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# Importance of Life Table of Insects in IPM

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Life table analysis is a vital ecological tool for understanding the population dynamics of insect pests and their natural enemies. It quantitatively describes survival, mortality, fecundity, and life expectancy across different developmental stages, enabling the identification of key mortality factors and vulnerable life stages. In entomology, where insects exhibit discrete life stages and variable mortality rates, life tables provide essential insights for predicting population growth or decline and for designing effective Integrated Pest Management (IPM) strategies. Various types of life tables, including age-specific, stage-specific, rolling, and age-stage, two-sex life tables, are used to analyze insect populations under diverse ecological conditions. Among these, the age-stage, two-sex life table offers a more realistic assessment by incorporating both sexes and stage differentiation. Life table parameters such as intrinsic rate of increase ($r_m$), net reproductive rate ($R_0$), finite rate of increase ($\lambda$), and mean generation time (T) are widely applied to evaluate host plant resistance, biological control agents, pesticide impacts, invasive pest potential, and vector insect control. Despite limitations related to sampling intensity and time requirements, life tables remain indispensable for developing sustainable, eco-friendly, and need-based pest management programs.

**Key words:** Life table; Population dynamics; Integrated Pest Management (IPM); Age-stage two-sex life table; Key mortality factors; Biological control; Pest ecology

## Life Table

- Life table is mathematical way of describing fate of an organism throughout its life cycle from birth to death. Life table gives information on fate of living organism at different growth stages as successive age intervals, the number of deaths, the survivors, the rate of mortality, and the expectation of further life.
- Life table is very useful for finding out the key mortality factors of organisms of interest and based on the population growth of an organism during the time of study, one can predict population built-up in the succeeding generations to come. Morris (1964)
- According to Deevey (1947) "life table is concise summary of certain vital statistics of a population, whose members start life together.'

## Role and Importance of life table

Study of factors to determine the need to modify the life system of the pest with a view to reducing its number below ETL.Study of applied ecology which involves application of biological knowledge for achieving desired populations. Determining the key mortality factor and predicting the appearance in future. Dividing pest control procedures that suits the available technology compatible with the economic and the environment quality requirement predicts timing of application and need-based application of insecticides by estimating intensity of pest population. Life table provides an important tool in understanding their life cycles. Especially a useful approach in entomology, where developmental stage is discrete and mortality rates may vary widely from one life stage to other. To know when population suffers high mortality, this is usually the time when it is most vulnerable.

## Application of life table

The weakest link in the life cycle can be determined and made use of common pests. The effect of most effective biotic factors causing death of the pest can found out and used effectively. Field life table studies on natural enemies can help in determining the cause of their failure in the field information can help to find out the best release techniques. Based on survivorship curves one can operate control measures when the mortality factors operating slow and thus can obtain economic results. It provides useful information on their mortality factors, information thus obtained can be incorporated in mass production techniques and make it more efficient. Studied on pest and natural enemies may provide exact time of release of predator and parasitoid and utilize them to their best potential.

## TWO SEX-life table

The TWOSEX-MS Chart program is a versatile tool that can be used to analyze the raw life table data of related insects, providing detailed insights into their development, survival, and daily reproductive capacity.

1. Age-stage-specific survival rate ($s_{xj}$: the probability that a newborn egg will survive to age $x$ and stage $j$)
2. Age-specific survival rate ($l_x$: the probability that a newborn egg will survive to age $x$)
3. Female fecundity (F: eggs/female)
4. Age-stage-specific fecundity ($f_{xj}$: the number of hatched eggs produced by a female adult at age $x$)
5. Age-specific fecundity ($m_x$: the number of eggs per individual at age $x$); and
6. Age-specific maternity ($l_x m_x$: the product of $l_x$ and $m_x$) were calculated.

✓ the population parameters, including -

1. **The intrinsic rate of increase ($r_m$),** were calculated using the Lotka–Euler equation with the age indexed from zero;
2. The **finite rate of increase** ($\lambda$) was calculated as $\lambda = er$;
3. The **net reproductive rate** ($R_0$) is the sum of all $l_x m_x$ **(age-specific maternity),** which considers the survival rate; and
4. The **mean generation time ($T$)** is the length of time required by a population to increase to $R_0$-fold of its size as time approaches infinity and the population settles down to a stable age-stage distribution.
5. Key indicators, **such as $r_m$, $\lambda$, $R_0$, and $T$, are essential for evaluating** the biological characteristics of insect populations. By recording these parameters, we can infer valuable insights into the structure of the insect population, its growth and decline patterns, and other ecological aspects. .

## 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 outcome 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 component in an insect pest's life cycle.

## Application of life table in integrated pest management

### Evaluation of the Pest Control Capacity of Natural Enemies of Pests

- By documenting the growth and development of pests under the pressure of natural enemies, this method assesses the pest control ability of natural enemies from the perspective of pest population dynamics. Natural enemies are usually classified as predators, parasitoids, and pathogens.
- The intrinsic natural growth rate $r_m$ of a population is of great interest as a key parameter in entomology and is considered particularly important in the study of predators.

| Natural Predators | Prey | Stage |
|---|---|---|
| Coccinellidae | Aphids, Scale insects, whiteflies, and spider mites. | Larva and adult (Li *et al*., 2021) |
| Lacewings (Chrysopidae) | Broad spectrum of agricultural and Forestry pests | Larva and adult (Hassan & Liu, 2022) |
| Stink bug (Pentatomidae) | Moth larvae, beetles etc. | |

- According to evolutionary models, more females will oviposit in large hosts than in small hosts, which is consistent with the finding that maize, being a larger host, supports a higher proportion of female offspring in *T. chilonis*. Identifying the most susceptible and favorite host (maize) will help us improve the large-scale production of *T. chilonis* under laboratory conditions.

### Evaluation of the pest control capacity of Bio-Pesticide

- Life table evaluation techniques can be employed to assess these impacts, providing valuable insights for the effective use of biopesticides in IPM strategies. This evaluation will help optimize the application of biopesticides and enhance their role in sustainable agriculture.
- To better understand the factors and effects of biopesticides on pest control, it is essential to evaluate their long-term impacts on pest population sizes and dynamics, as well as their potential effects on pests and other beneficial insects.
- Research has shown that treating second-instar larvae of *Helicoverpa armigera* Hubner (Lepidoptera: Noctuidae) with HearNPV, a nucleopolyhedrovirus to *H. armigera*, and then parasitizing them with *Habrobracon hebetor* Say (Hymenoptera: Braconidae) results in sublethal effects on *H. hebetor*, including reduced longevity and fecundity at sublethal concentrations (e.g., $LC_{30}$) and decreased population growth parameters (e.g., $R_0$ and $r_m$).
- However, under field conditions, *H. hebetor* can still effectively control *H. armigera* when released 2 days after HearNPV application, suggesting that their combined use in pest management is feasible.

### Screening of Insect -Resistant plant species

- For example, the biological parameters and fecundity life table of *Melanaphis sorghi* Theobald (Hemiptera: Aphididae), a pest that infests sorghum crops, were estimated on 15 sorghum hybrids. The results identified specific sorghum varieties that were less suitable for the pest and showed resistance to *M. sorghi*.

- The $r$, $R_0$, and $T$ of *Toxoptera aurantii* Boyer de Fonscolombe (Hemiptera: Aphididae) on six different tea tree varieties were analyzed to determine their population dynamics and host adaptation, which were used to guide integrated pest management and the screening of *T. aurantii*-resistant host varieties.

**Application in vector insect control**

- Life tables offer a valuable tool for understanding the life cycle and population dynamics of vector insects. By providing structured and data-driven insights, life tables enable the formulation of targeted and effective control strategies.
- Evaluating the life history characteristics of vector insects using life tables can help us understand their survival rate, longevity, and fecundity at different stages; this approach aids in the development of a better understanding of the population dynamics of vector insects.

## Application of life table in Vector insect control follows three steps

**1.Assessing the Risk of Transmission by Vector Insects**

By studying the population growth and survival rates of the malaria vector *Anopheles stephensi* Liston (Diptera: Culicidae) in different water pollutants and analyzing the impact of changes in water quality on this particular mosquito, the risk of transmission of vector-borne diseases can be assessed, which is an important guide for the development of effective public health strategies and policies.

**2. Modeling the Dynamics of Vector Insects**

- Life table data form the cornerstone of such modeling efforts. By integrating environmental factors, climatic data, and disease transmission parameters, life table data can be used to develop mathematical models that simulate and predict the population changes and disease transmission dynamics of vector pests.These models incorporate various factors, such as environmental conditions, climatic variables, and disease-transmission parameters.

A temperature-dependent phenology model for the whitefly vector has also been developed using the Insect Life Cycle Modeling (ILCYM) software. The impact of temperature on the whitefly's virus transmission efficiency was assessed via controlled lab experiments at eight constant temperatures (10–25 °C). The vector's transmission capacity was the strongest at 15 °C (about 70% infection probability) but dropped sharply to <10% at 10 and 20 °C.

**3. Interference with the Life Cycle of Vector Insects**

- The application of life table data is crucial for understanding the life cycle of vector insects and pinpointing key stages for intervention. These data reveal the various developmental stages of vector pests and their associated vulnerabilities.
- By targeting these stages, such as disrupting reproduction, larval hatching, or adult longevity, we can effectively reduce the population size and disease transmissibility of vector pests. This life-table-based approach provides a strategic framework for developing interventions that disrupt the life cycle of vector insects and mitigate the risk of disease transmission.

## Application in Invasive Pest Control

- The application of life tables to invasive pests is an important tool for the study and management of invasive pest population dynamics, life cycles, reproductive potential, and impacts on ecosystems. Life table analyses can help monitor the population sizes, growth rates, and trends of invasive pests.
- Investigations have employed life table analyses to evaluate the suitability of three plant species—tomatoes, potatoes, and eggplants—as hosts for the invasive mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae).
- These findings provide critical insights that will significantly aid in the development of targeted and effective management strategies for successfully controlling this invasive pest in major Mediterranean crop systems.

## Application of life table in chemical control of pests.

1. Evaluating the Fitness Costs of Pesticide Resistance in Pests
2. Guiding the Selection of Insecticides
3. Guiding the Application of Insecticides

**1.Evaluating the fitness Costs of pesticide resistance n Pests.**

- As pest resistance to insecticides gradually increases, the efficacy of these chemicals diminishes, and in some cases, they may even fail to control the pests, which in turn impacts agricultural production. Therefore, evaluating the fitness costs associated with pesticide resistance in pests is crucial for understanding the dynamics of resistance and developing effective control measures.
- An investigation into the correlation between imidacloprid resistance and the fitness of the melon aphid *Aphis gossypii* Glover (Hemiptera: Aphididae) was undertaken, offering valuable insights into the potential fitness trade-offs related to resistance against this neonicotinoid insecticide.
- The imidacloprid-resistant lines (ImR) presented
- ✓ prolonged developmental stages
- ✓ shortened longevity, and
- ✓ decreased fecundity.
- Key demographic parameters were significantly reduced in ImR, indicating that resistance has a fitness cost.

**2.Guiding the selection of insecticides**

- Selecting the appropriate insecticide has emerged as a pivotal step in effective pest management. This decision-making process necessitates a thorough understanding of both the target pest and its environmental context.
- The toxicity of eight pesticides was evaluated against several parasitic species, with a focus on how sublethal doses of dinotefuran and lufenuron affected their life history traits and detoxification enzyme functions. The results indicated that dinotefuran and lufenuron were particularly toxic to *B. odoriphaga* and *B. difformis* out of the tested compounds. Moreover, sublethal concentrations of these pesticides significantly impaired the life history parameters across both generations of the species

**3.Guiding the application of Insecticides**

A simulation using a sex-based life table can predict the optimal period for pest control and accurately determine the optimal timing and number of chemical control applications. Following the application of pesticides, the population size and age structure of pests undergo significant changes.

- By analyzing the population structure and considering factors such as the lethality of insecticides for different insect states and age classes, the persistence period of insecticides, and the economic threshold (ET), we can utilize the amphoteric life table and the TIMING—MS Chart to predict the effects of insecticide use on the growth and reproduction of pests and their progeny.A detailed life table was constructed for the coffee berry borer *Hypothenemus hampei* Ferrari (Coleoptera: Curculionidae) by meticulously calculating its survival and reproduction rates across various developmental stages. This comprehensive analysis allowed for the determination of $R_0$ for each population, thereby pinpointing the optimal timing for the most effective pest control interventions.

## Future Perspective

To fully realize the potential of life tables in IPM, future research must prioritize cross-disciplinary integration. Combining population models with food web analytics, genomic insights, and climate resilience frameworks will enable a holistic understanding of pest dynamics. Concurrently, establishing open-access databases of regionally calibrated life table parameters could guide context-specific interventions. By addressing these challenges, life table analyses can transition from a descriptive tool to a predictive engine for designing adaptive, ecologically informed pest management strategies that balance efficacy with environmental stewardship much less than that of T. howardi - the other pupal parasitoid. However, field evaluation is necessary to determine their efficacy.

## Conclusion

Life table study is very useful to analyze 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 and 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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