Marine Science Lesson Enhancements
based on **Grade 11 & 12 curriculum** in
Physics, Chemistry & Biology

Ecology

Ocean Explorer

Module 9

Bayworld Centre for Research & Education

Overview

1 - Population Ecology

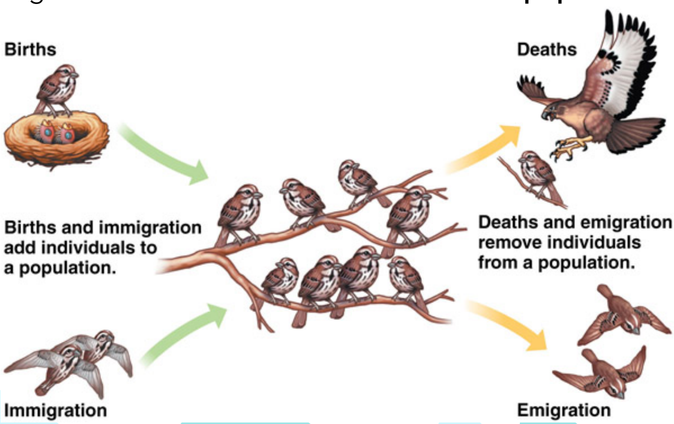
The term "population" is interpreted differently in various sciences :

- In **human demography** a population is a set of humans in an area.
- In **genetics** a population is a group of interbreeding individuals of the same species, which is isolated from other groups.
- In **population ecology** a population is a group of individuals of the same species inhabiting the same area.

Population ecology is the branch of ecology that studies the structure and dynamics of populations.

Populations can be defined at various spatial scales. Local populations can occupy very small habitat patches like a puddle. A set of local populations connected by dispersing individuals is called a **metapopulation**. Populations can be considered at a scale of regions, islands, continents or seas. Even the entire species can be viewed as a population.

Populations differ in their stability. Some of them are stable for thousands of years. Other populations persist only because of continuous immigration from other areas. Finally, there are temporary populations that consist of organisms at a particular stage in their life cycle. For example, larvae of dragonflies live in the water and form a **hemipopulation**.



What is a Population ?

A population is a group of individuals from the same species who live in a particular geographical area, undergo the same processes and have the capability of interbreeding.

Individual characteristics

Age
Stage
Size
Sex
Behaviour

Studied through a population (Population Ecology)

Population characteristics

Population numbers (or density)
Age (or stage) distribution
Sex ratio
Spatial distribution

Individual processes

Development
Growth
Feeding
Reproduction
Death

Studied through a population (Population Ecology)

Population processes

Population growth (changes in numbers or density)
Changes in age distribution
Mortality
Birth rates

2 - Estimating population size

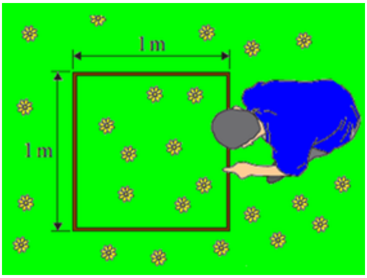
Wildlife managers use 4 approaches to estimate population sizes : total counts, incomplete counts, indirect counts, and mark-recapture methods.

Complete counts or Total counts

It counts every member of a population. Where populations of large species occur in open areas, such as waterfowl on lakes, seals on breeding beaches, or elephants on shortgrass prairie, aerial counts of most individuals are possible, especially with the aid of photography.

Incomplete counts

It involves counting part of a population and then extrapolating to the entire population. Quadrats may be established in a sample area and an attempt made to count all the individuals in each quadrat. Then what was counted inside the quadrat is multiplied by the total number of quadrats in the whole distribution area of the population.



$$\text{Population} = \frac{\text{Quadrat mean} \times \text{Total area}}{\text{Quadrat area}}$$

Indirect counts

As it is often impossible to obtain accurate, visual or auditory counts of the animals in a population, wildlife managers use indirect signs of the animals present as indices of relative abundance. An index of population indicates relative size of a population and shows population trends (up, down, stable) but does not provide an actual estimate of the number of animals. Eg. : numbers of meerkat holes, counting scats (fecal pellets) of duikers and rabbits, and counting numbers of nests or den sites in a given area. Remember that indirect counts are only indices of population sizes !

Mark-recapture methods

These methods are used extensively to estimate populations of fish, game animals, and many non-game animals. It involves capturing a number of animals, marking them, releasing them back into the population, and then determining the ratio of marked to unmarked animals in the population. The population P is estimated by the formula :

$$\mathbf{P} = \frac{\mathbf{M \times C}}{\mathbf{R}}$$

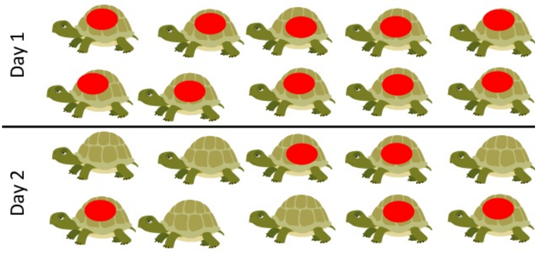
M : # of animals marked in the 1st trapping session
C : # of animals captured in a second trapping session
R : # of marked animals recaptured in the second trapping session

where M is the number of animals marked in the first trapping session, C is the number of animals captured in a second trapping session, and R is the number of marked animals recaptured in the second trapping session.

This is derived from the equation :

$$\frac{P}{M} = \frac{C}{R}$$

which states that the proportion of marked animals captured in the second trapping session is the same as the proportion of total marked animals in the total population.



Example : Tortoises

1 - 10 tortoises marked on day 1

2 - Of 10 tortoises caught on day 2, 5 were marked

3 - Half the tortoises were marked, so half of the population in total should be marked

4 - Therefore, total population is 10 x2, so 20 tortoises.

Are Mark-recapture methods perfect ?

The mark-recapture methods do not take into account some natural processes found in wild populations.

Some of the assumptions behind this method are :

- mortality is the same for marked and unmarked animals
- marked individuals do not lose their marks
- marked individuals are caught at the same rate as unmarked individuals (no trap-happy or trap-shy animals)
- the population has no significant recruitment, or ingress (births or immigration)
- the population has no significant egress (deaths or emigration)
- marked animals mixed randomly with unmarked animals
- each trapping session captures a representative sample of various age and sex categories from within the population.

For example, assumptions "no ingress" and "no egress" taken together mean that a population is closed. Thus this method is not perfect !

3 - Social organisation of populations

Animals which live or feed in groups frequently develop a social hierarchy in which some animals are dominants over the others. The dominance rule is often resolved by a fight, the dominant being the strongest animal. Some exceptions exist, such as elephants where the matriarch of the group is usually the oldest female.

The hierarchy is frequently a lot more complicated than just having a dominant animal on top of the others. It also includes special relationships with the mate over the rest of the group, or more ranks below alpha position.

Why dominate ?

Domination is a way to gain easy access to food or other resources. It can also include mating rights and a better choice of potential breeding partners.

For the individual, it is a way to increase its chances at survival and reproduction.
For the species, it enhances the chances at getting better genetics in the population, the dominant animals often being the strongest/better adapted individuals. By increasing the breeding of these strongest specimens over the weakest, the species evolves and keeps the best genetics.

Some populations do not have any social organisation within, as the individuals only get together during the breeding season (e.g. tigers). But the relationships between individuals can also show in the way they build their territories. Solitary animals have ways to communicate with other animals of their species by marking their territory (urine, scents) or even using loud calls. This can also be seen as social behaviours. Besides, the mother also develops social behaviours with her young while they are under her care, even if they leave later on.

Herds

The term 'herd' is used to describe a group of animals of the same species, commonly, a group of hoofed, grazing mammals. The herd may be a natural formation, as in the case of wild animals, or may be formed by human intervention, as in the case of domestic animals like cattle. Herds offer individual animals companionship, better foraging opportunities and more chances for mating and reproduction. A herd also offers more protection against predators than a solitary animal would otherwise have on its own.

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Flocks

Flocks of birds and schools of fish usually display the same behaviours as herds.

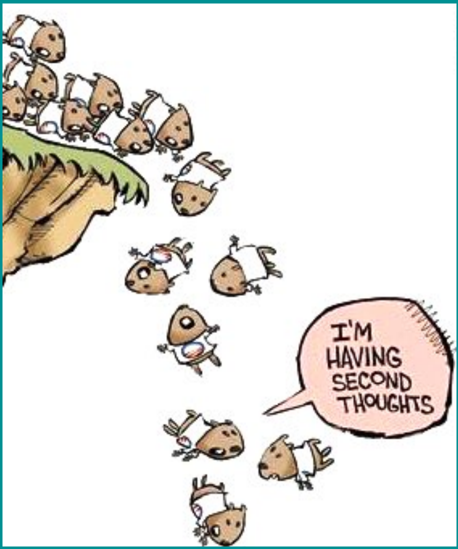
Mass behaviours in a Herd

The individual animals in the herd copy or imitate the behaviour of the other animals in the herd, particularly that of their closest neighbours. As a result, all the herd members behave in a related fashion and this allows the entire herd to respond to an external circumstance in a similar way. The herd then functions together as a single entity, for example, when it moves in a certain direction to get away from an attacking predator or when it travels a certain route for migration. These movements are quite unplanned, with the entire herd moving spontaneously, usually after taking its cue from one or more lead animals. The lead animal usually has a dominant social role within the herd hierarchy, although the social dynamics may keep changing.

Protection against Predators

A herd, by its sheer size, is a highly visible unit. This makes it easy for it to be targeted by predators. At the same time, given the number of animals in a herd, there is increased vigilance and individual animals stand a higher chance of escaping from a predator. So there are two important factors as to why animals live in herds; self-interest and survival instinct. Each individual animal tries to behave exactly as its neighbour in order to protect itself, and tries to minimise the danger to itself by moving along with the others and trying to get deeper into the herd. So the seemingly coordinated behaviour of the herd is mainly due to the uncoordinated movements of panicked, individual animals.

The Lemming effect



Lemmings are small rodents that have been thought to follow each other as they charge to their deaths into raging rivers or even off cliffs. Although this is absolutely untrue, the Lemming effect expression is used to describe the blind following of a leader without questioning it.

As humans, we also display herd behaviours. We are a social animal, and as such we refer to leaders in any type of domain.

Some examples :

- Fashion
- New products/Technology
- Art
- Discrimination

It is difficult not to "fit", not to follow trends and herd behaviours. But it is also often rewarding and proves your capacity to think for yourself.

5 - Example 2 : Co-operative hunting in Packs

A pack is a group of animals that hunt and live together (e.g. wolves). They are usually following strict hierarchy rules, with one animal leading the others (also named "Alpha").

Hunting in packs is a predatory technique used by numerous species such as wolves, wild dogs, lions, orcas, dolphins, mongooses and even hawks and kookaburras. There are more mouths to feed, but all calories expended during kill and capture are consumed by the entire pack.

Hunting in packs also requires a specialisation of each animal for a specific task during the hunt. Some can be the drivers, others will stay in ambush or will attack specific parts of the animal (legs, back, neck). But they all have to work together under the authority of the pack leader, the Alpha, for a kill to be successful.

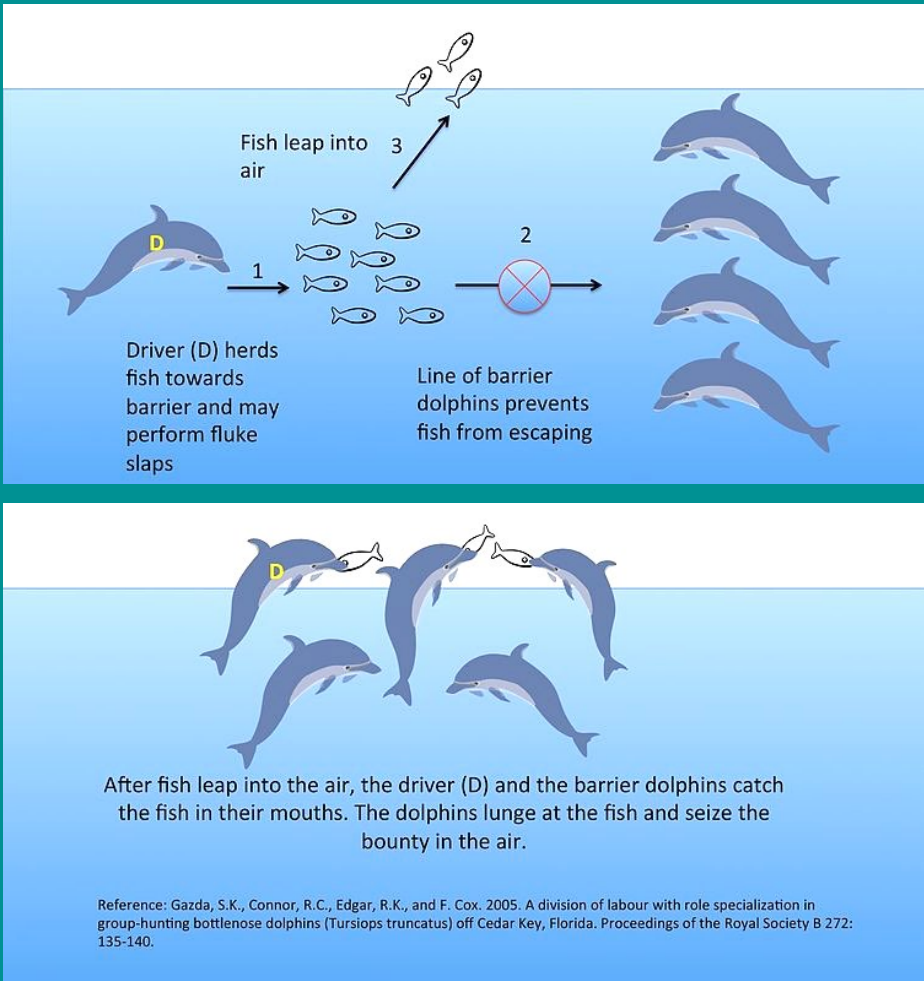
Why hunting in packs ?

It increases the success rate of the hunt. By having more hunters working together, it is easier to guide the prey towards its end, and it is less exhausting for the predators. They don't have to run for kilometres alone, they can rely on each other to relay them.

Hunting in packs also gives the ability to kill bigger species than what the predator could do alone. For example, orcas can kill blue whales weighing up to 100 tons, much larger than themselves !

Example : Dolphin hunting

Dolphins have numerous different hunting techniques. They communicate during the hunt to adapt to the prey movements, and they are also capable of changing their approach depending on the type of prey !



Barrier feeding in bottlenose dolphins

6 - Risk factors for wild populations

Species are replaced over time through a process called **natural selection**. Individual by individual, we imagine, species may have been starved out by competitors, or roughed up by storms, droughts, floods, novel diseases, parasites or, perhaps most often, a combination of all of these things. Many species will last only 5 or 6 million years ! Everything alive is in the grip of extinction. In fact, of all the species that have lived and are alive today on Earth, 99.9% are already extinct !

Info +

natural selection : *A fundamental process to evolution. Any characteristic of an individual that allows it to survive to produce more offspring will eventually appear in every individual of the species, simply because those members will have more offspring.*

The Extinction Vortex

An Extinction Vortex is a situation where genetic traits and environmental conditions combine to make a species gradually become extinct.

When a species sees its numbers decrease under a certain limit, the Extinction Vortex starts. Because of its small size, the species' population will fall into more problems : inbreeding, genetic drift and loss of genetic variability to cite a few.

- Inbreeding is the action to breed with close relatives instead of finding an unrelated partner. It leads to genetic disorders, such as diseases and malformations.
- Genetic drift is the rapid changes in the genetics of the species. In this case, it is not profitable as it often leads to mis-adapted individuals with less chances of survival.
- Loss of genetic variability is the consequence of the previous two conditions. Because the population numbers are very small, the genetic pool is reduced and there is less variation in the available alleles (different copies of the same gene). This doesn't help the population to recuperate as they do not have the variability needed to adapt to new conditions. The population is then more susceptible to environmental changes and will certainly disappear at the first occasion.

Objective

Estimate the size of a sample population using the mark-recapture technique and compare the mark-recapture technique to other methods of population estimating.

Preparation

Take a bag with a random number (between 30 and 100) of small similar items (e.g. dry beans). You will also need a marker pen.

Questions

1 - You are given the responsibility of determining the number of fish in the lake Malawi. How would you accomplish this task ?

Incomplete counts

In this procedure, the organisms in a few small areas are counted and projected to the entire area. For instance, if a biologist counts 10 squirrels living in a 200-square foot area, she could predict that there are 100 squirrels living in a 2000 square foot area. This is a simple ratio.

2 - A biologist collected 50 liters of pond water and counted 10 mosquito larvae. How many larvae would you estimate to be in that pond if the total volume of water in the pond was 80,000 liters ?

3 - What are the problems with this technique ? What could affect its accuracy ?

Mark and Recapture Technique

In this procedure, biologists use traps to capture animals and mark them in some way. The animals are then returned unharmed to their environment. Over a period of time, the animals are trapped again, with researchers recording how many of the original tagged individuals are recaptured. The ratio of animals trapped with the tags and the animals trapped that were not tagged is used to estimate the overall population number.

Procedure

4 - Take the bag of beans your prepared at first, it represents your population

- Capture 10 “animals” by removing them randomly from the bag
- Place a mark on them using the marker pen
- Return the 10 marked “animals” to the container
- Without looking, use a scoop to recapture animals in the population. Record the number of “animals” recaptured in total and the number that have a mark on them on the data table below.
- Return the “animals” to the bag and repeat ten times.

Trial Nb	# Captured	# Recaptured with mark
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

5 - Calculations : Find your Population Estimate using the formula below

10

$$\text{Population Estimate} = \frac{(\text{Total number captured}) \times (\text{Number marked})}{(\text{Total Number Captured with Mark})}$$

6 - Count how many “animals” are really in your population.

Analysis

7 - Compare the actual size to the estimated size. Did you overestimate or underestimate ?

8 - Continue the experiment by filling out the next data table.

Trial Nb	Nb Captured	Nb Recaptured with mark
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

9 - Recalculate your estimate using the formula.

a. Is the second estimate closer than the first one ?

b. To get the most accurate results, would you do more or less trials ?