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POPULATION ECOLOGY

Population Ecology

Study of population in relation to its environment is called population ecology. This includes influence of the environment on population density, distribution, age structure and population size.

Population Ecology is the branch of biology that deals with the number of individuals of a particular species that are found in an area and how and why those numbers change over time Populations have certain properties, such as birth rates and death rates that individual organisms lack.

What is a population?

- It is a group of individuals of same species, inhabiting a particular area, and who interbreed among themselves.
- Populations are dynamic. They are continuously changing, expanding or shrinking, according to their environment.
- Populations have growth rates, age distributions and spatial patterns (population ecology).
- They have genotypic and allelic frequencies (population genetics).

Population ecology + Population genetics = Population biology

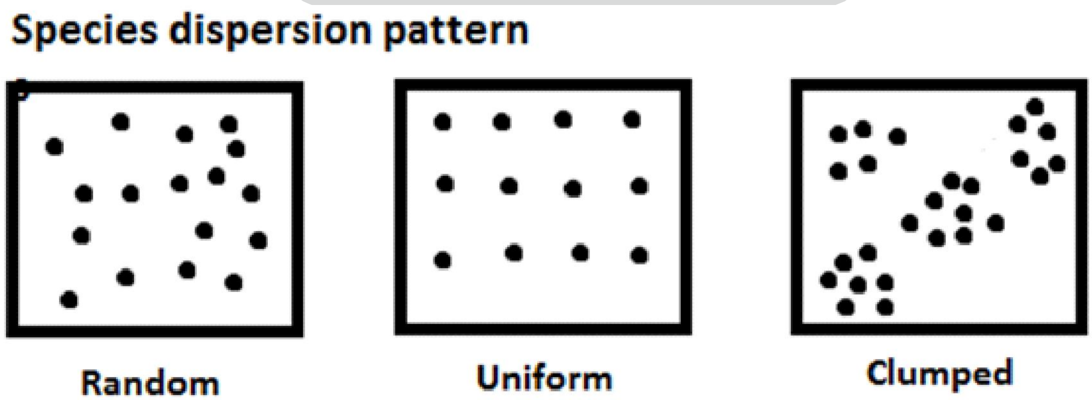
Why study population ecology?

It helps to:

- Predict future dynamics.
- Ascertain appropriate measures to be taken to contain populations.
- Manage threatened populations.

1. Species dispersion/distributin patterns

Individuals in a population show different spacing patterns also known as species dispersion.



Random spacing

1. Individuals are distributed randomly without any certain pattern.
2. Individuals do not interact very strongly with one another.
3. This type of distribution is found in species of plants that have wind dispersed seeds. These seeds spread extensively and germinate wherever they find a suitable habitat.

Uniform spacing

1. Individuals are evenly spaced in a population.
2. This pattern usually results from competition for resources.
3. In animals, uniform spacing is a result of behaviors such as defending territories for resources, space, mating.
4. In plants, competition for resources such as sunlight, nutrients and water lets only those plants co-exist, which are uniformly spaced.

Clumped spacing

1. Individuals are clumped into groups.
2. It is due to uneven distribution of resources.
3. These are most common in nature because many individuals share a most suitable habitat.
4. Social interactions like movements in groups such as herds, flock, pride, confer survival advantagesto individual members. This can also lead to clumped distributions.

Note: Patterns of dispersion should not be confused with the process of dispersal which refers to movement of individuals away from their place of birth or from high density areas and includes immigration and emigration.

2. Population density

The number of individuals of a species present in per unit of area or volume at a given time.

The methods of population sampling.

1. Quadrate method

For a population in which individuals are immobile quadrate method is very useful. For example: population of a plant species. This method is very simple and it calculates number of individuals per unit area in an immobile population very accurately.

Steps for using Quadrate method

1. The total area of species habitat is figure out.
2. Then a tiny quadrate area from total of area species habitat is taken.
3. This particular quadrate area is then counted for number individuals of that species.
4. This process of sampling of a small quadrate is repeated several times.
5. Then average density of individuals in all sampled quadrates is counted.
6. Then this average is multiplied by total area of habitat of that species.
7. The result is the density of that particular species.

Let's take an example

- There is an overall area of 200 square meters. And we have to calculate the density of grass blade in this whole area. So, this calculation for density of grass blade in whole area is a pretty hard task for anyone.
- So instead of calculating all the grass blades in that whole area, several samples are taken from quadrate from all around the whole area.
- So if the average density of blades of grass found in these quadrants is 10,000 blades of grass per meter squared, then by multiplying that by the number of square meters in the field (200), the an approximate total population can be calculated (2 million blades of grass).

Individuals / sample area = density

density ×total area = total population

10,000 × 200 = 2,000,000

Limitations of quadrate method

- This method is only useful when individual in a population do not change their position from one place to other place. This cannot be applicable for animal population.
- Sometimes one area in a particular habitat can bear double number of organisms as compare to another area in same habitat. This will lead to a biased result.

2. The mark and release method foe population sampling.

As you seen above it is a bit easy to estimate the population density of non- motile creatures. But in case of motile creatures we need a different concept for population sampling because above given concept is not applicable here. We can't simply use quadrate method here because motile organisms can move between two successive quadrate during sampling. For the sampling of motile organisms we need to recognise that which organism counted previously and which one is not counted yet. One would have to use some sort of distinct marking to make sure not to count certain individuals twice.

Steps for sampling through mark and capture technique

A very advanced method is used for counting a motile population. This method is known as the "capture- mark- release – recapture" method.

1. This is a simple procedure in which a small number of individuals from a population are captured.
2. Then we put a mark on their body for later identification.
3. Then after a particular time another sample from this population is again recaptured.
4. Now, by counting of the marked individual in this recaptured sample, we can approximate the total number of individual in overall population.

Example:

Let take an example of Gharial population in Chambal river of India. To figure out the number of Gharial, a research team captures, marks, and releases 500 Gharial, Several weeks later, after allowing the marked Gharial to recirculate into the unmarked population, another 500 are recaptured. If 50 of the newly captured Gharial are marked (10% of the second sample), this suggests that around 10% of the total Gharial in India were previously captured and marked. Since the first sample was of 500 Gharial, and that is only 10% of the population, it is reasonable to expect that the total population of the Gharial in India is close to 5000.

Formula;

$$\frac{\text{number marked first catch (M)}}{\text{Population size (N)}} = \frac{\text{number marked second catch(x)}}{\text{total number of second catch (n)}}$$

Or; $$M/N = x/n$$

Or; $$N = M \times n/x$$

Total marked / total individuals = sample marked / sample total

500 / total = 50 / 500

500 × 500 / 50 = total

total = 5000

Drawbacks & Limitations

The Mark-Recapture method of calculating population sizes is only useful under certain assumptions.

- This method is only successful when the number of marked and unmarked individuals stays same. And the second sample should accurately represent the ration of marked to unmarked individuals.
- So it means there will no migration of individuals, death , births , mark shedding and the marking should not effect further captures of marked individuals.
- There should be enough time for marked individuals to disperse thoroughly between unmarked individuals.

Population dynamics

It deals with the size and age composition of a population. It focuses on how, when and why population densities change.

These changes are a result of Primary ecological events and Secondary ecological events.

Primary ecological events which influence size/density of populations include:

- Natality: Birth rate
- Mortality: Death rate
- Immigration: Individuals migrate into a population
- Emigration: Individuals migrate out of a population

Change in population density = [(Natality + Immigration) - (Mortality + Emigration)]

Secondary ecological events are the biotic or abiotic factors that influence the primary ecological events. These are factors which affect:

- Frequency
- Magnitude
- Duration
- Extent of the primary ecological events.

For example: Cold winters could increase mortality rates or increase emigration, thus resulting in a decrease in population size, while hot summer days could reduce predation, increase natality and result in expansion of population.

Demography is the study of factors that affect population density and dispersion patterns.

- Demography is the study of the vital statistics of populations and how they change over time.
- Of particular interest are birth rates and how they vary among individuals (specifically females), and death rates.
- A life table is an age-specific summary of the survival pattern of a population.
- The best way to construct a life table is to follow the fate of a cohort, a group of individuals of the same age, from birth throughout their lifetimes until all are dead.
- To build a life table, we need to determine the number of individuals that die in each age group and calculate the proportion of the cohort surviving from one age to the next

Age structure

1. It is the number of individuals of each age group in a population.
2. Populations have overlapping generations where individuals of more than one generation co-exist
3. The age of a population influences its growth rate.
4. Population which has large number of young reproductive individuals would grow rapidly. In contrast, if a large proportion of population is relatively old and can no longer reproduce, populations decline.
5. Age structure is usually shown by a population pyramid.
6. The x-axis shows the percentage of population of males on the left and that of females on the right. The y-axis shows the different age groups usually at a 5 year interval.
7. Births add individuals only to the base of the pyramid.

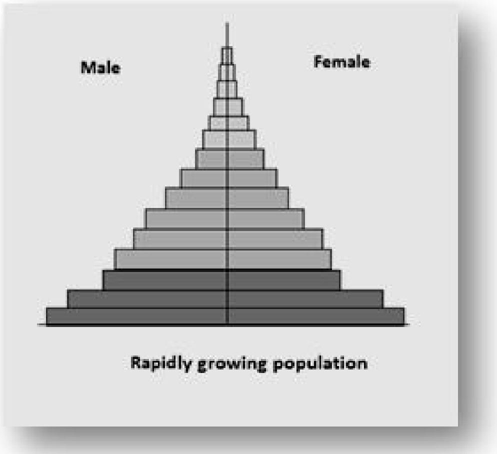
Growth of a population can be determined by the shape of the pyramid:

Indicates post-reproductive ages 45-85+

Indicates reproductive ages 16-44

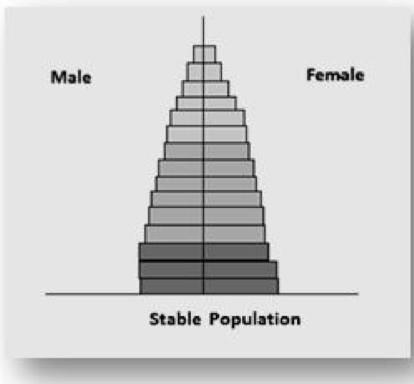
Indicates pre-reproductive ages 0-15]

I. A rapidly growing population



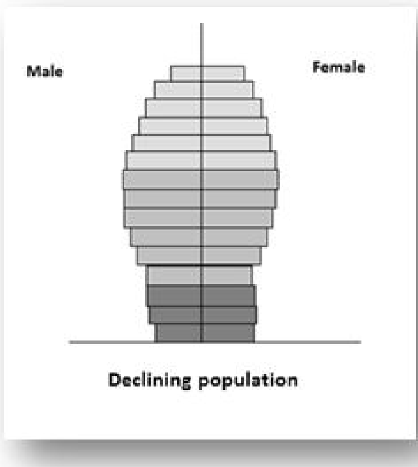
1. Has a broad base which is indicative of high proportion of reproductive individuals which means a rapid rate of population growth.
2. Has a narrow top which means a low proportion of older people.
3. High death rate.
4. Members have low life expectancy.

II. A stable population



1. Has roughly equal number of young and adult members.
2. Has almost equal birth and death rate.
3. This indicates the population is stationary.

III. A declining population



1. Has a narrow base which means low birth rates
2. Has a broad top which means large proportion of people are old in age.
3. Members have long life expectancy.

Population growth

1. Four processes determine population growth: Reproduction, mortality, immigration, emigration.
2. Fertility or fecundity i.e. addition of new individuals through reproduction whether sexual or asexual also determine the growth of a population.
3. **Fecundity** – potential reproductive output under ideal conditions.
   – Determined by genotype and not the environment.

   Fertility – Actual reproductive performance under prevailing conditions.

Fertility rates are less than fecundity rates in nature.

4. Fecundity is expressed as rate i.e. mean number of offspring produced per individual per unit time.
5. Mortality or death rate is mean number of deaths per thousand, per unit time, per unit area.
6. In order to predict future changes in population, we need to know fertility rate as well as death rate for each age category.
7. **Intrinsic rate of increase of populations (r)** – It is the growth rate per individual per unit time.

$$r = b - d$$

$$b = birth\ rate$$

$$d = death\ rate$$

In human demography, birth and death rates are expressed per thousand, so

$$r = \frac{b-d}{1000}$$

r ignores age distribution and generation time. This means if population A has smaller r than population B, but higher proportion of reproductive individuals, then population A would still be greater than population B. If generation time for population A is smaller than B, then also population A would be greater despite a smaller .

Population growth models

I. Difference equation

For developing population growth models, current population is taken as population at time t = 0.

Future time units are taken as = t.

Population at =

Population at time t =

So, the equation becomes: $N_t = N_0 + (B - D) + (I - E)$

This can be re-arranged as: $N_t = N_0 + (B + I) - (D + E)$

- In most populations studies, immigration and emigration rates are considered insignificant when compared to birth and death rates. The number of births and deaths are converted to per capita rates b and d respectively.
- becomes a single parameter known as .

- is the growth rate per time period, also known as **finite rate of increase**.

$$N_t = N_0 + (b - d)$$

$$N_t = \lambda N_0$$

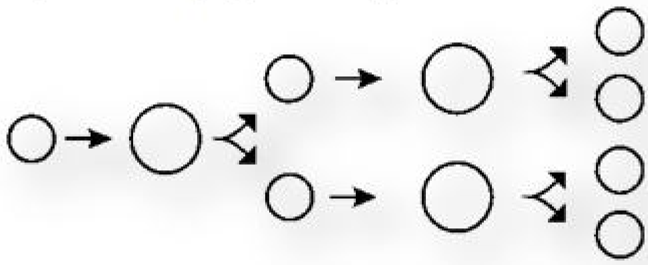
II. Differential equation

- It measures the instantaneous growth of population .
- Differential equation for population growth is

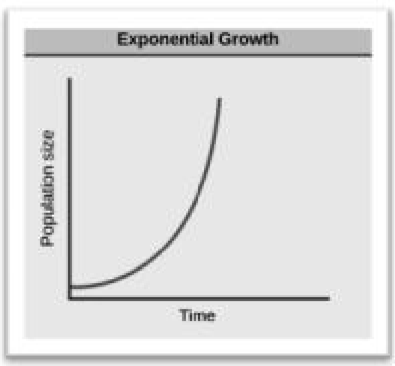
$$\frac{dN}{dt} = rN$$

- Here, $\frac{dN}{dt}$ means change in per unit change in time interval t.
- r is the intrinsic rate of increase , or its innate capacity for growth, which measures per capita birth rate minus per capita death rate.
- Models based on differential equations explain predator-prey, host-parasite relationships.

Exponential population growth



1. In this growth model, the basic idea is that every individual in the population doubles after each successive generation. If we start with 1 bacteria, it will divide into 2 in the next generation. These 2 cells divide into 4, 8, 16 and so on. We can say that the bacteria is growing exponentially.
2. This model assumes that population is growing in an environment with unlimited resources without predators or competition.
3. It also assumes that the rate of immigration and emigration is equal.
4. The population grows at its maximal rate, exploiting its **biotic potential**.



5. The graph for exponential growth shows a J-shaped curve.
6. Instantaneous rate of change of population is given as :