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Application of Life Tables in Analysing the Insect Biology

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Introduction: -

A "Life Table" is a kind of bookkeeping system that ecologists often use to keep track of stage-specific mortality in the populations they study. Life table is a condensed tabulation of certain vital statistics of insect population, which provides a format for recording, and accounting for all population change is the life cycle of a species. So, the construction of life table is an important component in the understanding of the population dynamics of a species. It is an approach that is especially useful 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 helpful 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.

`Life table provides an important tool in understanding the changes in population of insect pests during different developmental stages throughout their life cycle. Life table is an important analytical technique in studying distribution, determination of age and mortality of an organism and individuals can be calculated.

Population Demography: -

The statistical study of populations, allows predictions to be made about how a population will change. Thus, the Science includes the study of science, density of populations, their growth and their decline.

There are various tools for monitoring demography of population; LIFE TABLES is one of the tools of measuring population demography.

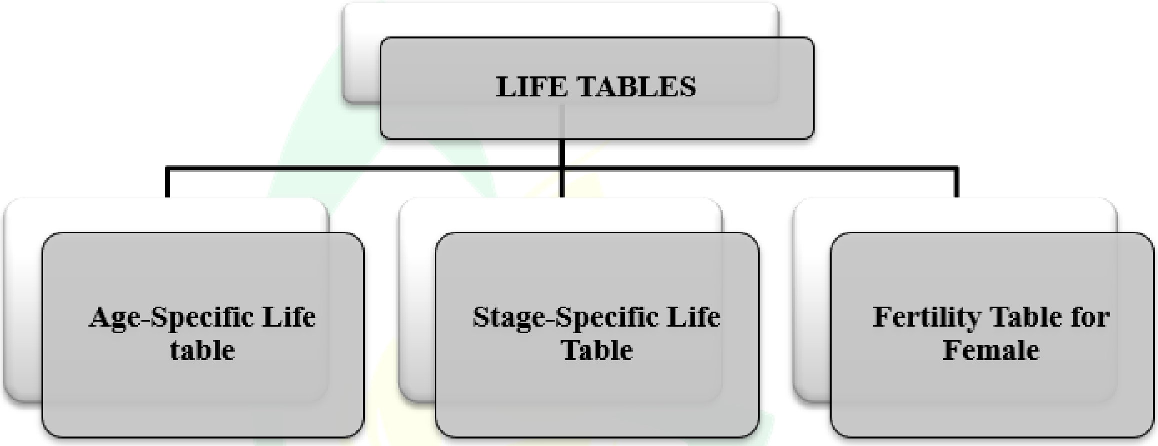
Founder and Origin of Life Table: -

Lotka (1925) is considered as father of Life tables.

Leopold was the first researcher to identify the value of the life table in the study of natural population and he called it as "Life equation" (Harcourt, 1969).

Morris and Miller (1954) presented the first detailed example of a life table for natural population of Spruce bud worm.

Types of Life Table: -



Age-Specific or Horizontal Life Table: -

It was first time introduced by Deevy, in 1947. Observations on the number of alive and dead out of hundred nymphs were recorded daily. It is based on the fate of a real cohort, conveniently the members of a population belonging to a single generation and of same age. The population may be stationary or fluctuating. The following assumptions were used in the construction of age specific life-tables.

- x = Age of the insect in days/Cohort
- l_x = Number surviving at the beginning of each interval, out of 100
- d_x = Number dying during the age interval, out of 100
- $100q_x$ = Mortality rate at the age interval x and calculated by using formula,

$$100q_x = [d_x / l_x] \times 100$$

- e_x = Expectation of life or mean life remaining for individuals of age x Life expectation was calculated using the equation,

$$e_x = T_x / l_x$$

- To obtain ex two other parameters L_x and T_x were also computed as below.
- L_x = The number of individuals alive between age x and x + 1 and calculated by the equation.

$$L_x = l_x+1 (x + 1)/ 2$$

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- T_x = The total number of individuals of x age units beyond the age x, and obtained by the equation;

$$T_x = l_x + (l_x + 1) + (l_x + 2) \ldots\ldots\ldots\ldots\ldots\ldots + l_w.$$

- Where, l_w = The last age interval.

Stage-Specific or Vertical Life Table: -

This concept of Life table was proposed by Harcourt, 1969 & Southwood, in 1978 reporting that Data on stage specific survival and mortality of eggs, nymph, pupae and adults of whitefly strains were recorded from the age specific life-tables on different host plants. Following standard heads were used to complete stage specific life table.

- x = Stage of the insect.
- l_x = Number surviving at the beginning of the stage x.
- d_x = Mortality during the stage indicated in the column x.

It is based on the fate of an imaginary cohort found by determining the age structure. Here population remains stationary with considerable overlapping of generations.

According to Hasan and Ansari (2009), age specific survivorship (l_x) of Earias vitella (Fabricius) decreased from 1st to 10th day while, survivorship was greatly reduced on the 38th day whereas the highest mortality (d_x) was noticed on the 36th day (15 %) and on the basis of stage specific life table, the apparent mortality ($100q_x$) of eggs were calculated (16 %).

The data calculated through various life parameters as given below:

- **Apparent Mortality ($100q_x$):-** It gives the information on number dying as percentage of number entering that stage, Apparent Mortality = [d_x / l_x] x 100
- **Survival Fraction of Particular Stage (S_x):-** [l_x of subsequent stage] / [l_x of particular stage].
- **Mortality Survival Ratio of particular Stage (MSR):-** [Mortality in particular stage] / [lx of subsequent stage].
- **K-values:-** It is a key factor which is primarily responsible for increase or decrease in number from one generation to another and was computed as difference between successive values for "log lx". However, the total generation mortality was calculated by adding K-values of different development stages or the insect which is indicated as "K".

$$K = k_E + k_{L1} + k_{L2} + k_{L3} + k_{L4} + kpp + kp$$

Where, k_E, k_{L1}, k_{L2}, k_{L3}, k_{L4}, kpp, kp are the K values at egg, first instar, second instar, third instar, fourth in stars of larval stage, pre-pupal and pupal stages of one insect.

- **Difference Between Age-Specific and Stage-Specific Life Table: -**

Age-Specific Life Table	Stage-Specific Life Table
Horizontal Life Table	Verticle Life Table
Constructed for those organisms which have short life span	Constructed for Long Lived organisms
Interval of observation is not regular but decided by the stage present	Certain fixed intervals are pre decided and observations are taken during the fixed intervals
Called Horizontal life table as all the stages are closely observed moving horizontally along the life of an organism	The flow of life cycle is cut vertically and observations are noted in each of the stage
Ex.- Annual Plants/Insects	Ex.- Herd of elephants because following cohort of such individuals from birth to death would take long time
Life history is prerequisite	Age determination is pre requisite

I. Female Fertility Table: -

The fertility table was constructed with the following assumptions:

- The survivorship rates were assumed to be the same for both the sexes, as it was not possible to identify the sexes prior to the adult stage.
- The sex could not be identified at the egg stage. Therefore, a sex ratio of 1: 1 was considered in each batch of eggs.
- The table was constructed on the suggestions made by Birch (1948) and Southwood (1978). It consisted of following columns:
- x = Pivotal age of female in days.
- l_x = Number of females alive at the beginning of the age interval x (as fraction of initial population of one).
- m_x = Average number of female eggs laid per female in each age interval assuming 50:50 sex ratio and computed as:

$$m_x = N_x/2$$

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- where, N_x = Total natality per female off springs in each age.
- Besides mx total number of females off springs in each age interval i.e., eggs laid by female in an age interval (x), lx.mx was also computed by multiplying the column l_x with mx. This is also termed as 'Reproductive expectation'.

➢ In Life table studies the word cohort is used very frequently which refers to population born at the same time with a shared characteristic.

➢ Age specific life tables are more commonly used in entomology than time- specific life tables. The former are based on the fate of a real cohort throughout a generation, while the latter are based on the fate of an imaginary cohort. Age specific life table provides a means of identifying the potential role of parasitoids and predators in the regulation of pest population. The data required to construct a life table for key factor analysis are a series of successive samples taken from each life stage of a generation.

Construction of Life Tables for Study of Population: -

The first step in constructing a life table is to obtain an estimate of the potential natality (Number of individuals entering post-ovarial stage). This is calculated from an estimate of the mean fecundity per female, which is multiplied by the number of females of reproductive age. Mortality refers to the total mortality obtained in a population.

A criterion for filling the Columns of one life able was proposed by Harcourt in 1969 for each age interval (stage).

- **Eggs:** In case of eggs, "lx" is based on direct sampling of the population at the completion of oviposition. The "d_x" value is obtained from the percentage found to be infertile.
- **Early instar larvae:** The "lx" for early instar larvae is obtained by direct sampling of the quadrates in the field and computed on hectare basis.
- **Late instar larvae:** The "lx" is obtained by deducting the mortality of larvae due to the parasitoid and unknown causes from the early instar.
- **Pupae:** The "lx" is determined after subtracting the mortality of late instar larvae due to parasitoids and unknown causes.
- **Adults:** This "lx" represents the number of pupae giving to adults. The mortality in the pupal stage due to parasitoids and unknown causes is subtracted from the "lx" of pupae and thus, the "lx" value for adults were determined for all practical purpose.

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- **Trend index:** This was simply "lx" for the early instars larvae in the next generation expressed as a ratio of previous generation.

$$\text{Trend index} = N_2/N_1$$

Where, N_2= Population of larvae in next generation N_1= Population of larvae in previous generation.

- **Generation survival:** This was index of population trend without the effect of fecundity and adult mortality.

$$\text{Generation survival (SG)} = N_3/\ N_1$$

Where, N_3= Population of adults in a generation N_1= Population of larvae in the same generation.

- **K – Value:** It is a key factor which is primarily responsible for increase or decrease in number from one generation to another and was computed as difference between successive values for log "lx". However, the total generation mortality was calculated by adding "K" values of different development stages or the insect which is indicated as "K".

$$K = k_E + k_{L1} + k_{L2} + k_{L3} + k_{L4} + kpp + kp$$

Where, k_E, k_{L1}, k_{L2}, k_{L3}, k_{L4}, kpp, kp are the "K" values at egg, first instar, second in star, third in star, fourth in star, pre-pupal and pupal stage.

Examples of Life-Tables: -

Age-Specific Life Table of Gram Pod Borer (*Helicoverpa armigera*) in Chickpea-

Pivotal age (in day) x	Numbers surviving to the beginning of age intervals (Ix)	Numbers dying during X (dx)	Mortality rate/100 alive at beginning of age interval (dx.100/I) (100 qx)	Alive between age X and x+1 Lx	No. of individual life days Tx	Expectancy of further life (Tx/lx)×2 ex
0-5	100	I	1.00	99.5	739.0	14.78
5-10	99	4	4.04	97.0	639.5	12.92
10-15	95	5	5.26	92.5	542.5	11.42
15-20	90	5	5.55	87.5	450.0	10.00

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20-25	85	2	2.35	84.0	362.5	8.53
25-30	83	2	2.41	82.0	278.5	6.71
30-35	81	3	3.70	79.5	196.5	4.85
35-40	78	0	0.00	78.0	117.0	3.00
40-45	78	22	28.21	39.0	39.0	1.00

Stage-Specific Life Table of *Harmonia dimidiata* (Coleoptera: Coccinellidae) fed on *Rhopalosiphum padi* (Hemiptera: Aphididae)-

Stage (X)	Numbr survivng at the beginning of stage (lx)	Number dying in each Stage (dx)	Apparent mortality ($100q_x$)	Survival fraction (S_x)	Mortality Survival Ratio (MSR)	Indispensable Mortality (IM)	Log lx	K-values
Egg	100	11	11	0.89	0.13	7.42	2	0.051
1st Instar	89	12	13.48	0.87	0.16	8.96	1.95	0.063
2nd Instar	77	4	5.19	0.95	0.06	3.20	1.89	0.023
3rd Instar	73	6	8.22	0.92	0.09	5.13	1.86	0.043
4th Instar	67	3	4.48	0.96	0.04	2.51	1.83	0.02

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Pre-pupa	64	5	7.81	0.92	0.09	4.87	1.81	0.036
Pupa	59	3	5.08	0.95	0.11	6.00	1.77	0.022
Adult	56	56					1.75	K= 0.258

Application of Life-Tables: -

- **Calculation of replacement rate:** A valid life table can be determining whether a population is growing, declining, or remaining stable.
- **Simulation:** Once a valid life table is constructed for on insect population, it may be used to stimulate the out-come of management decisions.
- **Determination of key factors:** Key factor analysis has proved to be a valuable aid in identifying the environmental factors most closely related to intergenerational population trend.
- **Pest Management:** With the help of life tables, we can calculate the life expectancy of beneficial insects and can be used for the biological control by predicting natural things in particular instar within which we get maximum mortality. On this basis, we can prepare a plan for the management of insect pest at particular time. Key factor analysis has proven to be a valuable aid in identifying the environmental factors most closely related to intergenerational population trend.
- Life tables have been prepared for several insect pests in India viz., *H. armigera*, *S. litura*, etc. and key mortality factors have been successfully identified.

Limitation of Life-Tables: -

- Life table analysis is only as valid as the accuracy of the sampling techniques used to obtain initial data.
- It requires everyday monitoring of population.
- It takes considerable time and manpower to obtain realistic results.
- If carried out correctly life table remain the most important analytical technique available for identifying key mortality components in an insect pest's life cycle.

Conclusion: -

Life table study is very useful to analyse the mortality of insect population, to determine key factors responsible for the highest mortality within population. Construction of life tables is an important tool for understanding the population dynamics of an insect. It serves as a framework for organizing dates on mortality and natality. It generates simple summary statistics such as life expectancy and reproduction rate. 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 the most vulnerable. By knowing such vulnerable stages from life table, we can make time-based application of insecticide for the management of insect pests, to conserve the natural parasites and predators and to reduce the environmental pollution.

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