Chapter 5
Predation and consumption rate analysis

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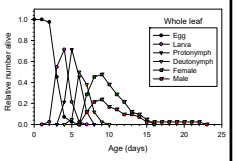
From life history description to life table study

Life table study = { Life history study + Experimental design + Life table theory + Proper data analysis



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Life table is the most and only **comprehensive and correct** way to **describe** the survival and reproduction of a population. But …

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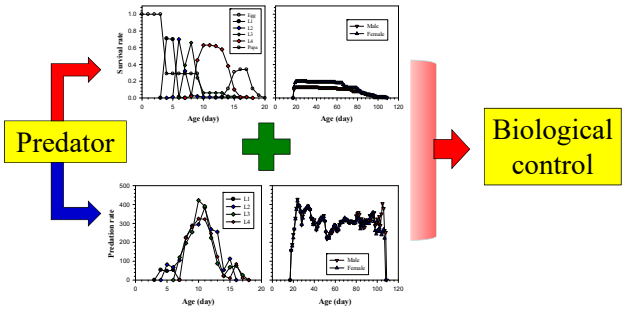
Linking Life Table and Predation Rate for Biological Control



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Linking life table with predation

- But, if you cannot apply your life tables in population projection, biological control, pest management, etc., then you have completed only the simplest and the most basic description of life history.
- Life table is the most important basis of population ecology. Based on life table, you can do good population projection, pest control, mass rearing, etc.

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Life tables are the basis of population ecology

- Prediction of population growth (pest and vector).
- Wild life conservation
- Predator-prey relationship
- Sustainable harvesting
- Biological control: mass rearing and release of natural enemies and quantitative economics.
- ……

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Further applications of life tables

- Population projection
- Insurance
- Harvesting theory
- Timing of control
- Mass rearing and harvesting
- Predator-prey relationship and biological control
- Conservation ecology and endangered species
- Introduced species
- Quarantine pests (risk assessment)
- Food chain analysis
- Ecosystem study
- Habitat evaluation and planning

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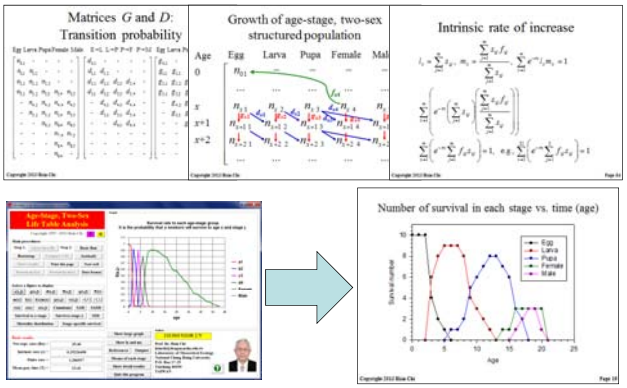
Life table analysis



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Life tables are the beginning, not the end.

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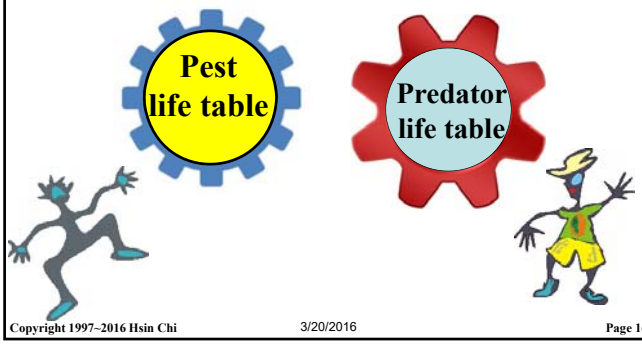
Similarly….

Life table alone cannot achieve much



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Life table theory is the most important basis of population ecology.

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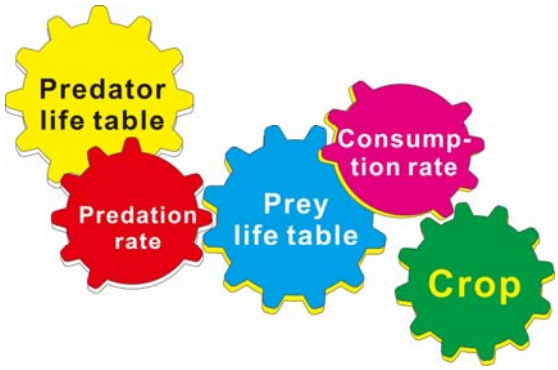
Application



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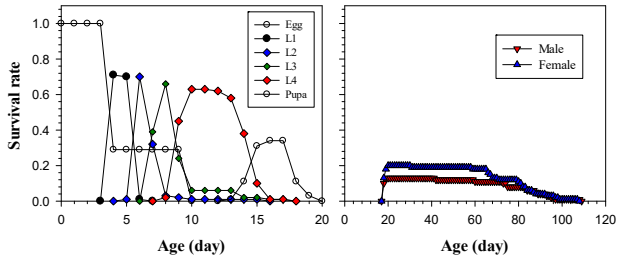
Life table describes the characteristics of a population itself



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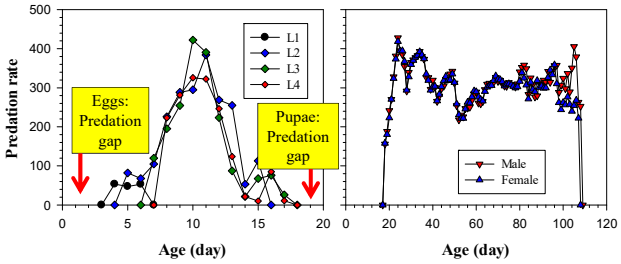
Predation study based on the age-stage, two-sex life table can describe the stage-specific predation rate



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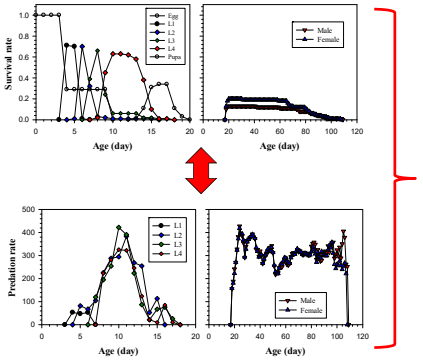
Ecological function of predator



Biological control

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Consumption and predation rate analysis

CONSUME-MSChart

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CONSUME-MSChart can be used to analyze raw data of consumption (pests), predation (predators) and parasitism (parasitoids) rates.

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Raw data of predation rate collected in life table study

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1F	E 0	E 0	E 0	L 4	L 10	L 15	L 18	L 25	P 0	P 0	P 0	P 0	P 0	P 0	P 0	P 0	F 40	F 55	F 64	F 32	F 19
2F	E 0	E 0	E 0	L 3	L 11	L 18	L 27	L 33	L 32	P 0	P 0	P 0	P 0	P 0	F 20	F 35	F 38	F 13	d		
3F	E 0	E 0	E 0	E 0	L 5	L 12	L 43	L 31	L 41	P 0	P 0	P 0	P 0	P 0	P 0	P 0	F 40	F 34	F 46	F 28	F 32
4F	E 0	E 0	E 0	L 7	L 6	L 17	L 22	L 38	L 28	L 22	P 0	P 0	P 0	P 0	P 0	P 0	P 0	P 0	F 26	F 38	F 48
5M	E 0	E 0	E 0	E 0	L 2	L 23	L 16	L 24	L 13	L 12	L 31	L 26	P 0	P 0	P 0	P 0	P 0	P 0	M 34	M 55	M 23

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Non-integer consumption rate collected in life table study

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1F	E 0	E 0	E 0	L 1.2	L 1.5	L 1.6	L 1.8	L 2.5	P 0	P 0	P 0	P 0	P 0	P 0	…
2F	E 0	E 0	E 0	L 3.4	L 1.1	L 1.8	L 2.7	L 3.3	L 3.2	P 0	P 0	P 0	P 0	P 0	…
3F	E 0	E 0	E 0	E	L 0.5	L 1.2	L 4.3	L 3.1	L 4.1	P 0	P 0	P 0	P 0	P 0	…
4F	E 0	E 0	E 0	L 7.5	L 6.3	L 1.7	L 2.2	L 3.8	L 2.8	L 2.2	P 0	P 0	P 0	P 0	…
5M	E 0	E 0	E 0	E 0	L 2.9	L 2.3	L 1.6	L 2.4	L 0.3	L 1.2	L 3.1	L 2.6	P 0	P 0	…

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Data format of CONSUME

F,Egg,L1,L2,L3,L4,Pupa,Female
M,Egg,L1,L2,L3,L4,Pupa,Male
N,Egg,L1,L2,L3,L4,Pupa,Unknown
L1,L4

Same as life table data

1,F,3,1,2,2,3,5,15
-1,3,**-1**,3,8,**-1**,8,16,**-1**,38,42,22,**-1**,**-1**, 30,45,35,60,63,38
60,65,50,59,70,60,63,48,60,**-1**
2,M,3,2,2,3,4,4,10
-1,34,22,**-1**,23,14,**-1**,8,13,21,**-1**,9,18,25,19,**-1**, **-1**
5,6,33,8,**0,0,0,0,0,0,0, -1 (You can omit these zeroes.)**
3,N,3,-2
-1,4,26, **-1 (Use -1 to end predation data of each stage.)**

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Data format of CONSUME

F,Egg,L1,L2,L3,L4,Pupa,Female
M,Egg,L1,L2,L3,L4,Pupa,Male
N,Egg,L1,L2,L3,L4,Pupa,Unknown
L1,L4
1,F,3,1,2,2,3,5,15
-1,3,**-1**,3,8,**-1**,8,16,**-1**,38,42,22,**-1**,**-1**
30,45,35,60,63,38
60,65,50,59,70,60,63,48,60,-1

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Explanation of data format for CONSUME

"Project: Silverleaf whitefly at 25C"
"User: Hsin Chi"
"Date: 2012.4.16.-2012.6.10."

These three lines are descriptive data. They must be enclosed in double quotes.

50 (*Number of insects you used at the beginning of life table study*)

3,7 (*Number of types and number of life stages. Please don't change the number "3". If there were only four life stages, e.g., egg, larva, pupa and adult, you should write 3,4. If there were only two stages, e.g., preadult and adult, you should write 3,2*)

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Explanation of data format for CONSUME

F,Egg,L1,L2,L3,L4,Pupa,Female (*F is the type code of "female".* **Egg, L1, …, Female** *are the stage codes of respective stage.*)

M,Egg,L1,L2,L3,L4,Pupa,Male (*M is the type code of "male".* **Egg, L1, …, Male** *are the stage codes of respective stage.*)

N,Egg,L1,L2,L3,L4,Pupa,Unknown (*N is the type code for individuals died in the immature stages.* **Egg, L1, …, Unknown** *are the stage codes of respective stage.*)

L1,L4 (*This line let you to calculate the total development time from L1 to L4.*)

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Explanation of data format for CONSUME

1,F,6,2,3,4,4,7,19
-1,5,4,-1,6,7,8,-1, 12,15,15,6,-1, 23,43,28,12,-1,-1
23,4,33,12,26,11,29,22,56,12,11,23,25,23,5,6,2,1,6,-1
The first individual is female.
The duration of egg,L1, …, adult are 6, 2, 3,…, 7 days, respectively.
Because the egg does not have predation rate, -1 is used to end the data of this stage.
L1 lived 2 days, the predation rates were 5 and 4.
L2 lived 3 days, the predation rates were 6,7, and 8.
L3 lived 4 days, the predation rates were 12,15,15, and 6.

Explanation of data format for CONSUME

1,F,6,2,3,4,4,7,19
-1,5,4,-1,6,7,8,-1, 12,15,15,6,-1, 23,43,28,12,-1,-1
23,4,33,12,26,11,29,22,56,12,11,23,25,23,5,6,2,1,6,-1
L4 lived 4 days, the predation rates are 23,43,28, and 12.
The pupa does not kill, -1 is used to end the data.
The female lived 19 days in adult stage. The predation rates are 23,4,33,12,26,11,29,22,56,12, 11,23,25,23,5,6,2,1, and 6.
Use "-1" to end of predation data of each stage.
You don't need to enter all zeros at the tail of each stage.

Make debugging easier

1,F,3,2,2,1,6,5,29 **(developmental time in one line)**
-1,20,51,-1,137,169,-1,284,-1,392,496,453,281,37,0,-1,-1
199,222,305,287,249,351,296,276,325,300
214,204,239,268,251,254,248,269,242,74
125,111,108,137,119,121,95,83,45,-1
2,F,3,2,2,1,6,5,18 **(developmental time in one line)**
-1,25,48,-1,135,153,-1,298,-1,351,424,314,257,62,0,-1,-1
148,204,304,311,297,318,325,278,267,273
169,155,163,183,188,194,180,164,-1

Attention!

You should use only pure text editor (NotePad or others) to prepare your data file (i.e., txt file). If you use Word or Excel to prepare you data and save it to txt file, you have to double-check it.

Attention!

Do NOT enter more than 30 data in each line. Press ENTER at the end of each line.

Exercise

Please modify your life table data file, **delete the fecundity data**, **add consumption data to all predatory stages**, and save it to a new folder.

"6-Consumption example"

Delete fecundity and add predation rate

1,F,3,5,8,5 ~~,0,12.5,4,-1~~

-1,2,3,4,3,5,-1,-1,5,6,12,13,15,-1

Egg ..... Larva Pupa Adult

5,M,4,8,6,3

-1,3,3,4,4,3,5,8,2,-1,-1,14,16,18,-1

.....

8,N,3,-6

-1,3,5,3,7,8,2,-1

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Predation example

"Example of predation raw data"
"Chi, H."
"2015.05.09"
10
3,4
F,Egg,Larva,Pupa,Female
M,Egg,Larva,Pupa,Male
N,Egg,Larva,Pupa,Unknown
Larva, Pupa
1,F,3,5,8,5,-1,1,2,2,3,2,-1,-1,4,5,6,7,10,-1
2,F,3,6,5,4,-1,3,4,2,6,8,5,-1,-1,8,9,12,10,-1
3,F,4,5,7,5,-1,4,3,7,5,3,-1,-1,8,4,13,12,12,-1
4,F,3,7,8,3,-1,3,4,2,6,7,3,2,-1,-1,8,15,16,-1
5,M,4,8,6,3,-1,1,2,3,2,2,4,3,2,-1,-1,7,14,12,-1
6,M,5,4,7,4,-1,4,5,3,6,-1,-1,5,16,12,15,-1
7,N,3,3,-9,-1,4,5,3,-1,-1
8,N,3,-6,-1,3,4,3,2,1,1,-1
9,N,6,-7,-1,1,2,3,2,1,2,1,-1
10,M,3,8,6,3,-1,1,2,3,2,3,4,3,2,-1,-1,12,10,14,-1

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CONSUME-MSChart

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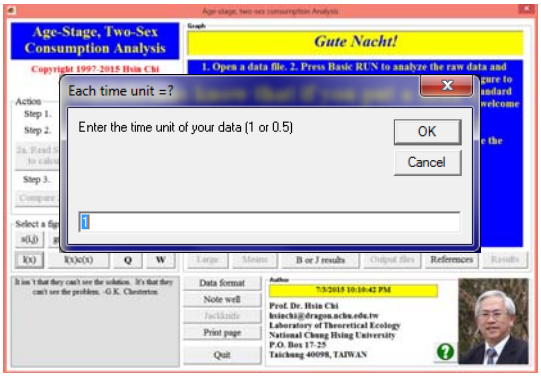
Select your time unit



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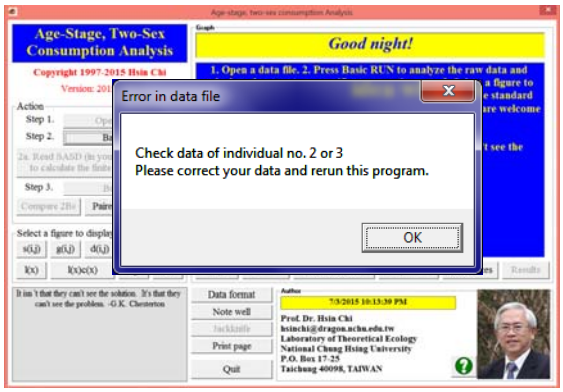
Debug your data



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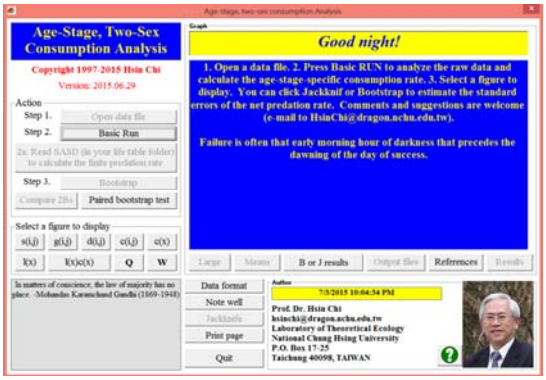
Click on Basic Run



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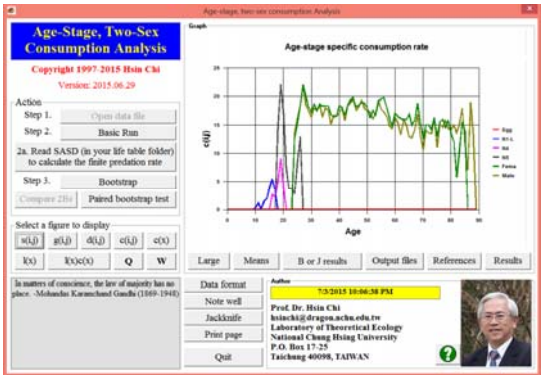
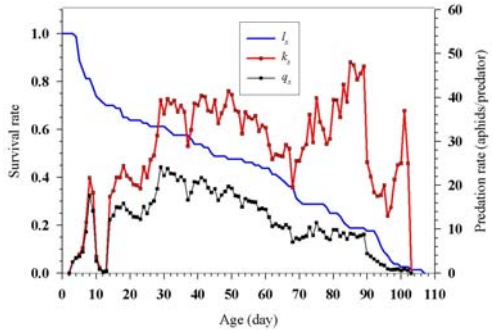
Congratulation!



Exercises

- Go through _output-basic.txt.
- Import graphic data and prepare figures of l_x, k_x, and q_x using Excel or SigmaPlot.
- Detect the relationship between oviposition rate and predation rate.

Prepare a figure for l_x, k_x, and q_x



Net predation rate (C_0 or P_0)

$$C_0 = \sum\sum s_{xj}c_{xj} = \sum\sum b_{xj} = \sum k_x l_x = \sum q_x$$

$$P_0 = \sum\sum s_{xj}p_{xj} = \sum\sum b_{xj} = \sum z_j$$

C_0 is the mean number of prey consumed by an average individual during its life span. The total number of killed prey by a cohort of size N is

NC_0 and NP_0

Net consumption rate (C_0)

0	0	-	-	-	-
1	0	-	-	-	-
2	0	-	-	-	-
3	0	1.5	-	-	-
4	0	2.6	-	-	-
5	0	2.4	-	-	-
6	-	3.5	0	-	-
7	-	3.3	0	-	-
8	-	2.7	0	-	-
9	-	1.1	0	-	-
10	-	0.6	0	-	-
11	-	0.4	0	-	-
12	-	0.1	0	-	-
13	-	-	0	-	-
14	-	-	0	0.8	-
15	-	-	0	0.9	-
16	-	-	0	2.4	0.5
17	-	-	0	1.9	2.8
18	-	-	-	2.7	2.9
19	-	-	-	3.4	4.3
20	-	-	-	3.8	1.2

$$C_0 = \sum\sum s_{xj}c_{xj}$$

Sum $C_0 = 45.8$

$$P_0 = \sum\sum s_{xj}p_{xj}$$

Net predation rate (P_0)

Transformation rate (Q_p) Conversion rate (Q_c)

The transformation rate from prey population to predator offspring (Q_p) is calculated as follows:

$$Q_p = \frac{C_0}{R_0} = \frac{48.5}{11.4} = 4.25$$

4.25 aphids ➞ 1 ladybird beetle egg

Critical thinking

Intrinsic rate of increase has often been used to compare the growth potential of pest populations. Is it justified to conclude that a pest population with a higher intrinsic rate will cause more damage than another with a lower intrinsic rate, while ignoring the difference in consumption rate between them?

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No!

- You cannot make good judgment about the predation capacity without the knowledge of predation rate incorporated into the life table.
- That is the reason why you have to study consumption rate; and for that you need CONSUME program.
- Linking life table with consumption rate is an important step of population ecology.

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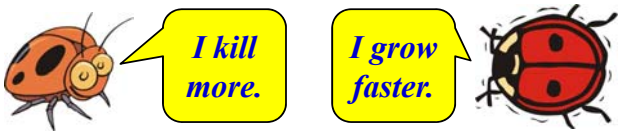
Creative thinking

How can we compare the efficiency of two predators?



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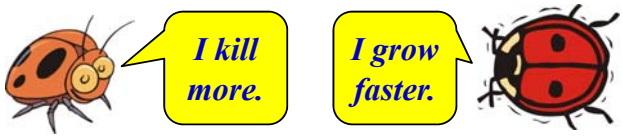
Creative thinking

A predator population with **higher intrinsic rate** may have a low net predation rate. On the other hand, a predator population with **higher net predation rate** may have a low intrinsic rate of increase. How can we compare the efficiency of two predators?



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Finite Predation Rate

Definition	Equation
Stable age-stage distribution (SASD) a_{xj} is the proportion of individuals belonging to age x and stage j in SASD.	$\sum_{x=0}^{\infty}\sum_{j=1}^{m} a_{xj} = 1$
Stable predation rate (ψ: Psi) The total predation capacity of a stable population in which its total size is unity.	$\psi = \sum_{x=0}^{\infty}\sum_{j=1}^{m} a_{xj} c_{xj}$
Finite predation rate (ω: omega) $\lambda\psi$ describes the predation potential of a predator population by combining its growth rate (λ), age-stage predation rate (c_{xj}), and stable age-stage structure (a_{xj}).	$\omega = \lambda\psi$ $= \lambda\sum_{x=0}^{\infty}\sum_{j=1}^{m} a_{xj} c_{xj}$

Biological Control (2013).

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Calculate finite predation rate

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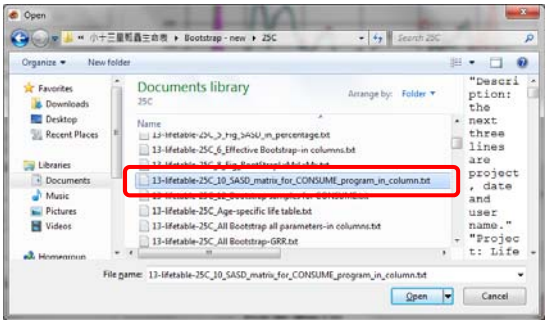
Read SASD from life table folder _10_SASD_for_CONSUME_



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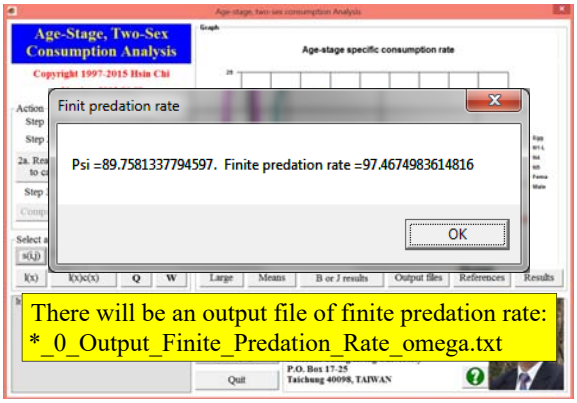
Finite predation rate



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Critical thinking

Do you have to collect the life table and consumption rate (or predation rate) during the same experiment?

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To avoid discrepancy and inconsistency between life table and predation data, it will be better to study them in the same study. But, if it is impossible, you can collect them separately and handle them properly.

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How to link C_0 and R_0

- To estimate the standard error of Q_p, we need to use the same bootstrap samples (100,000 bootstraps) used by TWOSEX.
- **TWOSEX** keeps all bootstrap samples in the file "_11_Bootstrap samples for CONSUME"

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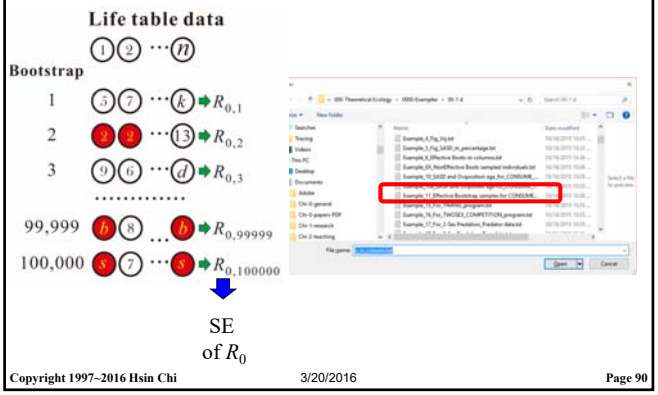
TWOSEX will write all bootstrap samples in the file "_11_Bootstrap samples for CONSUME.txt"



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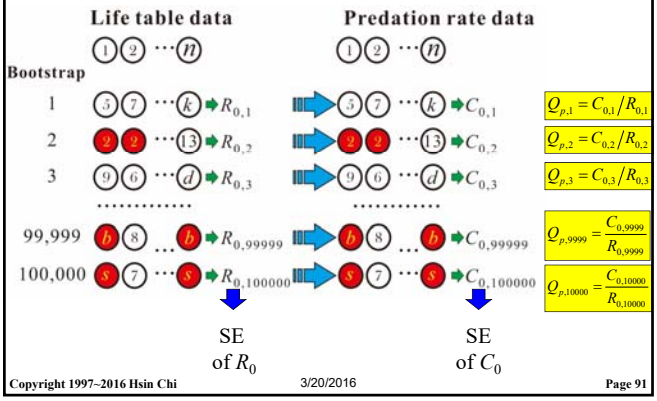
Same bootstrap samples for SE of Q_p



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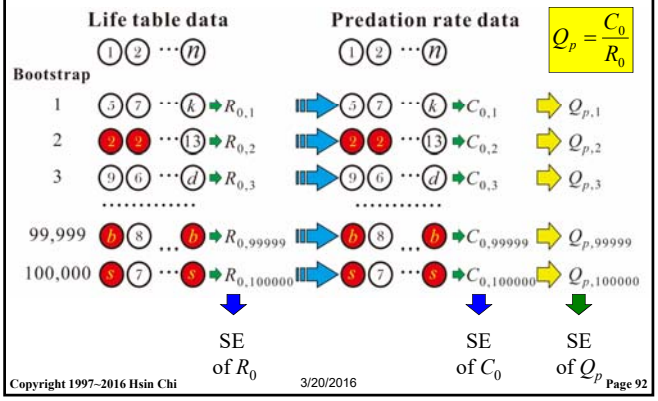
Same bootstrap samples for SE of Q_p



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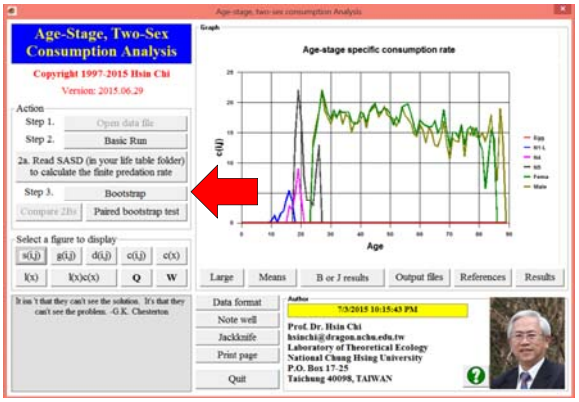
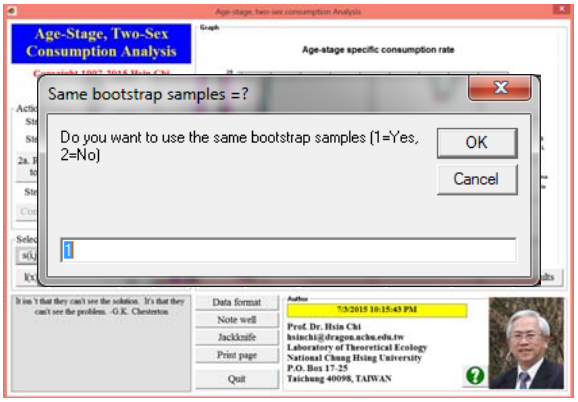
Bootstrap



 3/20/2016

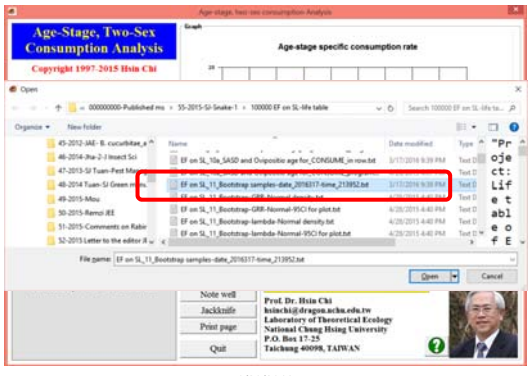
Use the same bootstrap samples?



 3/20/2016

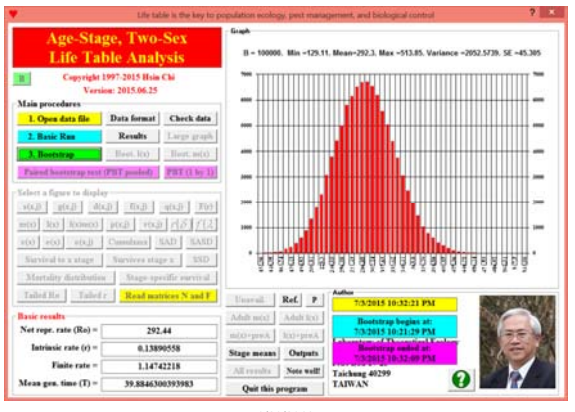
Use the same bootstrap samples

File no. _11_Bootstrap samples (in life table folder)



 3/20/2016

Bootstrap results



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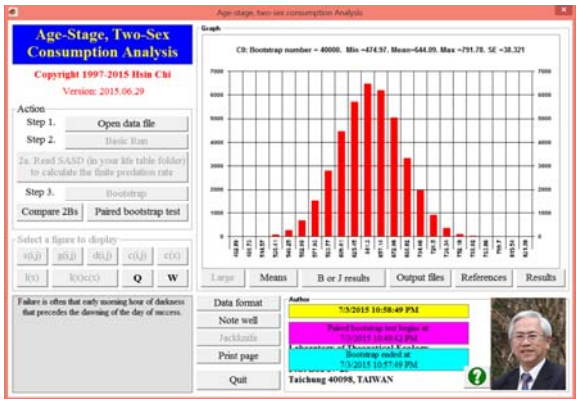
Bootstrap results



Three sources of joy

In the Four Books, Mencius (372-289 BC) says "the superior man has three causes of joy amongst which ruling the Empire has no place. When his father and mother are both alive and his brothers without trouble, this is his first source of joy."

Three sources of joy

"When he can look up to heaven without being ashamed, and down to men without blushing, this is a second source of joy. When he obtains men (Chi: and women) of the best talent under heaven, in order to teach and nourish them, this is a third source of joy. (Translated by The Late Rev. David Collie, 1828)

Sa'adi The Great (1210-1292?)

Saadi Shirazi "Two kinds of people did not gain from their efforts: One who stored but did not eat, One who learned but did not apply."

Chi: "Two kinds of people did not gain from their efforts: One who stored but did not eat, One who learned but did not **apply or teach**."

Analysis of group-reared data with predation rate using TWOSEX-MSChart

Stage	Age-stage survival number																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
E	10	10	10	4	2	1																
L				6	8	9	9	9	8	4	3	2	1									
P							1	1	2	5	6	7	8	8	7	6	3	2				
♀A															1	1	3	3	3	3	3	0
♂A																	1	2	3	3	1	0

Stage	Age-specific total predation rate																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
E	0	0	0	0	0	0																
L				16	28	39	49	55	68	44	35	22	10									
P							0	0	0	0	0	0	0	0	0	0	0	0				
♀A															45	80	90	83	75	42	24	0
♂A																	62	28	46	22	22	0

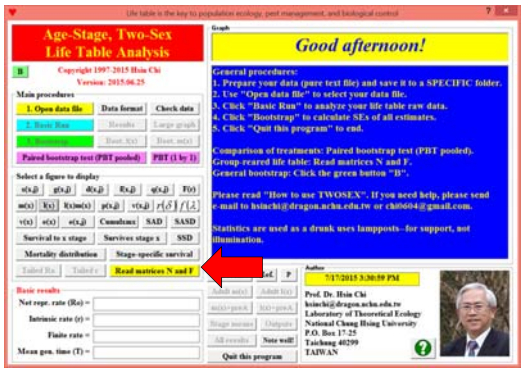
Group-reared data with predation rate

```
.....
N,Egg,Larva,Pupa,Unknown
Egg,0,5
10,10,10,4,2,1
-1
Larva,3,12
6,8,9,9,9,8,4,3,2,1
16,28,39,49,55,68,44,35,22,10
Pupa,6,17
1,1,2,5,6,7,8,8,7,6,3,2
-1
Female,14,20
1,1,3,3,3,3,3
45,80,90,83,75,42,24
Male,16,20
1,2,3,3,1
62,28,46,22,22
Female,14,20
0,15,8,39,26,16,10
```

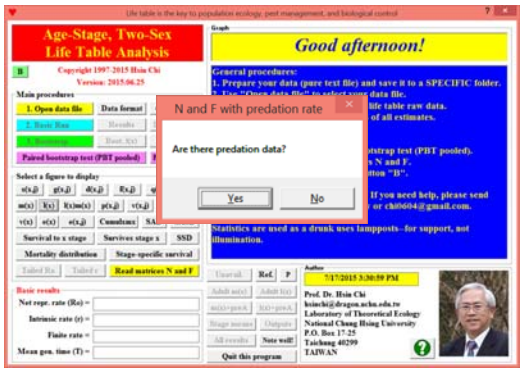
Age-stage total predation rate

Age-stage total fecundity

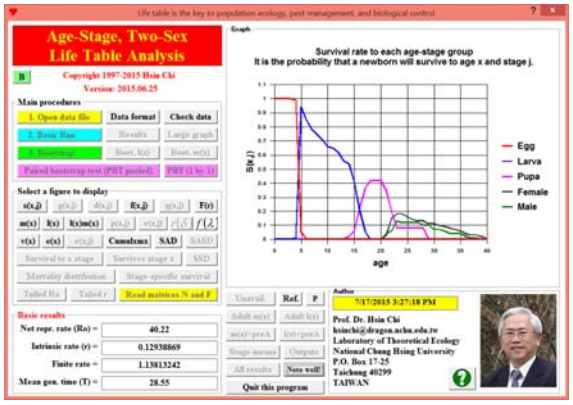
Group-reared life table with predation rate



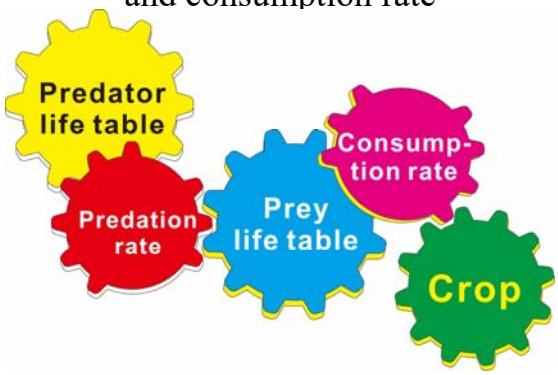
Are there predation data?

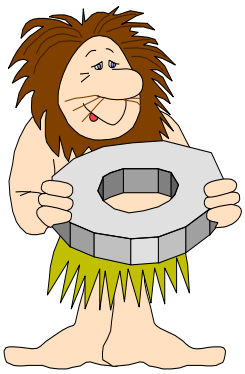


Group-reared life table with predation rate



Ecosystem study based on life tables and consumption rate





Teşekkür ederim!
سپاسگزارم
謝謝!
ขอบคุณครับ
Děkuji
Danke!
¡Muchas gracias!
Thank you!
ご清聴ありがとうございます！