Analysis of Insect Mortality

This audit trail has been produced by A.N. Actuary on 7th December 2022. It relates to the spreadsheet 'Module 5_Insect Mortality.xlsx'.

Objective

This spreadsheet has been produced to perform analysis on insect mortality for a university research project. The spreadsheet uses data on the number of insects living (l_x) for ages $0 \leq x \leq 25$, where x is measured in days, to produce life tables for male and female insects. It also contains a calculator that can be used by students to calculate n|mqx, i.e. the probability than an insect aged x will survive for n days but die during the subsequent m days.

The current population data has been used to create a demographic mix chart with the number of insects split by sex and five-day age group. The approximate expectation of life for each insect in the current population has been calculated.

The spreadsheet also includes adjusted life tables reflecting the expected reduced mortality resulting from increasing the temperature of the insects' tank. The reduction factors are 20% for males and 15% for females and are applied as follows:

For $0 \leq x < 25$, $q_x^{reduced} = (1 - reduction\ factor) \times q_x$

For $x = 25$, $q_x^{reduced} = q_x$

Data and Data Checks

A researcher at the university has provided two sets of data, and these are shown on the sheet 'Data'. The first set of data shows the number of insects living (l_x) for ages $0 \leq x \leq 25$, where x is measured in days. The second set of data shows the ID number, sex and age for each of the 30 insects in the current population.

The following checks have been performed on the data on the sheet 'Data checks':

- For the first set of data the maximum and minimum ages are calculated to check that $0 \leq x \leq 25$.
- Column F checks that each age is 1 day more than the previous age.
- Columns G and H check that the number of insects living reduce as age increases for males and females respectively.
- For the second set of data the number of each data item (ID number, sex and age) is counted and checked that it is equal to 30.
- Column N checks that each ID number is 1 more than the previous ID number.
- Column O checks that the sex is valid for each insect (i.e. either 'M' or 'F').
- Column P checks that the age is valid for each insect (i.e. $0 \leq x \leq 25$).

The checks all give satisfactory results and so the data is assumed to be accurate. No changes have been made to the data.

Assumptions

The following assumptions have been made in the model:

- The data provided is complete and accurate.
- Ages provided in the data are exact.
- All insects are either male or female.
- q_{25} = 1 for males and females.
- ID numbers for the population data are unique and sequential.

Parameters

This sheet sets out the parameters used in the model:

- The maximum age is 25 days.
- The minimum age is 0 days.
- The current population is 30 insects.
- The male and female reduction factors are 20% and 15% respectively.
- The initial value l_0 for the adjusted life table is 10,000.
- The inputs for the calculator are sex, age, survival period (n) and death period (m).

Each parameter has been set as a named range, with the name shown in grey next to the parameter. These parameters are used in the other sheets in the model.

This sheet also shows the colour coding used in the model.

The following checks have been performed on the inputs for the calculator:

- Check that the input for sex is valid (i.e. it is 'M' or 'F').
- Check that the input for age is valid (i.e. $0 \leq x < 25$).

Life Tables

This sheet creates life tables showing lx, dx, qx and px separately for males and females for ages $0 \leq x \leq 25$. lx has been provided by the researcher so this column simply links to the 'Data' sheet for both males and females. dx = dx+1 – dx for ages $0 \leq x < 25$. d25 = l25 as q25 = 1. qx = dx/lx for all ages. px = 1-qx for all ages.

The following checks have been performed:

- Check that q25 = 1 for both males and females.
- Columns O and P check that lx decreases as x increases for males and females respectively.
- Columns Q and R check that dx is less than or equal to lx at all ages for males and females respectively.
- Columns S and T check that qx is between 0 and 1 at all ages for males and females respectively.
- Columns U and V check that px is between 0 and 1 at all ages for males and females respectively.

q_x Chart

This sheet creates a chart showing qx for both males and females across all ages. The values for qx are taken from the 'Life tables' sheet. A line chart has been produced using this data with separate lines for males and females.

The following checks have been performed:

- Columns G and H calculate the change in qx as age increases for males and females respectively. qx generally increases with age, as expected. At low ages qx initially falls. This is reasonable and is observed in human populations.

Calculator

This sheet calculates n|mqx using the inputs on the 'parameters' sheet. As mentioned above, there are checks on the inputs to ensure they are valid. Cells D4:D6 look up the required values of lx based on the inputs. Where x is greater than 25, lx = 0. Cell D11 calculates n|mqx using the following formula:

$$_{n|m}q_x = \frac{l_{x+n} - l_{x+n+m}}{l_x}$$

Demographic Mix Chart

This sheet creates a chart showing the number of insects in the population split by five-day age group and sex. Columns D and E link to the 'Data' sheet. Column F assigns the age to a five-day age group using an IF formula. Cells J6:K10 count the number of insects in each sex and age group using a COUNTIFS formula.

A clustered column chart is created using the data in the table.

The following checks have been performed:

- Cell L11 sums the data across all of the age groups and cell L12 sums the data across the two sexes. Both of these should equal the total population of 30.
- Cell L13 checks that both totals are equal, and cell L14 checks that they are equal to 30.

Expectation of Life

This sheet calculates the approximate expectation of life for each insect in the population. First a table of kpx is created for male insects for $0 \leq x \leq 25$ and $1 \leq k \leq 25$ using the following formula:

$$_kp_x = \frac{l_{x+n}}{l_x}$$

Columns AB and AC then calculate the curtate expectation of life, e_x, and the approximate expectation of life. $\mathring{e}_x$, for $0 \leq x \leq 25$ using the following formulae:

$$e_x = \sum_{k=1}^{25-x} {}_kp_x$$

$$\mathring{e}_x \cong e_x + {}^1/_2$$

These calculations are then repeated for female insects.

For each insect in the population, VLOOKUP is used to look up the calculated expectation of life given the age and sex of each insect.

The following checks have been performed:

- Column AE checks that the expectation of life decreases as age increases.
- The maximum and minimum age and expectation of life across the population is calculated and there is a check that these values are between 0 and 25.

Adjusted Life Tables

This sheet calculates adjusted life tables using the reduction factors provided by the researcher. Adjusted qx is calculated separately for males and females using the following formulae:

For $0 \leq x < 25$, $q_x^{reduced} = (1 - reduction\ factor) \times q_x$

For $x = 25$, $q_x^{reduced} = q_x$

For both tables $l_0 = 10{,}000$. For each age dx = qx * lx. For $1 \leq x < 25$, lx = lx-1 – dx-1. For each age px = 1-qx.

The following checks have been performed:

- Columns O and P check that lx decreases as x increases for males and females respectively.
- Columns Q and R check that the reduced qx is less than the original qx up to age 24 for males and females respectively.
- There is a check that q25 = 1 for both males and females.