INSECT ECOLOGY

(ENT-504)

Practical Manual

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Practical Manual

Insect Ecology
(ENT-504)

Name of the student: ________________________________ Reg. No.: ________________

Department: ________________________ Faculty: ___________________ Term: _____

Expt. No.	Date	Topic	Sign. of Course Instructor	Remarks

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ACKNOWLEDGEMENT

We are extremely thankful to Prof. Apurba Kumar Chowdhury, Dean Post Graduate Studies, Uttar Banga Krishi Viswavidyalaya for his constant encouragement to prepare the manual. We want to express our heartfelt thanks to Prof. Jaydeb Ghosh, Head, Department of Entomology, Uttar Banga Krishi Viswavidyalaya for his keen interest and valuable suggestions during the course of preparation of the manual. We also want to thank Mr. Adrish Dey and Mr. SamratSaha, Ph.D. students of Department of Entomology for their assistance in preparing the manual.

We believe that this manual will be helpful for the students and others having interest on ecological aspects of insects. We would sincerely appreciate any and all suggestions for improvising the manual.

Place:

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Exercise-1: Study of distribution patterns of insects in crop ecosystems

Objective: To have idea on distribution patterns of insects in crop ecosystems.

Validating various methods of population estimation is crucial in ecological studies. Data on the distribution and dispersion of pest species form a reliable foundation for creating effective sampling strategies and understanding species behavior. Individuals within a population exhibit specific spatial arrangements, which are significant in studying ecosystem dynamics.

Distribution pattern/Dispersion

Dispersion refers to the spatial distribution pattern of a pest species within a population. The internal distribution patterns among species are significant as they relate to population characteristics. Individuals within any population may exhibit one of three fundamental distribution patterns, which are as follows:

1. Regular / Uniform distribution
2. Random/ Poisson distribution
3. Clumped / aggregated / over-dispersed/contagious distribution

To understand the distribution/Dispersion of insect species one need to calculate,

A) Mean ($\bar{x}$) = $\Sigma fx/n$

B) Variance (S^2) = $[\Sigma fx^2 - (\Sigma fx)^2 /n]/ (n-1)$

Where, f= Frequency of number of plants/branches

x= Number of insects per plant/branch

n= Total number of plants

C) Variance - Mean ratio (VMR) = $S^2/\bar{x}$

D) Index of David and Moore (IDM) = $(S^2/\bar{x}) - 1$

E) Index of Lexis = $\sqrt{S^2/\bar{x}}$

F) Charlier Co-efficient = $\sqrt{(S^2-\bar{x})}/\bar{x}$

Distribution pattern/Dispersion

Regular/uniform distribution	**Random or Poisson distribution**	**Aggregated/Clumped/ Aggregate/Negativebinomial distribution**
Variance is less than Mean (($S^2 < x$)	Variance is equal to Mean ($S^2 = x$)	Variance is more than Mean ($S^2 > x$)
Variance-mean ratio (VMR) <1	Variance-mean ratio (VMR) =1,	Variance-mean ratio (VMR) > 1
IDM < 0	IDM =0	IDM > 0
Index of Lexis <1	Index of Lexis =1	Index of Lexis > 1
Charlier Coefficient <0	Charlier Coefficient =0	Charlier Coefficient >0
Interspecies competitionis intensified by physical factors.	Relatively rare in nature and occurs where the environment is very uniform and there is no tendency to aggregate	Most frequently observed pattern and individuals show varying degree of clumping together due to attraction or instinct as in case of some insects. Large scale clumping helps to evade possible danger of predation, climate or diseases. Usually the environment decides the degree of aggregation of clumped patterns.

Q (1). Workout the mean, variance and different indices to conclude the Distribution/Dispersion patterns of insect species 'A' based on the following larval population data

Set A:

Number of Insects Per Plant x	**Plant Frequency f**	**fx**	**fx^2**
0	22		
1	4		
2	5		
3	7		
4	20		
5	12		
6	15		
7	9		
8	4		
9	5		
10	3		
Total	n=	Σfx=	Σfx^2=

Set B:

Number of Insects Per Plant x	**Plant Frequency f**	**fx**	**fx^2**
0	12		
5	21		
5	12		
3	20		
4	9		
5	2		
6	4		
7	12		
5	1		
3	2		
5	1		
Total	n=	Σfx=	Σfx^2=

Set C:

Number of Insects Per Plant **x**	**Plant Frequency** **f**	**fx**	**fx^2**
0	12		
5	21		
5	12		
3	20		
4	9		
5	2		
6	4		
7	12		
8	1		
7	2		
5	1		
Total	n=	Σfx=	Σfx^2=

In plant and animal populations, the **negative binomial distribution**, which indicates clumped dispersion, is commonly observed at **high population densities**. In contrast, the **Poisson distribution**, which represents random dispersion, is prevalent at **low densities**.

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Poisson distribution

In statistics, the Poisson distribution is a probability distribution used to model the frequency of events expected to occur over a specified period. It is commonly applied to analyze occurrences of independent events that happen at a constant rate within a defined interval of time.

Poisson distribution formula

For a random discrete variable X that follows the Poisson distribution, and **λ** is the average rate of value, then the probability of **x**is given by:

$f(x) = P(X=x) = (e^{-\lambda}\lambda^{x})/x!$

Where

- x = 0, 1, 2, 3...
- e is the Euler's number(e = 2.71828)
- λ is an average rate of the expected value (Mean)
- λ = variance, also λ>0
- mean (μ) = variance = λ
- np = λ is finite, where λ is constant (n= no. of trials and p= probability)
- The standard deviation $\sigma^2 = \sqrt{\mu}$
- If the mean (λ) is large, then the Poisson distribution is approximately a normal distribution.
- The Poisson distribution is limited when the number of trials (n) is indefinitely large and probability is tends to zero.

Applications of Poisson distribution

The Poisson distribution finds applications in several scenarios where random variables are used to:

- Count the number of defects in finished products
- Quantify the number of deaths in a country due to diseases or natural disasters
- **Assess the number of infected plants in a field**
- Measure the count of bacteria in organisms or radioactive decay in atoms
- Estimate the waiting time between successive events

Poisson distribution examples

Example 1: In a field, the pollinator visited the crop at a mean rate of 2 per min. Find the probability of arrival of 5 pollinators in 1 minute using the Poisson distribution formula.

Solution:

Given: λ = 2, and x = 5.

Using the Poisson distribution formula:

$P(X = x) = (e^{-\lambda}\lambda^{x})/x!$

$P(X = 5) = (e^{-2}2^{5})/5!$

$P(X = 5) = (e^{-2}2^{5})/ (5*4*3*2*1)$

P(X = 5) =

Answer: The probability of arrival of 5 pollinators per minute is…………………

Example 2: Find the mass probability of function at x= 6, if the value of the mean is 3.4.

Solution:
Given: $\lambda = 3.4$, and $x = 6$.
Using the Poisson distribution formula:
$P(X = x) = (e^{-\lambda}\lambda^{x})/x!$
$P(X = 6) = (e^{-3.4}3.4^{6})/6!$
$P(X = 6) =$

Answer: The probability of function is.. %

Example 3: If 3% of the fruits are infested by fruit fly. Find the probability that in a sample of 200 fruits, less than 2fruits are defective.

Solution:
The probability of defective units p = 3/100 = 0.03
Give n = 200.
We observe that p is small and n is large here. Thus it is a Poisson distribution.
Mean $\lambda = np = 200 \times 0.03 = 6$
P(X= x) is given by the Poisson Distribution Formula as $(e^{-\lambda}\lambda^{x})/x!$
$P(X < 2) = P(X = 0) + P(X= 1)$
$=(e^{-6}\, 6^{0})/0! + (e^{--6}6^{1})/1!$
$= e^{-6} + e^{--6} \times 6$
=

Answer: The probability that less than 2 fruits are infected is ……………………………..%

Example 4: Insects of a certain type lay eggs on leaves such that the number of eggs on a given leaf has a Poisson distribution with a mean 4.For any given leaf, the probability is 0.05 that it will be visited by such an insect and leaves are visited independent of each other

a) What is the number of leaves visited by the insect?
b) What is the probability that a given leaf has no eggs?
c) If a leaf is inspected and has no eggs, what is the probability that it has been visited by an insect?
d) If 2 leaves are inspected and none have any eggs, what is the probability that at least one leaf has been visited by an insect?

Solution:
Mean $\lambda=4$
$p=0.05$
P(X= x) is given by the Poisson Distribution Formula as $(e^{-\lambda}\lambda^{x})/x!$

a) $\lambda = np$

b) $P(X=0) = (e^{-4}4^{0})/0!$
$P(X=0) = e^{-4} x\ 4$
$P(X=0) =$

Answer: The probability that that a given leaf has no eggs is………………………

c) $P(X=1) = (e^{-4}4^1)/1!$
$P(X=1) = (e^{-4}4^1)/1$
$P(X=1) = e^{-4}*4$
$P(X=1) =$

Answer: The probability that that one leaf has been visited by an insect is ……………

d) $P(X<2) = P(X=0) + P(X=1)$
$=(e^{-4}4^0)/0! + (e^{-4}4^1)/1!$
$= (e^{-4} \times 4) + (e^{-4} \times 4)$
=

Answer: The probability that at least one leaf has been visited by an insect is……………..

Distribution	Binomial Distribution	Negative Binomial Distribution
Definition	The **binomial distribution** is characterized by two possible outcomes (the prefix "bi" meaning two or twice): success (S) or failure (F).	The **Negative binomial distribution** (also known as the Pascal Distribution) is a discrete probability distribution used for random variables in a negative binomial experiment. In this distribution, the random variable represents the number of repeated trials, x, required to achieve a specified number of successes, k. Essentially, it quantifies the number of failures before a success occurs. This differs from the binomial distribution, where the focus is on the number of successes achieved within a fixed number of trials.
Properties:	1: The number of observations n is fixed. 2: Each observation is independent. 3: Each observation represents one of two outcomes ("success" or "failure"). 4: The probability of "success" p is the same for each outcome.	1: The number of observations n is fixed. 2: Each observation is independent. 3: Each observation represents one of two outcomes ("success" or "failure"). 4: The probability of "success" p is the same for each outcome.
Formula Probability**:**	$P(x, k, p) =$ $P(X=x) = {}^nC_x * p^x * (q \text{ or } 1-p)^{n-x}$ ${}^nCx = (n)! / [(x)!*(n-x)!]$ where, x=number of trials (Variable) k = Successes (constant) p= probability of success q= probability of failure= 1-p	$nb(x, k, p)$ or $b^*(x, k, P) = P(X=x)$ $= {}^{x-1}C_{k-1} * p^k * (1-p)^{x-k}$ ${}^{x-1}C_{k-1} = (x-1)! / [(k-1)!*(x-k)!]$ where, x=number of trials (Variable) k = Successes (constant) p= probability of success q= probability of failure= 1-p
Mean Variance, Standard deviation	Mean, $\mu = np$ Variance, $\sigma^2 = npq$ Standard deviation $\sigma = \sqrt{(npq)}$	Mean, $\mu = kq/p$ Variance, $\sigma^2 = kq/p^2$ Standard deviation $\sigma = \sqrt{kpq}$ **Mean<Variance**

Negative Binomial Distribution:

The **Negative binomial distribution** (also known as the Pascal Distribution) is a discrete probability distribution used for random variables in a negative binomial experiment. In this distribution, the random variable represents the number of repeated trials, x, required to achieve a specified number of successes, k. Essentially, it quantifies the number of failures before a success occurs. This differs from the binomial distribution, where the focus is on the number of successes achieved within a fixed number of trials.

Properties:
1: The number of observations n is fixed.
2: Each observation is independent.
3: Each observation represents one of two outcomes ("success" or "failure").
4: The probability of "success" p is the same for each outcome.

Formula
Probability:
nb(x, k, p) or b*(x, k, P) = P(X=x) = $^{x-1}C_{k-1} * p^{k} * (1 - p)^{x - k}$
$^{x-1}C_{k-1}$ = (x-1)! / [(k-1)!*(x-k)!]
where,
x=number of trials (Variable)
k = Successes (constant)
p= probability of success
q= probability of failure= 1-p

Mean, $\mu = kq/ p$
Variance, $\sigma^2= kq/ p^2$
Standard deviation $\sigma=\sqrt{kpq}$
Mean<Variance

Sample question: You are surveying insect population in a particular area and searched for a particular population (A). The probability (p) ofthe presence of the population is 20%. What is the probability that 15 numbers of insects you have searched before you can find 5 insects of A population?

Step 1: Find p, k and X.
In the question p = 20% (0.2) and k = 5
The number of failures, (x-k), is 15 – 5= 10

Step 2: Insert those values from Step 1 into the formula:
nb (10, 5, 0.2) = $^{(15-1)}C_{(5-1)}*(0.2)^5*(0.8)^{10}$

Step 3: nb (10, 5, 0.2) = $^{14}C_4*(0.2)^5*(0.8)^{10}$
= $\{14!/[4!*(14-4)!]\}*(0.2)^5*(0.8)^{10}$
= $[14*13*12*11*10*9*8*7*6*5*4*3*2*1/4*3*2*1*10*9*8*7*6*5*4*3*2*1]*(0.2)^5*(0.8)^{10}$
= 1001*0.0003*0.1074
= 0.0344

Answer: The probability of finding 5 insects of population 'A' is 3.44%

Q (2). You are surveying insect population in a particular area and searched for a particular population (A). The probability (p) of the presence of the population is 30%. What is the probability that 20 numbers of insects you have searched before you can find 5 insects of population 'A'?

Exercise-2: Sampling techniques for the estimation of insect population and damage

Objective: To understand sampling techniques for estimation of insect pest population.

Purpose of Population Estimation:
- ✓ To determine a pest species, it's population, distribution and changes over time
- ✓ To determine local or newly introduced pest population
- ✓ To monitor pest level to control and recommend when, where and how to deal with a specific problem

Important Terminologies:

Population	The number of individuals of a particular species in a particular area
Sample	A group of insects taken from a larger population for measurement
Sample size	The number of individual samples measured or observations used in a survey or experiment
Sampling	The process of collecting repeated data of an insect in its environment over a specified time
Sampling unit	The portion within the sampling area from which measurements are taken

Categories of Sampling for Insect pest population Estimation

Absolute sampling/ Estimate	Determines the total number of insects per unit area (*eg*. 1 ha, 1 msq. quadrate, etc.) Numbers per unit of the habitat (*eg*. per plant, shoot or leaf) - indicate density of population
Relative sampling/ Estimate	The samples usually represent an unknown constant proportion of the population To measure pest in terms of some values
Population Indices	Population indices do not count insects at all Rather they are measures of insect products or effects- plant damage, frass or nests

Sampling techniques for insect pest population estimation

Absolute sampling	**Relative sampling**	**Population Indices**
Quadrate method	Catch per unit	Insect products- Frass, exuviae*etc.*
Capture-recapture method	Line-transect method	Plant damage a) Direct damageb) Indirect damage
In-situ count	Shaking and beating method	
	Knockdown sampling	
	Trapping	
	Remote sensing	

1. Absolute sampling / Estimate

Quadrate method:
- Small areas or quadrates chosen at random from a large area which contains the insect population
- Number of insects counted

Capture-Recapture method:
- Insects marked with marker released in field to mix with general population and later collected/recaptured
- For estimating population of flying insects - butterflies, grasshoppers

2. Relative sampling / Estimate

i. Catch per unit time

- Various types of collection nets available for use in different habitats: sweep net, aerial net, suction net, visual searching, etc.
- Number of insects counted – generally obtain a mean (within 25 percent of the actual population).

ii. Line Transect method

- One person walks in a straight line at a constant speed through a habitat - number of insects are counted.
- Used for quantitative comparisons between different species in the habitat.

iii. Shaking and Beating

- Insects collected by shaking or beating plants – fallen insects counted.
- A piece of cloth or polythene laid out under the plants.

iv. Knockdown sampling

- Insecticides (e.g., pyrethrum or other safer ones) sprayed on plants enclosed in a polythene envelope.
- Insects are knocked down (not killed) due to insecticidal effect.
- Plants are shaken and fallen insects are counted.

v. Trapping

- Various types - aquatic trap, pitfall trap, light trap, sticky/adhesive trap, suction trap, water trap, bait trap, pheromone trap, etc.
- Trapped or collected insects are counted/estimated.

vi. Remote sensing

- Changes in plant response to pest attack are recorded by a device from far away.
- Remote sensing platform includes aircraft, satellites, or ground-based systems.
- Rarely followed.

3. Population Indices

Insect products

- Done for insect species that are difficult to sample.
- Most often sampled is frass of lepidopteran defoliators.
- The rate at which frass is produced can be estimated from the amount falling into a box.

Plant damage

Amount of damage caused by insects to crop plants directly correlates to function of pest density, their characteristic feeding or opposition behaviour of the species.

Direct and Indirect damage.

Direct damage

- Direct injury done to plants by feeding insects, which eat economic parts or burrow in stems, fruit, or roots, etc.
- Examples include fruit borers, stem borers, etc.

- Insect pests attack the produce directly, destroying a significant part of its value.
- E.g., number of damaged bolls per cotton plant, apples per tree, pods per plant, etc.

Indirect damage

- Damage by indirect pests may be measured by estimating the extent of defoliation in case of defoliating pests.
- Insect itself does little or no harm but transmits bacterial, viral, or fungal infections/diseases into the crop indirectly affecting yield.

Stage of Sampling:

Usually, the most injurious stage is counted, with egg masses often included. For hoppers, both nymphs and adults are counted to assess damage accurately.

Precautions while sampling:

The precision of a pest population estimate based on a given sampling technique depends on:

- The properties of the population, such as its density and degree of aggregation.
- The characteristics of the sampling plan, including the number and size of samples.

Importance of sampling:

- To assess the pest situation and determine pest activity in the field.
- For monitoring and decision-making in successful Integrated Pest Management (IPM) programs.
- To predict pest problems before they occur.

Q (1). Work out the population density and percentage frequency of different pests occurring in a given area by quadrat method

Sl.No.	Insect species	No. of individuals/ Quadrat ($1m^2$)				Total no. of individuals in all the quadrat studied (N)	Total no. of quadrats in which each species occurred (A)	Total no. of quadrats studied (B)	Population density (N/B)	Frequency percentage (A/B)x100
1	A	2	0	1	3					
2	B	0	0	2	1					
3	C	3	4	2	3					
4	D	2	1	2	3					
5	E	1	0	1	1					
6	F	4	5	3	5					
7	G	1	1	0	0					

Q (2). Work out the population index as frequency percentage of a borer pest causing direct damage to a crop in a given area

Variety	Plant No. (X)	No. of fruit (A)	No. of bored fruit (B)	% infested fruit C=(B/A)x100	Mean % (∑C/X) of each variety
1	1	3	2		
	2	1	0		
	3	3	1		
	4	3	0		
	5	2	2		
	6	4	1		
	7	5	1		
2	1	6	2		
	2	4	1		
	3	4	1		
	4	3	1		
	5	5	2		
	6	5	2		
	7	6	2		

Exercise-3: Measures of central tendencies

Objective: To understand the different measures of central tendencies for statistical analysis of insect population.

A measure of central tendency is a statistical concept that summarizes a dataset by identifying its central position. The **four primary measures** of central tendency are the **mean**, **median**, **mode**, and **midrange**. The midrange, also known as the mid-extreme, is calculated as the arithmetic mean of the maximum and minimum values in the dataset.

Characteristics of a good measure of central tendency:

- It should be well-defined and precise.
- It should be easy to understand and compute.
- It should consider all observations in the dataset.
- It should be suitable for algebraic operations.
- It should be stable and not heavily influenced by extreme values.

Mean, calculated as the average of all numbers in a given dataset, is often considered the most stable measure of central tendency because it incorporates every observation within the distribution.
The mean $\bar{x}$ of a data set is the sum of all the data divided by the count **n**.

Median is the central value in a dataset that divides it into two equal halves. To find the median, the dataset must be arranged in ascending order, and then the middle value is identified. This value separates the dataset into two equal parts, with an equal number of values above and below it.

Median Formula
The median $\tilde{x}$ is the data value separating the upper half of a data set from the lower half.

- Ordering a data set $x_1 \leq x_2 \leq x_3 \leq ... \leq x_n$ from lowest to highest value,
- The median $\tilde{x}$ is the data point separating the upper half of the data values from the lower half.
- If the size of the data set **n is odd** the median is the value at position **p** where
  p= (n+1)/2
  $\tilde{x} = x_p$
- If **n is even** the median is the average of the values at positions **p and p + 1** where
  p=n/2
  $\tilde{x} = (x_p + x_{p+1})/2$

Mode
The mode represents the most frequently occurring value within a dataset. In a bar chart, the mode corresponds to the tallest bar. A dataset displays a multimodal distribution when multiple values occur with equal frequency as the mode. Conversely, if no value repeats, the dataset is said to be without a mode.

Quartiles
Lower Quartile (Q1) = (N+1) * 1 / 4
Middle Quartile (Q2) = (N+1) * 2 / 4
Upper Quartile (Q3) = (N+1) * 3 / 4
Interquartile Range = Q3 – Q1

Outliers

Potential outliers are values that fall either above the upper fence or below the lower fence of a sample set.

Upper Fence = $Q_3 + 1.5 \times$ Interquartile Range

Lower Fence = $Q_1 - 1.5 \times$ Interquartile Range

Q (1): Find out the central tendencies of the following set of data

9, 10, 12, 13, 13, 13, 15, 15, 16, 16, 18, 22, 23, 24, 24, 25

Exercise-4: Determination of optimal sample size

Objective: To determine optimal sample size for studying an insect population.

Four common types of sampling plans
• Fixed sample size
• Sequential
• Variable-intensity
• Binomial

Fixed sample size

- The most common approach is to use a fixed sample size (e.g., "10"), although the optimal size can be calculated.
- Optimal sample size decreases as population density increases.
- Fewer samples should suffice at higher population densities.

Optimal sample size

There are several methods available to calculate the optimal sample size when using a fixed sample. It is crucial to ensure an accurate assessment of the population. However, calculation of the optimal size is often infrequent, possibly due to unfavorable results.

Calculating optimal sample size

Within a homogeneous habitat, the number of samples needed to estimate the mean accurately, assuming a standard error of 5% of the mean is calculated as follows:

$n = s^2 / Ex$

Where n is the number of samples,
s is the standard deviation,
E is the predetermined standard error as a decimal of the mean (in this case 0.05),
x is the mean.

Example-1: 6 counts of leaf tissue reveal 17, 15, 10, 18, 25 and 20 insects per leaf with standard error of 5% of the mean, find out the optimal size of the sample

S.N	x count in each sample	x-*x* count mean	$(x-x)^2$ differences squared
1	17	-0.5	
2	15	-2.5	
3	10	-7.5	
4	18	0.5	
5	25	7.5	
6	20	2.5	
Total	105		

Mean= $x = \sum x /$ total leaf=105/6=17.5

Variance= $\sum (x-x)^2 /$ (total leaf-1) =25.1

Standard deviation(s) =√variance=5.01

Note that as the sample size increases, the standard deviation decreases, resulting in reduced variability. This reduction in variability is crucial when comparing treatments or fields.

Therefore, optimal sample size is:
$\mathbf{n = s^2 / E\, x}$

Where **n** is the number of samples,
s is the standard deviation,
E is the predetermined standard error as a decimal of the mean (in this case 0.05),
x is the mean.
n = $5.01^2 / (5 \times 17.5)$
= $(5.01)^2/0.87$
= 330
Note that the optimal sample size increases as the standard deviation decreases to achieve a smaller predetermined standard error, necessitating more extensive sampling.

Sequential sampling

- Variable number of samples are taken.
- Samples are taken until the population can be classified, such as determining if treatment or control is needed.
- More sampling is conducted at intermediate levels for efficiency.
- In most cases, sequential sampling plans classify populations into two categories: requiring treatment or not.
- Additional details on calculating sequential sampling plans, including determining dividing lines, are available in most sampling texts.

Variable intensity sampling

- Modification of sequential sampling:
- Ensures that sampling covers the entire sampling universe broadly.
- Distributes sampling efforts evenly.

Binomial sampling:

- Records presence or absence and the proportion of infested or damaged samples.
- Does not involve counting the exact number of insects.

In cases involving insects like aphids, counting individual insects can be extremely challenging. It may be more practical to use a presence-absence approach, simply noting whether plants (or parts of plants like individual leaves) are infested.

Exercise-5: Testing the goodness of fit for insect population

Objectives:

- To investigate the goodness of fit for insect pest population data.
- The chi-square test (Snedecor and Cochran, 1989) determines whether a sample of data fits a specific distribution.
- One advantage of the chi-square goodness-of-fit test is its applicability to any univariate distribution with a known cumulative distribution function.
- The chi-square goodness-of-fit test analyzes binned data (data organized into classes).
- This requirement isn't restrictive as non-binned data can be converted into a histogram or frequency table for chi-square testing.
- The value of the chi-square test statistic, however, depends on how the data is grouped into bins.
- A drawback of the chi-square test is its dependence on a sufficient sample size for the chi-square approximation to be valid.
- The chi-square test provides an alternative to the Anderson-Darling and Kolmogorov-Smirnov tests for goodness of fit.
- It can also assess discrete distributions such as the binomial and Poisson distributions.

The Kolmogorov-Smirnov and Anderson-Darling tests are restricted to continuous distributions.

A chi-squared test (symbolically represented as χ^2) is essentially a method of data analysis that involves observing a random set of variables, typically comparing two statistical datasets. Introduced by Karl Pearson in 1900 for categorical data analysis and distribution, it is commonly referred to as Pearson's chi-squared test.

The chi-square test assesses the likelihood of observed data under the assumption that the null hypothesis is true.

A hypothesis is a proposition that a particular condition or statement could be true, subject to testing afterward. Chi-square tests typically involve summing squared deviations or errors relative to the sample variance.

The chi-squared test is done to check if there is any difference between the observed value and expected value. The formula for chi-square can be written as;

$$X^2 = \sum \frac{(Observed\ value - Expected\ value)^2}{Expected\ value}$$

or

$$X^2 = \sum \frac{(Oi - Ei)^2}{Ei}$$

Where, Oi is the observed value and Ei is the expected value.

Distribution of different insects in four locations

Insect orders	Location (Oi)				Total	Proportion			
	A	B	C	D	N=(A+B+C+D)	A=(Ax/nx)	B=(B/n)	C=(C/n)	D= (D/n)
1	17	23	4	42	86	0.20 (17/86)	0.27	0.05	0.49
2	25	12	17	16	70	0.36	0.17	0.24	0.23
3	43	34	34	45	156	0.28	0.22	0.22	0.29
4	56	53	23	35	167	0.34	0.32	0.14	0.21
5	34	23	55	12	124	0.27	0.19	0.44	0.10
Total(T)	175	145	133	150	603				

Calculation of the X^2 test on figure in Table 1[Ei=(N1/NT)xAT]

Insect orders	Expected number in location (Ei)				Oi – Ei				$(Oi – Ei)^2/Ei$			
	A	B	C	D	A	B	C	D	A	B	C	D
1	24.96	20.68	18.97	21.39	-7.96	2.32	-14.97	20.61	2.54	0.26	11.81	19.85
2	20.32	16.83	15.44	17.41	4.68	-4.83	1.56	-1.41	1.08	1.39	0.16	0.11
3	45.27	37.51	34.41	38.81	-2.27	-3.51	-0.41	6.19	0.11	0.33	0.00	0.99
4	48.47	40.16	36.83	41.54	7.53	12.84	-13.83	-6.54	1.17	4.11	5.20	1.03
5	35.99	29.82	27.35	30.85	-1.99	-6.82	27.65	-18.85	0.11	1.56	27.95	11.51
Total	175.00	145.00	133.00	150.00	0.00	0.00	0.00	0.00	5.01	7.64	45.12	33.50

DF= (No. of Row-1) x (No. of Column-1) = (5-1) x (4-1)=12
X^2 = 5.01+7.64+45.12+33.50= 91.28
The value of X^2 (91.28)

Using the table, the critical value for significance level with df = 12 lies between 21.03 and 32.91 (p=0.05-0.001)

The Chi-square statistic is 91.28, so the test results are significant.

Q (1).Calculate the X^2 test of the distribution of the insects

Insect orders	Location (Oi)				Total	Proportion			
	A	B	C	D	N=(A+B+C+D)	A=(Ax/nx)	B=(B/n)	C=(C/n)	D= (D/n)
1	20	17	23	4					
2	15	32	23	34					
3	33	41	25	30					
4	45	34	55	54					
5	17	45	37	47					
Total (T)									

Exercise- 6: Fitting Holling's Disc equation:

Objectives:

- Holling's disc equation is a method for calculating the functional response of predators to increased prey density.
- The equation is based on laboratory experimental data simulating predation.
- In theory, the efficiency with which the predator consumes the prey should decline as the prey density increases, due to extra time spent handling the prey.
- Thus the relationship between prey density and numbers consumed by predators is not a straight line but a curve.

This relationship was first summarized mathematically by C. S. Holling (1959) and He considered three types of functional response.

- ✓ In type I there is a linear relation between prey density and the maximum number of prey killed,
- ✓ In type II the proportion of prey consumed declines monotonically with prey density.
- ✓ In type III the proportion of prey consumed increases with prey density

The most frequently observed functional response is the 'type 2' response, in which consumption rate rises with prey density, but gradually decelerates until a plateau is reached at which consumption rate remains constant irrespective of prey density.
The type 2 response can be explained by noting that a predator has to devote a certain handling time to each prey item it consumes (i.e. pursuing, subduing and consuming the prey item, and then preparing itself for further search). As prey density increases, finding prey becomes increasingly easy.

The three basic components of the response of predators to the density of their prey (*D*) are:
(i) The instantaneous rate of discovery (*a*)
(ii) The time for which predator and prey are exposed (*T*)
(iii) The handling time per prey captured (*h*)

These form the basis of Holling's disc equation:
Y=N/T= a*D*/ (1+a*Dh*)
Where, *N*= number of prey taken by a predator in time *T*.
Y is consumption rate

Predator success rate *a* can be derived from the predation cycle, as it is the product of
(i) Encounter rate,
(ii) The probability that the predator detects prey it has encountered,
(iii) The probability that the predator attacks prey it has detected
(iv) Attack efficiency.

Similarly, predator handling time *h* is the sum of the time needed

(1) To capture a prey item (including time wasted for unsuccessful attacks)
(2) To consume a prey item
This equation describes a decelerating rate of increase of feeding rate to an asymptotic value as prey density increases and is based on the assumptions that a predator:
(i) Takes all the prey it encounters (i.e. there is no selectivity),
(ii) Searches randomly,
(iv The handling time required to kill and consume a prey item are constant and independent of prey density or feeding rate.

Q (1): Find out the consumption rate of the predator in each case

Case no.	No. of prey in a area (*D*)	Predator's instantaneous rate of discovery/ predator success rate (a) (minute)	Predator handling time/Time spent by a predator in handling a single prey (*h*) (minute)	Consumption rate of the predator (Y)
1	4	0.705	0.0439	2.51
2	9	0.675	0.0431	
3	16	0.799	0.0415	
4	25	0.757	0.0411	
5	49	0.739	0.0415	
6	81	0.634	0.0412	
7	100	0.720	0.0405	
8	256	0.762	0.0408	

In case no. 1
Y=N/T= a*D*/(1+a*Dh*)
a=0.705
D=4
h=0.0439

Exercise-7: Prey Predator interaction

Objective: To have an understanding of the predator prey interaction in an insect population.

Predator-prey models form the foundation of ecosystems. Many species depend on others as their primary food source, such as foxes and rabbits, lions and zebras, or ladybirds and aphids. In these interactions, one species (the predator) benefits while the other (the prey) is harmed.

A sound modeling approach begins with the simplest reasonable model and gradually introduces complexity as necessary. Instead of starting with the logistic model, we aim to grasp the dynamics of prey and predator populations through the simplest possible approach.

'Classic' predator-prey model

Let's consider two populations, denoted as x(t) and y(t), at a reference time t. Here, x represents the prey population, while y represents the predator population. The functions x and y are continuous and can denote population numbers, population density (number per unit area), or any other scaled measure of population sizes.

In absence of predator, prey population will increase:

$dx/dt = ax$ where $a > 0$

In absence of prey, predator population will decline:

$dy/dt = - cy$ where $c > 0$

These two populations interact and Lotka-Volterra factor in terms of 'xy' is included to each equation in the model:

$dx/dt = ax - byx = (a - by)x$ .... (i)

$dy/dt = - cy + dxy = (- c + dx)y$................................. (ii) $a, b, c, d > 0$

This is called coupled differential equation as we can't find explicit formula for x and y without knowing one.

N.B: The parameter 'a' represents the birth rate of prey, assuming no intraspecific competition. Prey mortality occurs solely due to predation, influenced by predator density multiplied by parameter 'b', indicating higher predator numbers lead to increased prey mortality. On the other hand, the birth rate of predators depends on prey density multiplied by parameter'd', reflecting the predator's capacity to prey upon the available prey. Parameter 'c' represents the simple death rate of predators.

The equilibrium solution:

dx /dt = 0 and dy/dt =0

So,

(x, y) = (0, 0) It is extinction

(x, y) = (c/d , a/b) It is coexistence

Examples:

1. Given the differential equation for Rabbit(R) and Fox (F) population:

dR/dt= 0.07R - 0.001RF

dF/dt= - 0.03F + 0.00003RF

a) Set the equilibriums

b) Find out the expression for the rate of change of foxes with respect to rabbits.

Solution:

a) In case of equilibrium,

R (0.07 – 0.001F) = 0

and

F (- 0.03 + 0.00003 R) = 0

Assuming that, neither R nor F is 0, we can say

0.07 – 0.001F =0

Or, 0.08 = 0.001F

Or, F = 0.07/0.001 = 70 foxes

Similarly,

R= 0.03/0.00003 = 1000 rabbits

b) $dF/dR = \dfrac{dF/dt}{dR/dt}$

$$= \frac{- 0.03F + 0.00003\ RF}{0.07\ R - 0.001\ RF}$$

Q (1). In a classic predator prey model, X represents prey population and Y represents predator population in a particular area. Time 't' is measured in months. The relationship between them is defined by the differential equation given below:

$dX/dt = 0.06 X - 0.002XY$

$dY/dt = - 0.03 Y + 0.00005 XY$

a) Find out the two points of equilibrium.

b) i. Explain what will happen to the prey population if there are no foxes?

ii. Explain what will happen to the fox population if there are no rabbits?

c) How to express the rate of change of foxes in relation to rabbits?

d) If at t=0, there are initially 3000 rabbits and 60 foxes

i. Calculate and say whether the population are increasing or decreasing?

ii. Estimate the population in 3 months using a step of 0.25

Exercise-8: Measure of niche breadth, niche overlap and diagrammatic representation of niches of organisms.

The niche of a species (or an individual) is the ultimate distributional unit, within which each species is held by its structural and instinctive limitation.
Niche is not simply the place where organism live but it is the sum total of all ecological requisites and activities of a species. It refers to the ways in which it interacts with its environment.

Objectives:
i. To compare the composition and organization of communities.
ii. To examine shifts in the behaviour or ecology of one species in response to another species. (In particular, niche shifts are commonly used to study interspecific competition, based on Gause's Principle of Competitive Exclusion).

Niche breadth

Depending upon the pattern of utilization and degree of specialization in resource use, behaviour, and physiology, species are categorised as generalist and specialist. Specialist species have narrow niches whereas generalist species have broad niches..

Levins (1966) measure of niche breadth is:

Breadth = $B = 1/\Sigma pi^2$

*p*i = proportion of individuals that use resource *i*, or the proportion of diet of each individual composed of *i*.

Because *p*i is in the denominator, species that use many resources will have large value of *B*, reflecting a generalist pattern of resource use.

Q (1). Calculate niche breadth (Levin's index)

Resource category	Species				Proportion for each species in each category				Proportion squared			
	A	**B**	**C**	**D**	***pi* (A)**	***pi* (B)**	***pi* (C)**	***pi* (D)**	**p_i^2 (A)**	**p_i^2 (B)**	**p_i^2 (C)**	**p_i^2 (D)**
i	4	3	7	1								
ii	8	0	0	4								
iii	6	18	8	5								
iv	3	5	2	3								
v	0	6	1	4								
vi	5	1	4	2								
vii	2	0	0	9								
Total												
Niche breadth = $B = 1/\sum p_i^2$												

Q (2). Calculating Niche overlap - Pianka's index

The parameter niche overlap is used to measures the degree to which two different species overlaps in their use of a particular resource. Estimating niche overlap is important to understand how different species partition resources in the community do.
However, estimating niche overlap and resource partitioning is of great importance when multiple species utilize same resources in similar ways forming a **guild**. In this case, they may influence each other's population growth through interspecific competition. Niche overlap can be measured in a variety of ways.

Measure developed by Pianka (1986)

O_{jk} =	$\sum p_{ij}p_{ik}/\sqrt{(\sum p_{ij}^2 \sum p_{ik}^2)}$

Resource category	**species**					
	product of the proportion for each species pair in each category					
	a*b	**a*c**	**a*d**	**b*c**	**b*d**	**c*d**
i						
ii						
iii						
iv						
v						
vi						
vii						
Totals						
O_{ij} (overlap)						

Exercise-9: Calculation of Biodiversity indices

A. Calculation of Alpha diversity:

Alpha diversity of the zone was quantified using Simpson's diversity Index (SDI) Shannon-Wiener index (H'), Margalef Index (α) and Pielou's Evenness Index (E1).

i. Calculation of relative abundance of the species:

Relative abundance (%) = (Number of individuals of one species/Number of individuals of all species) X 100.

ii.Gini-Simpson Diversity Index or Simpson Diversity Index (Simpson Index=D)

D= 1- (Pi) 2
D= diversity of species (range 0-1)
s = no. of species
Pi = proportion of total sample belonging to i-th species
D= 1-[{∑ (n*(n-1)}/ {(N*(N-1)}]
n =Number of individuals
N= Total number of individuals in the community.
Simpson's index is one of the most popular and robust ways to measure diversity in a community; as D increases, diversity increases. It measures the probability that two randomly selected individuals belong to different species.
Simpson's Diversity Index is a measure of diversity which takes into account the number of species present, as well as the relative abundance of each species. As species richness and evenness increase, so diversity increases.

iii. Shannon-Wiener index

Shannon-Wiener index (H') is another diversity index and is given as follows:

H' = – Σ Pi ln (Pi)

Where Pi = S/N;
S = number of individuals of one species,
N = total number of all individuals in the sample,
ln = logarithm to base e (Shannon & Wiener, 1949)
Benchmark value of species diversity index (Busniah 2019)

H' < 1.5 Low diversity
1.5 < H' < 3.5 Moderate diversity
H' > 3.5 High diversity

The higher the value of H' the higher the diversity.

iv. Margalef index

Species richness is calculated using the Margalef index which is given as

$$\alpha=(S-1)/\ln(N)$$

Where S = total number of species,
N = total number of individuals in the sample (Margalef, 1958).

v. Pielou's evenness index

Species evenness was calculated using the Pielou's Evenness Index (E1).

$$E1=H'/\ln(S);$$

Where H' = Shannon-Wiener diversity index,
S = total number of species in the sample (Pielou, 1966).
Benchmark value of evenness index according to Krebs value (Busniah 2019)

$E < 0.4$ Low diversity
$0.4 < E < 0.6$ Moderate diversity
$E > 0.6$ High diversity

As species richness and evenness increase, diversity also increases (Magurran, 1988).

Example-1:

Species	Number found	Pi	ln(Pi)	Pi*ln(Pi)	$(Pi)^2$	$\Sigma(n_i(n_i - 1))$	(N(N - 1))
1	84	0.3281	-1.114	-0.366	0.1077	6972	65280
2	4	0.0156	-4.159	-0.065	0.0002	12	
3	91	0.3555	-1.034	-0.368	0.1264	8190	
4	34	0.1328	-2.019	-0.268	0.0176	1122	
5	43	0.1680	-1.784	-0.300	0.0282	1806	
Total	256	1.0000		-1.366	0.280	18102	

Shannon diversity index

$H = -\sum[(Pi) * \ln(Pi)] =-1.366$

Gini-Simpson Diversity Index or Simpson Diversity Index

$D= 1-\Sigma(n_i(n_i - 1)) / (N(N - 1))= 1- (18102/65280) =(1- 0.277)= 0.723$

Or $D= 1- (Pi)^2= (1- 0.280) =0.720$

Hence, the community is diverse in nature and the probability that two randomly selected individuals belong to different species is 72%

Example-2:

Species	Number found	Pi	ln(Pi)	Pi*ln(Pi)	$(Pi)^2$	$\Sigma(n_i(n_i - 1))$	(N(N - 1))
1	40	0.160	-1.83	-0.29			
2	25	0.100	-2.30	-0.23			
3	20	0.080	-2.53	-0.20			
4	16	0.064	-2.75	-0.18			
5	44	0.176	-1.74	-0.31			
6	8	0.032	-3.44	-0.11			
7	13	0.052	-2.96	-0.15			
8	9	0.036	-3.32	-0.12			
9	4	0.016	-4.14	-0.07			
10	16	0.064	-2.75	-0.18			
11	32	0.128	-2.06	-0.26			
12	23	0.092	-2.39	-0.22			
Total	**250**			**-2.32**			

i. Shanon diversity index (H)= – Σ Pi ln (Pi) = 2.315

ii. Margalef Richness index: α=(S–1)/ln (N) = 1.992226362

iii. Pielou's Evenness index:

[Hmax= Log (No of spp)= Ln(12)= 2.4849]

Evenness= H/Hmax= 0.9319

Q (1). Calculate the Shannon diversity index, Gini-Simpson Diversity Index or Simpson Diversity Index, Margalef index and Evenness index with proper interpretation:

Species	Number found	Pi	ln(Pi)	Pi*ln(Pi)	$(Pi)^2$	$\Sigma(n_i(n_i - 1))$	(N(N - 1))
1	25						
2	84						
3	21						
4	9						
5	25						
6	11						
7	9						
8	23						
9	40						
10	15						
Total							

Beta (β) diversity is calculated by Sorensen's Coefficient of Community Similarity – where species in common

S_s= 2a / (2a+b+c)

S_s = coefficient of similarity (range 0-1)

a = no. of species common to both samples

b = no. of species in sample 1

c = no. of species in sample 2

Dissimilarity = D_S = b + c / 2a + b + c **Or** 1.0 - S_s

Example:

Species	Sample 1	Sample 2
1	1	1
2	1	0
3	1	1
4	0	0
5	1	1
6	0	0
7	0	0
8	1	0
9	1	1
10	0	0
11	1	1
12	0	0
	Total occurrences = b = 7 # joint occurrences = a = 5	Total occurrences = c = 5 # joint occurrences = a = 5

Sorensen's Coefficient

- S_s = (2 * 5) / (10 + 7 + 5) = 0.45 (45%)
- D_s = 1 – 0.45 = 0.55 (55%)

Q (2). Find out the Sorensen's Coefficient with proper interpretation:

Species	Sample 1	Sample 2
1	2	0
2	3	2
3	1	1
4	0	0
5	5	2
6	0	0
7	2	5
8	0	3
9	0	3
10	4	2
11	5	0
12	1	4
13	0	0
14	3	0

Exercise-10: Field visits

Date: ……………………………………………..
Type of ecosystem: …………………………………

Observation:

Date: ……………………………………………..
Type of ecosystem: …………………………………

Observation:

Date: ……………………………………………..
Type of ecosystem: …………………………………

Observation:

Date: ……………………………………………..
Type of ecosystem: …………………………………

Observation: