Practical Manual

INSECT ECOLOGY

ENT-504 3(2+1)

M.Sc. (Ag.) Entomology

Dr. Akshay Kumar
Dr. Ranjitha M. R.

2024

Department of EntomologyCollege of Agriculture
Chandra Shekhar Azad University of Agriculture & Technology, Kanpur-208002

Syllabus ENT-504 3(2+1): Practical

Types of distributions of organisms. Methods of sampling insects, estimation of densities of insects and understanding the distribution parameters- Measures of central tendencies, Poisson distribution, Negative Binomial Distribution. Determination of optimal sample size. Learning to fit basic population growth models and testing the goodness of fit. Fitting Holling's Disc equation, Assessment of prey-predator densities from natural systems and understanding the correlation between the two. Assessing and describing niche of some insects of a single guild. Calculation of niche breadth, activity breadth and diagrammatic representation of niches of organisms. Calculation of diversity indices- Shannon's, Simpson's and Avalanche Index and understanding their associations and parameters that affect their values. Problem solving in ecology. Field visits to understand different ecosystems and to study insect occurrence in these systems.

Name of Student ....

Roll No. ....

Session ....

Semester ....

Course Name : ....

Course No. : ....

Credit ....

CERTIFICATE

This is to certify that Shri./Km. ....ID No...................................

has completed the practical of course...course No. .... as per the syllabus of M.Sc. (Ag) Entomology .... semester in the year.....................in the respective lab/field of college.

Date: Course Teacher

Contents

Practical No. 01

Objective: Explore and understand the types of distribution patterns: random, clumped, and uniform.

Activity: Study the distribution pattern of insect pests in the CSAUAT agro-ecosystem.

Procedure: ....

....

....

....

....

....

....

....

....

....

....

Question 1: An ecologist studying pollination observes the frequency visits by bees to a flower bed. The sampling unit is a 1-minute interval and for 10 intervals following were the count of bees were as: 4, 6, 3, 3, 9, 4, 6, 2, 5, 2. How are the visits by bees dispersed?

Observations: ....

....

....

....

....

....

....

....

....

....

Interpretation: ……………………………………………………………………………………………………

……

……

……

Question 2: A biologist investigates the dispersion of the green-winged orchid in a meadow nature reserve. Twelve 1m x 1m quadrats (sampling units) are placed at random in the meadow and the numbers of vegetative basal rosettes are counted. The counts obtained are: 0, 0, 4, 2, 58, 1, 0, 22, 5, 7, 17, 1. How is the orchid dispersed in the meadow?

Observations: ……………………………………………………………………………………………………

……

……

……

……

……

……

……

……

……

Interpretation: ……………………………………………………………………………………………………

……

……

……

……

……

CHANDRA SHEKHAR AZAD UNIVERSITY OF AGRICULTURE AND TECHNOLOGY • KANPUR •

Practical No. 02

Objective: Understand the Life Table Analysis

Activities: Construct the life table for the following and draw the conclusion

Problem 1: A typical female of the shoot fly maggot lays 250 eggs. On average, 32 of these eggs are infertile and 64 are killed by parasites. Of the survivors, 64 die as larvae due to disease or parasites and 90 die as pupae due to desiccation. Construct a life table for this species and calculate a value for "R", the replacement rate (assume a 1:1 sex ratio). Is this population increasing, decreasing, or remaining stable?

	Stage	No. surviving	No. dying	Reasons		
1.	Egg			Infertile		
				Parasitized		
2.	Larvae			Disease/ parasites		
3.	Pupae			Desiccation		
4.	Adults					

Observations: ....

....

....

....

....

....

....

....

....

Interpretation: ....

....

....

....

....

Problem 2: The tobacco caterpillar female lays 500 eggs; on average 30 per cent of these eggs are infertile and 90 are killed by *Trichogramma* species. Of the surviving larvae 220 die due to viral disease, etc.; 60 per cent of the pupae could not emerge as adults due to some reasons, but in the absence of predators and parasitoids the remaining pupae emerge as healthy adults. Construct a life table for this species and calculate a value for "R", the replacement rate (assume a 1:1 sex ratio). Is this population increasing, decreasing, or remaining stable?

	Stage	No. surviving	No. dying	Reasons		
1.	Egg			Infertile		
				Parasitized		
2.	Larvae			Disease/ parasites		
3.	Pupae			Desiccation		
4.	Adults					

Observations: ………

……

……

……

……

……

……

……

……

……

Interpretation: ……………………………………………………………………………………………………

……

……

……

……

Life table analysis

Q1 (a): Analyze the life table and plot a graph to show the survivorship curve.

Years	n
0	530
1	159
2	80
3	48
4	21
5	5

Observations: ………

……

……

……

……

……

……

……

……

……

Interpretation: ……………………………………………………………………………………………………

……

……

………

………

Q1 (b): Analyze the life table and plot a graph to show the survivorship curve.

Years	n
1	1000
2	990
3	970
4	940
5	900
6	850
7	750
8	500
9	200
10	40
11	1
12	0

Observations: ………

………

………

………

………

………

………

………

………

………

Interpretation: ………

………

………

………

………

Q 2: Analyze cohort life table showing survival, fertility and population growth. Give your comments.

Age (x)	No. Surviving(Sx)	Fertility (mx or bx)
0	1000	0
1	900	4
2	250	3
3	10	2
4	0	0

Observations: ………

……

……

……

……

……

……

……

……

……

Interpretation: ………………………………………………………………………………………………………

……

……

……

……

Q 3: Cohort life table showing survival, fertility and population growth; analyze the given table and conclude.

Age (x)	No. Surviving	Fertility
0	1000	0
1	900	4
2	800	3
3	700	2
4	600	1
5	500	0

Observations: ………………………………………………………………………………………………………

……

……

……

……

……

……

……

……

……

Interpretation: ………………………………………………………………………………………………………

……

……

Practical No. 03

Objective: To understand about the pest survey and surveillance

Activities: Study about the pest survey and surveillance from different crop cafeteria

Procedure:……………………………………………………………………………………………………

Observation:……………………………………………………………………………………………………

CHANDRA SHEKHAR AZAD UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
KANPUR

Practical No. 04

Objective: To understand the methods of sampling, estimation of densities of insects, and understanding distribution parameters.

Activities: Collection of insect pests from different sampling methods

Procedure:……………………………………………………………………………………………

………

………

………

………

………

………

………

………

………

………

………

Observation:……………………………………………………………………………………………

………

………

………

………

………

………

………

………

………

………

………

………

………

………

………

………

………

………

Practical No. 05

Objectives: To study spatial distribution and minimum sample size for insect monitoring

Activities:

1) To study on Population density of insect pests in different crops.
2) To study on -Spatial distribution
3) To study the regression methods: Taylor's power law and Iwao's patchiness regression (IPR)

Procedure:…………………………………………………………………………

Observations:…………………………………………………………………………

CHANDRA SHEKHAR AZAD UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
KANPUR

Practical No. 6

Objective: Fit the basic population to growth models

Activities:

1. To study on exponential growth model in cereal or pulse crops in natural conditions
2. To study on logistic growth model in cereal or pulse crops in natural condition

Procedure:..

....

....

....

....

....

....

....

....

....

....

Observation:..

....

....

....

....

....

....

....

....

....

Practical No. 7

Objectives: To study about the goodness of fit for the insect pest population

Activities: To test the Chi-square test with the population of insect pests

Procedures:………

……

……

……

……

……

……

……

……

……

……

……

……

……

Observations:………………………………………………………………………………………………………

……

……

……

……

……

……

……

……

……

……

……

……

……

……

……

……

……

……

Practical No. 8

Objective: To study about predator-prey interactions with the Lotka-Volterra model

Activates:

1. To study on prey-predator interaction in cereal crop.
2. To analyses Lotka-Volterra model between aphid and *Coccinella* species.

Procedures:……………………………………………………………………………

Observations:……………………………………………………………………………

Practical No. 9

Objectives: To study on assessing and describing ecological niche

Activities: To study assessing and describing ecological niche based on insect populations in cereal crops.

Procedures:……………………………………………………………………………………………

………

………

………

………

………

………

………

………

………

………

………

………

………

………

………

Observations:…………………………………………………………………………………………

………

………

………

………

………

………

………

………

………

………

………

………

………

………

………

………

Practical No. 10

Objective: To study and assess the insect diversity in crops

Activities:

1. To study the Shannon Index and Simpson Index of insect population in cereal crops.
2. To calculate the similarity index between two insect population of two different ecosystems.

Procedures:………

………

………

………

………

………

………

………

………

………

………

………

Q 1. In the Simpson index, p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), Σ is still the sum of the calculations, and s is the number of species.

S. No.	Order	Insect species	No. of individuals (n)	n/N	pi	p_i^2	ln pi	pi ln pi

Observations: ………

………

………

Interpretation:………

………

………

………

………

………

………

………

………

………

………

Practical No. 11

Objective: To study the Functional and Numerical Responses through Holling's Equation.

Activities: Calculations on Hollings equations.

Procedures:………

……

……

……

……

……

……

……

……

Q. 1 Study on the functional response of Reduviid bug over a 6-day period of exposure with its prey at different densities from 1 to 16, each treatment replicated 6 times. Using the Disc equation of Holling: Y' = a * (Tt – bY) * X

Where, X = prey density; Y = total number of prey killed over a given period of time (Tt); Y/ X = attack ratio; Tt = total time in days when prey was exposed to the predator; b = time spent in handling each prey by the predator; a = rate of discovery per unit of searching time (Y/ X/ Ts).

Summary of analyzing the functional response (Y') of Reduviid bug at different prey densities for 6 days

X Prey density	Y Prey attacked	Max. Y (k)	Days/ k b = Tt/ k	bY	Days searching Ts =Tt –bY	Attack ratio Y/X	(Y/X) /Ts	Disc Equation
1	1							
2	1.92							
4	3.5							
8	5.49							
16	9.66							

Observations: ………

……

……

……

……

……

……

……

……

……

……

Interpretation:………

……

……

……

……

……

……

……

……

……

Q. 2 Analyze the given summary table of feeding *Pterophorus lienigianus* Z as prey by a Reduviid bug exposed for 6 days. Establish the linear regression between prey density and prey attacked; prey density and attack ratio; prey density and searching time and depict them as graphs showing the trend line with values of co-efficient of correlation/ co-efficient of determination.

Summary table of functional response (Y') parameters of Reduviid bug with prey

X Prey density	Y Prey attacked	Max. Y (k)	Days/ k b = Tt/ k	bY	Days searching Ts =Tt –bY	Attack ratio Y/X	(Y/X) /Ts	Disc Equation
1	0.92 + 0.09							
2	1.67 + 0.17							
4	3.05 + 0.33							
8	4.75 + 0.75							
16	7.55 + 0.82							

Observations: ……………………………………………………………………………………………

……

……

……

……

……

……

……

……

……

……

Interpretation:…………………………………………………………………………………………

……

……

……

……

……

……

……

……

……

Practical No. 12

Objective: To understand about the Pest forecasting

Activities: Study on insect pest forecasting in mustard.

Procedures:…………………………………………………………………………………

…………………………………………………………………………………

Observations:…………………………………………………………………………………

…………………………………………………………………………………

Practical No. 13

Objective: To understand Liebig's Law of Minimum

Activity: To study about the application of the law in insect ecology

Procedures:………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

Observations:………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

………………………………………………………………

Practical No. 14

Objective: To understand Shelford's Law of Tolerance

Activity: To study about the application of the law in insect ecology

Procedures:……………………………………………………………………………………………

Observations:……………………………………………………………………………………………

CHANDRA SHEKHAR AZAD UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
KANPUR

Practical No. 15

Objective: To study about the analyzing frequencies I

Activity: To solve the problems of analyzing frequencies I

Procedures:……………………………………………………………………………………

Q 1: A biologist collects a sample of dipteran (*Dixella* sp.) pupae from emergent vegetation from a pond. Based on the pupal characters the biologist could identify four species in the pond. Is the distribution of frequencies among the species/categories homogeneous? The observations taken were as:

D. autumnalis	***D. aestivalis***	***D. amphibian***	***D. attica***	**Total**
24	32	10	9	75

Interpretation:……………………………………………………………………………………

Observations:……………………………………………………………………………………

Example 2: In a sampling for chironomid larvae from the benthic zone of a pond, 16 nudge larvae were collected, then the larvae were reared to adults, which comprise 12 males and 4 females. We need to test whether the male: female ratio is 1: 1 or there is a departure from unity.

Interpretation:……………………………………………………………………………………

……

……

……

Observations:……………………………………………………………………………………………………

……

……

……

……

……

……

……

……

……

Q 3: A biologist collects leaf litter from a 1-square metre quadrat placed randomly at night on the ground in two woodlands – woodland with clay soil and another with chalk soil. The biologist sorts through the litter and collects woodlice (Isopoda) of 2 species, *Oniscus* and *Armadilidium*. Find out as to which type of woodland is preferred by which species of woodlice?

Table: Frequency of woodlice in different woodlands

Species/ Woodland & soil type	*Oniscus*	*Armadilidium*	Totals
Clay soil	14	06	20
Chalk soil	22	46	68
Totals	36	52	88

Interpretation:……………………………………………………………………………………………………

……

……

……

……

……

……

Observations:……………………………………………………………………………………………………

……

……

……

……

……

……

……

……

Objective: To study about the analyzing frequencies II

Procedures:………

……

……

……

……

Q 1. Grasshopper species of the genus *Hieroglyphus* are well known pests of paddy, maize, sorghum, millets and sugarcane. Analyze the association of grasshopper species with the crops surveyed and give your comments.

Crops	**Numbers of Grasshopper Species Collected from Crops Surveyed**			
	H. nigrorepletus	***H. banian***	***H. annulicornis***	***H. oryzivorous***
Maize	25	07	05	13
Sorghum	30	02	06	12
Sugarcane	06	26	04	02
Paddy	05	28	12	15

Interpretation:……………………………………………………………………………………………………

……

……

……

……

Observations:……………………………………………………………………………………………………

……

……

……

……

……

……

……

……

Q 2. Meniscus midges of the genus *Dixa* are found in running water and are indicators of surface pollutants (oil, hydrophobic chemicals, etc.). The mobile larvae pupate independently on emergent stones, vegetation, etc. where they may be collected. A biologist investigating habitat preferences of four species of *Dixa* obtains randomly pupae from three streams of different degrees of eutrophication (oligotrophic, mesotrophic and eutrophic).

Table: Frequency of meniscus midges of the genus *Dixa*

Sites	***D. nebulosa***	***D. submaculata***	***D. dilatata***	***D. nubilipennis***	**Totals**
1: Oligotrophic	12	07	05	17	41
2: Mesotrophic	14	06	22	09	51
3: Eutrophic	35	12	7	11	65

Totals	61	25	34	37	157

Interpretation:………

………

………

………

………

Observations:………

………

………

………

………

………

………

………

………

………

Q 3. A biologist investigating the population dynamics of feather lice (Mallophaga) obtains samples from native birds in July and September. Lice are sorted into age-classes corresponding to 1st, 2nd, 3rd instar nymphs and adults. The frequencies are, respectively, 38, 70, 32, 70 in July and 4, 22, 11, 42 in September. Is there a statistically significant difference between the proportions of the age-classes in the two samples? Use the G-test to analyse

Interpretation:………

………

………

………

………

………

Observations:………

………

………

………

………

………

………

………

………

………

………

………

Practical No. 17

Objective: To study the Biodiversity in agro-ecosystem.

Activity: To analyze the recorded data from collection from the light trap

Procedures:……

………

………

………

………

………

………

………

………

………

………

Observations:……………………………………………………………………………………………………….

………

………

………

………

………

………

………

………

………

………

………

………

………

………

………

………

………

………

………

………

Practical No. 18

Objective: To study the Biodiversity in agro-forest ecosystems.

Activity: To analyze the recorded data from collection from the trap

Procedure:………

……

……

……

……

……

……

……

……

……

……

Observations:………………………………………………………………………………………………………

……

……

……

……

……

……

……

……

……

……

……

……

……

……

……

……

……

……

……

……

……

CHANDRA SHEKHAR AZAD UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
KANPUR

ROUGH WORK

Appendix

Life Table Analysis: A **"life table"** is a kind of **bookkeeping system** that ecologists often use to keeptrack of stage-specific mortality in the populations they study. It is an especially useful approach in entomology where developmental stages are discrete and mortality rates may vary widely from one life stage to another. From a pest management standpoint, it is very useful to know when (and why) a pest population suffers high mortality -- this is usually the time when it is most vulnerable. By managing the natural environment to maximize this vulnerability, pest populations can often be suppressed without any other control methods.

To create a life table, an ecologist follows the life history of many individuals in a population, keeping track of how many offspring each female produces, when each one dies, and what caused its death. After amassing data from different populations, different years, and different environmental conditions, the ecologist summarizes this data by calculating average mortality within each developmental stage.

Example: In a hypothetical insect population, an average female lays 200 eggs before death. Half of these eggs (on average) are consumed by predators, 90 per cent of the larvae die dueto parasitization or predation and three-fifths of the pupae die due to desiccation or disease (these numbers are averages, but they are based on a large database of observations). Thedata has been tabulated below:

Development Stage	Number Alive	MoralityFactor(s)	NumberDying	Percent Morality
Egg	200	Predation	100	50
Larva	100	Parasitization	90	90
Pupa	10	Freezing	6	60
Adult	4	(2 females and 2 males if sex ratio is 1:1)		

The table above shows a **cohort** of 200 eggs (the progeny of female born at the same time) represents the maximum **biotic potential** of the species (*i.e.* the greatest number of offspring that could be produced in one generation under ideal conditions).

The first line of the life table lists the main cause(s) of death, the number dying, and the percent mortality during the **egg stage**. In this example, an average of only 100 individuals survives the egg stage and become larvae.

The second line of the table lists the mortality of these 100 larvae: only 10 of them survive to become pupae (90% mortality of the larvae).

The third line of the table lists the mortality experience of the 10 pupae - three-fifths ($3/5^{th}$) die of disease or other reasons. This leaves only 4 individuals alive in the adult stage to reproduce. Assuming a 1: 1 sex ratio, 2 males and 2 females will start the next generation.

$$R = \frac{\text{Number of daughters}}{\text{Number of mothers}}$$

$$R = \frac{2}{1} = 2 \text{ (doubling)}$$

If these females do not die, they will each lay an average of 200 eggs to start the next generation. Thus, there are two females in the cohort to replace the one original female—this population doubles in size each generation!!

In ecology, the symbol **"R"** (capital R) is known as the **replacement rate**. It is a way to measure the change in reproductive capacity from generation to generation. The value of **"R"** is simply the number of reproductive daughters that each female produces over her lifetime:

- If the value of "R" is less than 1, the population is decreasing -- if this situationpersists for any length of time the population becomes extinct.
- If the value of "R" is greater than 1, the population is increasing -- if this situation persists for any length of time the population will grow beyond the environment's carrying capacity. (Uncontrolled population growth is usually a sign of a disturbed habitat, an introduced species, or some other type of human intervention.)
- If the value of "R" is equal to 1, the population is stable -- most natural populationsare very close to this value.

Survey: Involves systematically collecting data on pest presence, distribution, and population density in a specific area. Surveys are often done periodically or in response to specific concerns, such as crop damage or pest outbreaks. They help in identifying problem areas and guiding control measures.

Pest Surveillance: Continuous monitoring of pest populations over time, often using traps, sensors, and field observations. Surveillance is proactive, aiming to detect changes in pest levels early and prevent outbreaks. It supports timely interventions and long-term pest management strategies.

Objectives of Pest Surveillance

- ✓ Identify emerging pest populations before they cause significant damage.
- ✓ Track pest population trends over time to understand fluctuations and potential risks.
- ✓ Evaluate how well pest management strategies (e.g., pesticides, biological controls) are working.

- ✓ Provide data to inform decisions on when and where to apply control methods for maximum efficiency.
- ✓ Minimize crop damage and associated costs by addressing pest issues early.
- ✓ Contribute to long-term, sustainable pest management strategies by providing critical data.
- ✓ Help reduce unnecessary pesticide use and promote safer, more targeted pest control practices.
- ✓ Ensure adherence to national and international pest management and biosecurity standards.
- ✓ Provide real-time data to improve pest control technologies and strategies.

Kinds of survey: All insect pests' surveys attempt to asses some characteristics of the insect life systems, depending upon them the type of survey. Broadly divided in to two groups;

Qualitative survey: This survey is important to study the interactions of herbivores and carnivores, and their relationship with the vegetation of the region. Here the primary concern firstly relates to the herbivores which act as pests of the crops as well as on the alternate hosts among the wild vegetation (weeds) e.g., Army worm *Mythimna separate*, which survives on Jhonson grass *Sorghum halepense*; and on Burmuda grass when the crops are not standing on the fields. It is a pest of graminaceous foliage whorl, particularly, paddy and sugarcane. Within the last decades it hasstarted attacking ear heads of rice cultivars, now it has acquired new name as ear head cutting caterpillar.

Quantitative survey: Quantitative surveys estimating the abundance and population densities ofinsect in cropping systems. There are two types of measuring

- ✓ **Absolute estimates**
- ✓ **Relative estimates Methodology for surveillance**

Fixed plot survey:

- ✓ Two fields of about one acre in size are selected in two different villages in the jurisdiction ofeach agricultural officers.
- ✓ Five micro plots each of the size of one squire meter area are fixed in each field.
- ✓ These micro plots are laid one each in four quarters of the field and one in the middle.
- ✓ The micro plots should be fixed about 10 meters away from the bunds.
- ✓ The observations for most of the pests are confined to five micro plots in each field.

Roving survey:

- ✓ The roving survey is conducted every week at the rate of two fields in each of four villages in the in the jurisdiction of each agricultural officers (T & V).
- ✓ The reports involved in the surveillance programme are of three kinds.
- ✓ **White card report or Normal report:** This is a weekly report in which pest and disease situations are reported regularly.
- ✓ **Yellow card report:** This is a special reporting system whichever pest or diseases is noticedat 50% of the economic threshold level but still not attained ETL status. The information is immediately passed on altering the Joint Director of Agriculture (T&V), his subject matter specialist and the scientists.
- ✓ **Red card report:** This reporting system is adopted when a pests or disease has reached the critical economic threshold level where immediate action programme has to be launched for controlling the pests or diseases.

Sampling: Where the population is too large or hypothetical, the investigator has to obtain information about the population from a part thereof "The selection of a part of the population to represent the whole population is known as sampling and the part selected is known as sample". Sampling requires a representative part of the total population and base our estimate on that part.

Objectives of sampling:

- ✓ Identifying & monitoring pests & natural enemies
- ✓ Understanding biological & environmental factors that affect pests & natural enemies
- ✓ Using treatment threshold for control decisions
- ✓ Knowing efficacy of control tactics & impact on non-target pests & natural enemies

Measurements taken to estimate population density (sampling methods) fall into three groups

- ✓ Absolute methods
- ✓ Relative methods
- ✓ Population indices

Absolute methods

(i) Distance of the nearest neighbor (pest)
(ii) Sampling a unit of habitat
(iii) Recapture of marked individuals from population in a field
(iv) Removal trapping method

Relative methods

1. **Impaction or sticky trap method:** Insects are trapped in flight on a surface coated with long-lasting glue. Using attractive colours increases the effectiveness of such traps. The selection of colour depends on the insect to be collected/ sampled. Usually used as a monitoring device. The trap catches are affected by weather conditions and by the position and height of the trap in the field. Sticky traps are useful to sample thrips, aphids, whiteflies, etc.

2. **Light traps:** A light trap usually comprises an electric bulb as an attractant, and a funnel to direct attracted insects into a container or collecting bag. Many insects are attracted to light in thenear ultraviolet region (320-400 nm.), hence ultraviolet lamps are often used. Rapid kill of the specimens is often necessary to have good specimens for examination. Temperature, wind speed, rain, cloudy weather, moonlight and open and woodland situations affect the trap catches.Light traps have been used to capture lepidopterans.
3. **Malaise trap:** The trap is a netting tent with one open side into which is placed a small container at the highest point. Insects flying or crawling through the opening, move up the nettingand are collected in the container. These traps have been useful in the study of highly active Diptera and Hymenoptera, besides, Coleoptera, Lepidoptera and Planipennia.
4. **McPhail trap:** It is a simple invaginated glass trap, which is used principally to sample Diptera. Recent efforts have been made to improve the trap by using new yellow coloured, robust PVC bottle that increases the number of catches.
5. **Pheromone trap:** Pheromone traps are generally species-specific. Sex pheromone of female insects can attract males over long distances and have been used for monitoring pest populations. A typical pheromone trap is delta-shaped, open at both ends and protects a horizontally placed sticky trap. A sealed polyethylene vial containing the pheromone is placed upright on the sticky trap and acts as a slow release mechanism for the chemical. Speed and direction of wind, height of crop, relative to the trap and adhesive used affect the trap collection. Pheromone traps have been used to monitor Lepidoptera, but also find use for other insects such as Hymenoptera.
6. **Radar:** Entomological radars are usually small, mobile, incoherent pulse systems, which use awavelength of 3.2 cm. These radars transmit short impulses from their antennae in a narrow, conical beam. Objects illuminated by the pulse reflect or scatter the pulse energy returning part ofthe scattered energy to the radar. The echo is detected and amplified at the radar receiver and the presence of the target displayed. Insects of around 100 mg can be detected using this method up to 2.5 km. Other sorts of radar of interest in entomology include ground-based scanning radar, airborne radar, tracking radar, frequency-modulated continuous wave radar, harmonic radar andbistatic and doppler radars.
7. **Suction traps:** Suction traps consist of machines with engine driven fans which suck insects into a fine mesh net, filtering out the insects which can then be collected in a container. Traps maybe fitted with a segregating device to separate the catch according to time, thus providing information on the periodicity of flight. They can be mobile or fixed. Originally, they were designed to sample aphids and other aerial pests of agricultural crops.
8. **Water traps:** Yellow water traps, also known as yellow pan traps have been used to sample awide range of insect species including thrips, aphids and cabbage root fly. The traps are moreeffective if raised above ground and the catch efficacy increases if vertical baffles are placed inthe trap. Use of a small amount of detergent or volatile chemicals in the water increases thecatch. Ethyl nicotinate has been used with success. Painting the inner wall of the trap blackimproves the catch and at the same time spares the collection of beneficial insects.

Study area: A study conducted in student's instructional form, CSAUAT, Kanpur. The orchard was at an altitude & a latitudeand longitude of -° N and -° E, respectively, and was sampled twice monthly from the beginning of crop season until the end of the season. Choose any five spots from each cultivar, almost uniform and similar in sowing time, size, height, vegetative growth, etc. These randomly chosen crop plants did not receive any pesticidal control before and during the period of the study. Regular bimonthly collected the samples as per observation (specific instructions) per plant is randomly picked from the target site. Every sample will be place in a container; all samples were transferred to the laboratory for inspection using a stereo- microscope. The total numbers of live insects (nymphs and adult females) will counted and recorded, linkedto the inspection date, and presented as mean number of individuals per leaf ± standard error (SE), to express the population size of pest.

Distribution indices: Several estimates are based on sample means and variances, such as index of dispersion, clumping,crowding and Green's index (Green, 1966).

- **Mean ($\bar{X}$):** The mean number of individuals as a general average per leaf during the whole year.
- **Range of means of a population:** The difference between the maximum mean number of a population and the minimum for the whole year was calculated by applying the following equation:
- **Range of Density (R)** = Population density maximum – Population density minimum during the entire year.
- Variance (S^2), standard deviation (S), standard error (SE) and median (Me) for samples were determined.
- **Coefficient of variance (C.V.):** To assess the fidelity of sampling, the coefficient of variation values for the studied years were compared

$$C.V. = \frac{S}{\bar{X}} x\ 100$$

Where, S is the standard deviation of the mean and X is the mean of population.

- Relative Variation (R.V.) is employed to compare the efficiency of various sampling methods (Hillhouse and Pitre, 1974). The relative variation for the studied years was calculated as follows:

$$R.V. = \frac{SE}{\bar{X}} x\ 100$$

Where SE is the standard error of the mean and X is the mean of population. - Variance to mean ratio (S_2 / X): The simplest approach used for determining the insect distribution was variance to mean ratio suggested by Patil and Stiteler (1974). The value of variance-to-mean is one for 'Poisson' distribution, less than one for positive binomial and more than one for negative binomial distribution. Dispersion of a population can be classified through a calculation of the variance-to-mean ratio; namely: S2 / X = 1 random distribution, < 1 regular distribution, and > 1 aggregated distribution (where, S_2 = sample variance; X = mean of population).

1. Exponential growth model: Malthus' model, once population size exceeds available resources, population growth decreases dramatically. This accelerating pattern of increasing population size is called exponential growth, meaning that the population is increasing by a fixed percentage each year. When plotted (visualized) on agraph showing how the population size increases over time, the result is a J-shaped curve.

G= r x N OR ***dN/dt = r x N;*** In these equation

- G (or dN/dt) is the population growth rate, it is a measure of the number of individuals added pertime interval time.
- 'r' is per capita rate of increase (the average contribution of each member in a population to population growth; per capita means "per person").
- 'N' is the population size, the number of individuals in the population at a particular time.

Per capita rate of increase (r): In exponential growth, the *population growth rate* (*G*) depends on population size (*N*) and the per capita rate of increase (*r*). In this model *r* does not change (fixed percentage) and change in population growth rate, *G*, is due to change in population size, *N*. As new individuals are added to the population, each of the new additions contribute to population growth at the same rate (*r*) as the individuals already in the population.

r= (birth rate + immigration rate) – (death rate and emigration rate)

- ✓ If r is positive (> zero), the population is increasing in size; this means that the birth and immigration rates are greater than death and emigration.
- ✓ If r is negative (< zero), the population is decreasing in size; this means that birth & immigration rates are less than death and emigration rates.
- ✓ If r is zero, then the population growth rate (G) is zero and population size is unchanging, a condition known as zero population growth. "r" varies depending on the type of organism, for example a population of bacteria would have a much higher "r" than an elephant population. In theexponential growth model r is multiplied by the population size, N, so population growth rate is largely influenced by N. This means that if two populations have the same per capita rate of increase (r), the population with a larger N will have a larger population growth rate than the onewith a smaller N.

2. Logistic Growth model: Exponential growth cannot continue forever because resources (food, water, shelter) will becomelimited. Exponential growth may occur in environments where there are few individuals and plentiful resources, but soon or later, the population gets large enough that individuals run out of vital resources such as food or living space, slowing the growth rate. When resources are limited, populations exhibit **logistic growth**. In logistic growth a population grows nearly exponentially at first when the population is small and resources are plentiful but growth rate slows down as the population size nears limit of the environment and resources begin to be in short supply and finally stabilizes (zero population growth rate) at the maximum population size that can be supported by the environment (**carrying capacity**). This results in a characteristic S-shaped growth curve. The mathematical function or logistic growth model is represented by the following equation:

$$G = r \times N \times (1 - N/K)$$

where, (K) is the **carrying capacity** – the maximum population size that a particular environment can sustain ("carry").

Goodness of Fit: Use chi-square or other statistical methods to determine how well the models fit observed data.

- ✓ The chi-square test (Snedecor and Cochran, 1989) is used to test if a sample of data came from apopulation with a specific distribution.
- ✓ An attractive feature of the chi-square goodness-of-fit test is that it can be applied to any univariate distribution for which you can calculate the cumulative distribution function.
- ✓ The chi-square goodness-of-fit test is applied to binned data (i.e., data put into classes).
- ✓ This is actually not a restriction since for non-binned data you can simply calculate a histogram or frequency table before generating the chi-square test.
- ✓ However, the value of the chi-square test statistic are dependent on how the data is binned.
- ✓ Another disadvantage of the chi-square test is that it requires a sufficient sample size in order forthe chi-square approximation to be valid.
- ✓ The chi-square test is an alternative to the Anderson-Darling and Kolmogorov-Smirnov goodness- of-fit tests.
- ✓ The chi-square goodness-of-fit test can be applied to discrete distributions such asthe binomial and the Poisson.

The Kolmogorov-Smirnov and Anderson-Darling tests are restricted to continuous distributions. The chi-square test is defined for the hypothesis:

H_0: The data follow a specified distribution

H_a: The data do not follow the specified distribution

Test Statistic: For the chi-square goodness-of-fit computation, the data are divided into k bins and the test statistic is defined as

$$X^2 = \sum_{i-1}^{k} \frac{(Oi - Ei)^2}{Ei}$$

where, Oi is the observed frequency for bin i and Ei is the expected frequency for bin i. The expected frequency is calculated by

$$E_i = [(Yu) - (Yl)]$$

where, F is the cumulative distribution function for the distribution being tested, Yu is the upper limit for class i, Yl is the lower limit for class i, and N is the sample size.

This test is sensitive to the choice of bins. There is no optimal choice for the bin width (since the optimal bin width depends on the distribution). The Most reasonable choices should produce similar, but not identical, results. For the chi-square approximation to be valid, the expected frequency should be at least 5. This test is not valid for small samples, and if some of the counts are less than five, you may need to combine some bins in the tails.

Significant level: α

Critical region: The test statistic follows, approximately, a chi-square distribution with (k - c) degrees of freedom where k is the number of non-empty cells and c = the number of estimated parameters (including location and scale parameters and shape parameters) for the distribution + 1. For example, for a 3-parameter Weibull distribution, c = 4.

Therefore, the hypothesis that the data are from a population with the specified distribution is rejected if $\chi^2 > \chi^2_{1-\alpha, k-c}$ where $\chi^2_{1-\alpha, k-c}$ is the chi-square critical value with k - c degrees of freedom and significance level α.

Predator-prey interactions with Lotka-Volterra model

- ✓ Lotka-Volterra model is the simplest model of predator-prey interactions.
- ✓ The model was developed independently by Lotka (1925) and Volterra (1926).
- ✓ Initially proposed by Alfred J. Lotka in the theory of autocatalytic chemical reactions in 1910.
- ✓ In 1925 he used the equations to analyse predator– prey interactions in his book onbiomathematics.
- ✓ Volterra's enquiry was inspired through his interactions with the marine biologist Umberto D'Ancona, his son-in-law.
- ✓ The Lotka–Volterra equations, also known as the predator–prey equations, are a pair of first order nonlinear differential equations.
- ✓ Frequently used to describe the dynamics of biological systems in which two species interact,one as a predator and the other as prey.

Assumptions:

1. The prey population finds ample food at all times.
2. The food supply of the predator population depends entirely on the size of the prey population.
3. The rate of change of population is proportional to its size. During the process, the environment does not change in favour of one species, and genetic adaptation is inconsequential.
4. Predators have limitless appetite.

Lotka–Volterra equations: Prey equation: $dx/dt = \alpha x - \beta xy$

Predator equation: **$dy/dt = \delta xy - \gamma y$**

x is the number of prey
y is the number of some predator
dx/dt and dy/dt represent the instantaneous growth rates of the two populations;
t represents time;
α, β, γ, δ are positive real parameters describing the interaction of the two species

Prey equation: dx= αx/dt -βxy

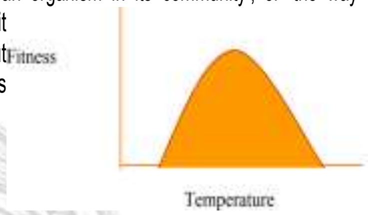
- ✓ The prey are assumed to have an unlimited food supply and to reproduce exponentially, unless subject to predation
- ✓ This exponential growth is represented in the equation above by the term αx.
- ✓ Rate of predation upon prey is assumed to be proportional to rate at which thepredators and the prey meet, this is represented above by Qxy.
- ✓ If either x or y is zero, then there can be no predation.

Predator equation: dy = δxy/dt – γy

In this equation, δxy represents the growth of the predator population.

- ✓ Note the similarity to the predation rate; however, a different constant is used, as the rate at which the predator population grows is not necessarily equal to the rate at which it consumes the prey.
- ✓ γy represents the loss rate of the predators due to either natural death or emigration, it leads toan exponential decay in the absence of prey.

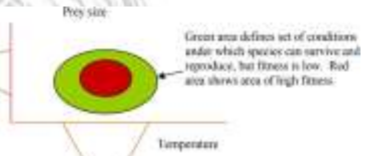
Ecological Niche: 'The total of the adaptations of an organismic unit'. Niches identify the 'role of an organism in its community', or 'the way a species makes its living'. The niche of a species (or an individual) refers to the ways in which it interacts with its environment, so niches are closely related to environmental tolerance curves, but niches can have behavioral dimensions (e.g., method of locomotion - running, swimming, flying) as well environmental ones (e.g., temperature limits).



Data on niches can be used to:

a. Make comparisons of the composition and organization ofcommunities.
b. Examine shifts in the behavior 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).

Hutchinson's model of niche as a 'hyper volume': Niches can be described or defined by relating fitness or utilization to environmental variable (abiotic and biotic)



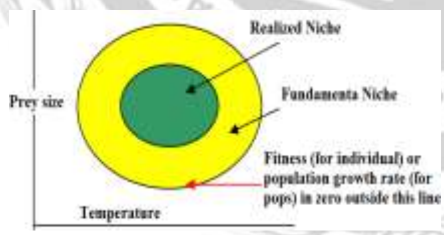
Start with a tolerance curve for one environmental variable and a second variable that affects the animal's fitness.

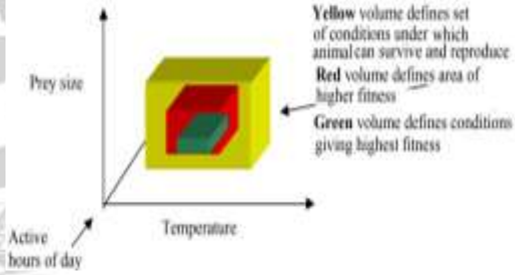
Then add a third variable that affects the animal's fitness:

If we then add a fourth axis (and onward), the result is a hyper volume - a range if conditionsdefines by many axes, which defines the set of conditions under which the animal can survive and reproduce. Can refine to show 'fitness density' (as in 2-d example).

Hyper volume idea is good for illustration, but remember: Not all niche axes are environmental - some niche axes are behavioral (e.g. nocturnal vs diurnal activity pattern) not all axes can be ordered linearly (e.g types of anti-predator behavior), so they don't lend themselves to this graphical approach.

Fundamental *vs* Realized Niche: It is the entire set of conditions under which an animal (population, species) can survive and reproduce itself. Realized niche is the set of conditions actually used by given animal (pop, species), after interactions with other species (predation and especially competition) have been taken into account. Sometimes FN and RN are termed precompetitive and post competitive niches, reflecting a traditional focus on interspecific competition's effect on niches.





The assessment insect diversity in crops.

Diversity Indices:

1. A diversity index is a mathematical measure of species diversity in a given community.
2. Based on the species richness (the number of species present) and species abundance (thenumber of individuals per species).
3. The more species you have, the more diverse the area, right?
4. However, there are two types of indices, dominance indices and information statistic indices.
5. The equations for the two indices we will study are:

Shannon Index: $$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Where, S is the number of species. Also called species richness, pi is the relative abundance of each species, calculated as the proportion of individuals of a given species to the total number of individuals in the community: ni/N, ni is the number of individuals in each species; the abundance of each species and N is the total number of all individual

$$D = 1 - \frac{\sum_{i=1}^{S} n_i(n_i - 1)}{N(N-1)}$$

Simpson index (D):

Where: S is the number of species, N is the total percentage cover or total number of organisms and ni is the percentage cover of a species or number of organisms of species i.

The Shannon index is an information statistic index, which means it assumes all species are represented in a sample and that they are randomly sampled. Can you point out any problems in these assumptions? In the Shannon index, p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), ln is the natural log, Σ is the sum of the calculations, and s is the number of species. The Simpson index is a dominance index because it gives more weight to common or dominantspecies. In this case, a few rare species with only a few representatives will not affect the diversity and point out any problems in these assumptions?

Community Similarity

1. Calculating community similarities (what the communities have in common in terms ofspecies) helps us determine if we are comparing apples to apples and oranges to oranges.
2. There are many indices that do this, we will use Sorenson's coefficient.
3. Sorenson's coefficient gives a value between 0 and 1, the closer the value is to 1, the more the communities have in common.

   Complete community overlap is equal to 1; complete community dissimilarity is equal to 0.

The equation is: Sorenson's Coefficient (CC) = 2C/ S1+S2

Where C is the number of species the two communities have in common, S1 is the total numberof species found in community 1, and S2 is the total number of species found in community 2

Functional and Numerical Response

Holling (1959) studied predation of small mammals on pine sawflies, and he found that predation rates increased with increasing prey population density. This resulted from 2 effects:

(1) Each predator increased its consumption rate when exposed to a higher prey density, and

(2) Predator density increased with increasing prey density.

Holling considered these effects as 2 kinds of responses of predator population to prey density: (1) the functional response and (2) the numerical response.

Modeling Functional Response: Holling (1959) suggested a model of functional response, which remains most popular among ecologists. This model is often called "disc equation" because Holling used paper discs to simulate the area examined by predators. Mathematically, this model is equivalent to the model of enzyme kinetics developed in 1913 by Lenor Michaelis and Maude Menten.

His model illustrates the principle of time budget in behavioral ecology. It assumes that a predator spends its time on 2 kinds of activities:

1. Searching for prey.
2. Prey handling that includes chasing, killing, eating and digesting.

Consumption rate of a predator is limited in this model because even if prey are so abundant that no time is needed for search, a predator still needs to spend time on prey handling. Total time equals to the sum of time spent onsearching and time spent on handling:

Assume that a predator captured Ha prey during time T. Handling time should be proportional to the number of preycaptured, where Th is time spent on handling of 1 prey.

Capturing prey is assumed to be a random process. A predator examines area (a) per time unit (only search time isconsidered here) and captures all preys that were found there. Parameter (a) is often called "area of discovery", however it can be called "search rate" as well.

After spending time T-search for searching, a predator examines the area = a T search, and captures a HT-search prey where H is prey density per unit area: Hence: Now we can balance the time budget: The last step is to find the number of attacked prey Ha: This function indicates the number of prey killed by 1 predator at various prey densities.This is a typical shape of functional response of many predator species. At low prey densities, predators spend mostof their time on search, whereas at high prey densities, predators spend most of their time on prey handling.

Holling (1959) considered 3 major types of functional response:

Type I Functional response is found in passive predators like spiders. The number of flies caught in the net is proportional to fly density. Prey mortality due to predation is constant.

Type II Functional response is most typical and corresponds to the equation above. Search rate is constant. Plateau represents predator saturation. Prey mortality declines with prey density. Predators of this type cause maximum mortality at low prey density. For example, small mammals destroy most of gypsy moth pupae in sparse populations of gypsy moth. However in high-density defoliating populations, small mammals kill a negligible proportion of pupae.

Type III Functional response occurs in predators, which increase their search activity with increasing prey density. For example, many predators respond to kairomones (chemicals emitted by prey) and increase their activity. Polyphagous vertebrate predators (*e.g.*, birds) can switch to the most abundant prey species by learning to recognize it visually. Mortality first increases with prey increasing density, and then declines.

Numerical Response: Numerical response means that predators become more abundant as prey density increases. However, the term "numerical response" is rather confusing because it may result from 2 different mechanisms:

- Increased rate of predator reproduction when prey are abundant (numerical response/ se)
- Attraction of predators to prey aggregations ("aggregational response")

Reproduction rate of predators naturally depends on their predation rate. The more prey consumed, the more energythe predator can allocate for reproduction. Mortality rate also reduces with increased prey consumption. The most simple model of predator's numerical response is based on the assumption that reproduction rate of predators is proportional to the number of prey consumed. This is like conversion of prey into new predators. For example, as 10preys are consumed, a new predator is born. Aggregation of predators to prey density is often called "aggregational response". This term is better than "numerical response" because it is not ambiguous. Aggregational response wasshown to be very important for several predator-prey systems. Predators selected for biological control of insect pests should have a strong aggregational response. Otherwise they would not be able to suppress prey populations.Also, aggregational response increases the stability of the spatially-distributed predator-prey (or host-parasite) system.

Pest forecasting - Forecasting of pest incidence or outbreak based on information obtained from pest surveillance. Or Forecasting is the prediction of the type of fluctuation which will ensue. Forecasting pest incidence often requires systematically recorded specific field data in an elaborate manner overconsiderable period of time which can be easily retrieved and analyzed.

Types of pest forecasting -

Short term forecasting- It covers a particular season or one or two successive seasons onlyand is usually made employing insect trapping methods or some other sampling of the pest within the crop. Or one or two crop seasons.

Long term forecasting- It covers large areas and based mainly on the possible effects of weather on the insect abundance or by extrapolating from the present population density into the future. Or cover large areas & based on weather conditions.

Pest forecasting comprises following three main points: -

- Quantitative measurement of population of pest on ecological zones.
- Study of life history of the insect pest.
- Study of fluctuation in pest population due to natural enemies & other factors

Uses of pest forecasting -

i.) Predicting pest outbreak which needs control measure.
ii.) To know the suitable stage at which control measure gives the maximum protection.

Liebig's Low of Minimum

- In the 19th century (1840), the German scientist Justus von Liebig formulated the "Law of theMinimum,"
- Liebig's law of the minimum, often simply called Liebig's law or the law of the minimum,
- Which states that if one of the essential plant nutrients is deficient, plant growth will be poor even when all other essential nutrients are abundant.
- Liebig's Law of the Minimum was developed for the nutrition of agricultural plants, but can alsobe applied to population abundance.
- Reproduction (birth of new organisms) and death are the fundamental processes regulating change in population size over time.
- Low abundance of resources, or other non-ideal environmental conditions, reduces the reproduction rate or increases the death rate in a population, in addition to lowering rates of growth or activity for individual organisms.
- As an example, if a plot of ground is deficient in iron, but has plenty of other nutrients, a plant that requires a lot of iron will struggle if it is grown in that plot without amending the soil. Adding more nitrogen, potassium, or phosphorus to the soil won't change the plant's difficulty in growing. It could worsen the situation if it increases the plant's need for iron.
- Liebig's Law has been extended to biological populations (and is commonly used in ecosystem models). For example, the growth of an organism such as a plant may be dependent on a number of different factors, such as sunlight or mineral nutrients (e.g. nitrate or phosphate). The availability of these may vary, such that at any given time one is more limiting than the others. Liebig's Law states that growth only occurs at the rate permitted by the most limiting. For instance, in the equation below, the growth of population *O* is a function of the minimum of three Michaelis-Menten terms representing limitation by factors *I, N,* and *P*.

$$\frac{dO}{dt} = min\left(\frac{I}{k_I + I}, \frac{N}{k_N + N}, \frac{P}{k_P + P}\right)$$

It is limited to steady-state conditions and tightly controlled factor interactions.

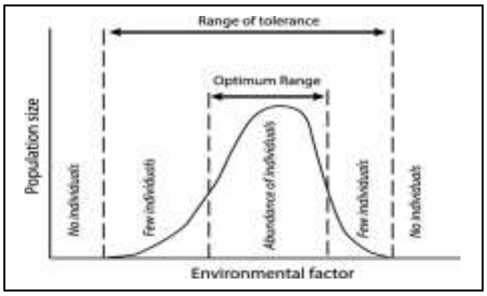
Shelford's Law of tolerance

- Shelford's law of tolerance is a principle developed by American zoologist Victor Ernest Shelford in 1911.
- Shelford's law of tolerance states that an organism's success is based on a complex set of conditions and that each organism has a certain minimum, maximum, and optimum environmental factor or combination of factors that determine success
- According to the law of tolerance, populations have optimal survival conditions within critical minimal and maximal thresholds.
- As population is exposed to the extremes of a particular limiting factor, the rates of survival begin to drop.

The distribution of a species in response to a limiting factor can be represented as a bell-shaped curve with three distinct regions:

1. **Optimal zone:** Central portion of curve which has conditions that favour maximal reproductive success and survivability.

2. **Zones of stress:** Regions flanking the optimal zone, where organisms can survive but withreduced reproductive success.
3. **Zones of intolerance:** Outermost regions in which organisms cannot survive (representsextremes of the limiting factor).



Problem-Solving–Analyzing frequencies Field biologists spend a good deal of time counting and classifying things on nominal scales such as species, color, habitat, etc., hence statistical tests that analyze the frequencies are important. **Chi-square** tests are variously referred to as tests for homogeneity, randomness, association, independence, and goodness of fit. The G-test is an alternative to the chi-square test for analyzing frequencies. The two methodsare interchangeable; if a chi-square test is appropriate then so too is a *G*-test and the assumptions ineach are the same. Moreover, the outcome of the *G*-test is a test statistic (*G*) which is compared with the distribution of chi-square in the same tables as the chi-square test. *G*-test is easier to execute with adesk-top hand calculator, especially with contingency tables. Second, mathematicians believe that the*G*- test has theoretical advantages in advanced applications (Fowler *et al*, 1998).

Solved example: An Entomologist collects different insect orders at the light trap from two locations and has the following data for each order:

Location(A): 12,10,18,24,8,16,14,22,26,20
Location(B): 8,14,22,20,26,18,6,4,24,16

Loc-A	Loc-B	Insect Orders	Loc-A	Loc-B
12	8	Hymenoptera	132	56
10	14	Diptera	90	182
18	22	Coleoptera	306	462
24	20	Orthoptera	552	380
8	26	Hemiptera	56	650
16	18	Thysanoptera	240	306
14	6	Isoptera	182	30
22	4	Dictyoptera	462	12
26	24	Lepidoptera	650	552
20	16	Neuroptera	380	240
		$\sum n_i(n_i-1)$	3050	2870
170	158	**N(N-1)**	28730	24806
		$\sum n_i(n_i-1)/N(N-1)$	0.1062	0.1157
Simpson Index (D)= 1- $\sum n_i(n_i-1)/N(N-1)$			**0.8938**	**0.8843**

The Simpson Diversity Indices computed do not differ significantly for the two locations A&B.

Relative density (%) estimates:

Insect Orders	Loc-A	Loc-B
Hymenoptera	7.06	5.06
Diptera	5.88	8.86
Coleoptera	10.59	13.92
Orthoptera	14.12	12.66
Hemiptera	4.71	16.46
Thysanoptera	9.41	11.39
Isoptera	8.24	3.80
Dictyoptera	12.94	2.53
Lepidoptera	**15.29**	**15.19**
Neuroptera	11.76	10.13

Note: The relative density estimate indicates that at both locations Lepidoptera were the most abundant followed by Orthoptera and Coleoptera.