary (say two whistle blasts), and a signal that marks the end of the game (say continual whistle blasts). At the end of the exercise, gather the group in and calculate how many lives are left. You may decide to kill people off who have been obviously lazy and haven't fed enough!

### **Rules:**

If an animal loses all of its lives, it must return to the 'Graveyard' immediately;

There is to be no 'pack hunting';

Catching prey is by a light tag, not by rugby tackles;

When giving lives to a predator, hunter or disease, they must be your own lives, not those of a lower trophic level;

If injured, you and the nearest person to you become immune. Come back to the 'Graveyard';

Even if you have stamped your feeding card ten times, or have fed enough, you must remain in the woods until the end of the exercise;

There is to be no tree climbing;

There is to be no leaving the prescribed area;

Animals are not immune when returning to the 'Graveyard' to get new lives (reproduction).

### **Discussion Points**

- What were the ratios of the numbers at the different trophic levels at the end of the exercise? Was it 100:10:1 as it was to begin with? Why was this?
- What would have happened if the initial ratios had been changed? What would have happened if there had been a greater proportion of carnivores - how does this fit in with the idea of density dependent mortality factors?
- Did every animal reproduce successfully? What would have happened to the population if there had been more females of each species? More males? How is sex ratio a density dependent factor?
- Were there enough places to hide from predators, disease and humans? How is this an example of density dependent control?
- Was disease density dependent or density independent?
- What was the effect of the 'natural disaster'? Was anyone killed at this point? Is this density dependent or independent control of population size?
- How did humans affect the community?
- Was it fair that the herbivores had so many more lives than the large carnivores? Would it have been better to have had fewer carnivores with more lives?
- What other factors could we have included? Could this game have been made more sophisticated?
- How realistic in terms of how animals behave was this game? Did you adopt any behavioural traits that you felt helped you to survive? Were the behaviours adopted by the herbivores the same as that for the carnivores? How did that change when the hunters entered the woods?
- How does population size change – what are the roles of births/deaths/immigration/emigration?

### ***The Application of the Survival Exercise to Illustrate In-Situ Conservation of the Capercaille.***

It is possible to adapt the survival exercise to model the in-situ conservation of the capercaille. The capercaille, *Tetrao tetrix* is a boreal species that had as its former distribution the whole of the European land mass, from Scotland, through Europe and into Siberia. It is still found in large numbers in Scandinavia and Eastern Europe, and it is still found at altitude in parts of its former range. It is an enigmatic and attractive bird species, the largest member of the grouse family, and a species which the PNC have been interested in reintroducing for many

years. This species provides an excellent case study of a species whose conservation in-situ has been supported by ex-situ techniques.

The capercaille is the largest of the European grouse species, and is restricted to coniferous forests, where there is a significant proportion of pine with elements of deciduous trees and bogs, which support berry-bearing shrubs such as cowberry, bilberry and juniper. The capercaille feeds largely on pine needles, buds and aspen leaves from November to March, supplemented with berries during the late summer and autumn. The chicks feed on insect grubs in the spring to provide essential protein.

The Capercaille males exhibit lekking behaviour – they come together in all- male groups during the winter, and females visit the lek to choose a mate.

The capercaille became extinct in the area that is now the Parc National des Cevennes during the 18th century. The major cause for its extinction in the area was the gradual change in land use from forests to pasture and cultivated fields – another name for the capercaille is the wood grouse, forests being the preferred habitat. The forest structure required by capercaille is very different to the tight, constricted forestry provided by commercial forests grown for timber production. Capercaille require mature, open pine forests, with clearings in which bilberry and heater grow, and old pines in which to safely roost at night. It is a large bird with a wing-span of up to 125cm.

The chicks of the capercaille are predated by the fox and pine marten, which, along with wild boar, take eggs from the nest. Adult birds are predated by goshawk, and pine marten, which will only eat the head of the adult bird. It is thought that a population explosion of these predators was also a likely cause for the reduction in capercaille numbers in the area, particularly since the reduction of lynx and wolves, which would have maintained the populations of the smaller carnivores at a more acceptable level.

Some control measures have taken place, specifically targeting numbers of red fox in the release areas, but this species re-introduction programme has been fraught with difficulties and has only been of limited success. Adult birds were brought into the Cevennes National Park from Austria and Italy. The adult birds were kept in aviaries



and used to produce over 600 chicks. Of these, some were reared by their parents, whilst others were reared artificially, being kept warm under artificial lighting, and fed a supplemented diet enriched with vitamins and minerals. The success of the chicks reared more naturally by their parents was more marked.

The chicks were reared and released over a 15 year period between 1978 and 1993. 80 to 90% died before reproducing – due to predation, flying into electric fences and power-lines and dispersing out of the protected area of the national park. Between 50 and 60 birds remained after the completion of the programme. There are at present thought to be approximately 30 adult birds

in the park – 20 were counted during the summer of 2003. The reintroduced population is thought to be decreasing by 9% each year.

The major reason for the lack of success of this programme is thought to have been the large distance over which the birds disperse after release. The core protected-area of the PNC is only 90,000Ha and there are no barriers for the birds flying out of the area. When spread over a wide area, they are less able to find partners for breeding. Many birds are killed flying into wire fences and electric power-lines.

Capercaillie are also particularly susceptible to disturbance, particularly during the lekking season (in winter) and when rearing their young. An increase in the amount of tourism, albeit 'green tourism', with people walking (especially with dogs which are not under control) and mountain biking through the areas where the birds have been reintroduced, is also implicated in the lack of success in this programme.

***Adapt the survival exercise as follows, running a number of 'rounds':***

Each student receives a role – capercaillie, fox, pine marten or lynx - and a letter which no one else may see until the exercise begins. There are two of each letter. The two recipients of each letter are partners. Each time both partners has fed twice, they may both return to base and receive one off-spring each (this is represented by another life).

The adaptation of the survival exercise introduces the idea of increased reproductive success under good habitat conditions. Each player receives lives as before, but this time, the environmental conditions are changed for each round of the exercise. Students are brought together at the end of each exercise to discuss the outcomes.

The game runs for four rounds:

- The natural situation, prior to human settlement in the Cevennes;
- The exploitation stage;
- The extinction vortex;
- Species recovery through in-situ conservation.

***Round one: The natural situation, prior to human settlement in the Cevennes:***

Capercaillie: Total of 200 lives, divided equally amongst players;

Fox (2 students minimum): Total of 10 lives, 5 to each student;

Pine marten (2 students minimum): Total of 10 lives, 5 to each student;

Lynx (2 students minimum): Total of 2 lives, one to each student;

Disease: 1 student.

Allow the game to run for fifteen minutes. On return to base, are the ratios of organisms the same? Did the number of capercaillie increase or reduce?

**Round 2: The exploitation stage:**

Capercaillie: Total of 200 lives, divided equally amongst players;

Fox (2 students minimum): Total of 20 lives, 10 to each student;

Pine marten (2 students minimum): Total of 20 lives, 10 to each student;

Lynx: None. Lynx have been hunted out by humans.

Hunters: Assign 20% of the students to act as hunters. They may kill only capercaillie. If they see a student playing a capercaillie, they must shout their name. The capercaillie must surrender a life to the hunter.

Disease: 1 student.

Allow the game to run for fifteen minutes. With the removal of lynx by humans, the numbers of fox and pine marten increase. With the impact of increased predation and hunting, what happens to the number of capercaillie? What did the capercaillie spend the majority of their time doing?

**Round 3: The extinction vortex:**

Capercaillie: Total of 50 lives, divided equally amongst players. Only allocate letters A and B. Players may now only reproduce successfully if they can find someone with a different letter;

Fox (2 students minimum): Total of 20 lives, 10 to each student;

Pine marten (2 students minimum): Total of 20 lives, 10 to each student;

Lynx: None. Lynx have been hunted out by humans.

Hunters: Assign 20% of the students to act as hunters. They may kill only capercaillie. If they see a student playing a capercaillie, they must shout their name. The capercaillie must surrender a life to the hunter.

Disease: 2 students.

Allow the game to run until all the capercaillie are in the graveyard. How long does this take? What did the capercaillie spend the majority of their time doing? Why is there a greater effect of disease in this scenario?

**Round 4: In-situ conservation:**

Capercaillie: Total of 200 lives, divided equally amongst players;

Fox (2 students minimum): Total of 10 lives, 5 to each student;

Pine marten (2 students minimum): Total of 10 lives, 5 to each student;

Lynx (2 students minimum): Total of 2 lives, one to each student – lynx have been reintroduced as part of the programme, to control the foxes and pine marten;

Disease: 1 student.

Put out an extra 4 feeding stations, representing the provision of supplementary food for the capercaillie. This time, the each capercaillie in the pair only needs to feed once to reproduce and each receive an extra life. Allow the game to run for fifteen minutes. On return to base, are the ratios of organisms the same? Did the number of capercaillie increase or reduce? What did the capercaillie spend the majority of their time doing?

### **Discussion Points**

- What limiting factors control the final population size capercaille?
- What do you understand by the term 'carrying capacity'?
- How does the population size fluctuation of predators in this scenario (eg. Foxes and pine martens) affect the population size of capercaille?
- How does the population size fluctuation of prey in this scenario (eg. Capercaille) affect the population size of foxes and pine martens?
- How could competition between capercaille influence their final population size (ie. inter-specific competition)?
- What intra-specific competition exists in this scenario?