Analysis of group-reared life table
群體飼育生命表分析

齊 心 教授
Prof. Dr. Hsin Chi
Institute of Applied Ecology, Fujian Agriculture and Forestry University
College of Plant Protection, Shandong Agricultural University

Life table raw data 生命表原始紀錄 (age 0~21 d)

	Sex	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	M	**E**	**E**	**E**	**E**	**E**	**E**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**P**	**P**	**P**	**P**	**P**
2	F	**E**	**E**	**E**	**E**	**E**	**E**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**P**	**P**	**P**	**P**	**P**	**P**
3	F	**E**	**E**	**E**	**E**	**E**	**E**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**P**	**P**	**P**	**P**	**P**
4	F	**E**	**E**	**E**	**E**	**E**	**E**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**P**	**P**	**P**	**P**
5	M	**E**	**E**	**E**	**E**	**E**	**E**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**P**	**P**	**P**	**P**
6	F	**E**	**E**	**E**	**E**	**E**	**E**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**P**	**P**	**P**	**P**
7	M	**E**	**E**	**E**	**E**	**E**	**E**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**P**	**P**	**P**
8	**F**	**E**	**E**	**E**	**E**	**E**	**E**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**P**	**P**	**P**	**P**	**P**
9	**F**	**E**	**E**	**E**	**E**	**E**	**E**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**P**	**P**	**P**	**P**
10	**M**	**E**	**E**	**E**	**E**	**E**	**E**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**P**	**P**	**P**	**P**
11	M	**E**	**E**	**E**	**E**	**E**	**E**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**P**	**P**	**P**	**P**
12	F	**E**	**E**	**E**	**E**	**E**	**E**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**P**	**P**	**P**	**P**
13	F	**E**	**E**	**E**	**E**	**E**	**E**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**P**	**P**	**P**
14	M	**E**	**E**	**E**	**E**	**E**	**E**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**P**	**P**	**P**
15	F	**E**	**E**	**E**	**E**	**E**	**E**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**P**	**P**	**P**
16	F	**E**	**E**	**E**	**E**	**E**	**E**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**P**	**P**	**P**
17	M	**E**	**E**	**E**	**E**	**E**	**E**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**P**	**P**
18	**F**	**E**	**E**	**E**	**E**	**E**	**E**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**P**	**P**
19	**N**	**E**	**E**	**E**	**E**	**E**	**E**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**P**	**P**	**P**
20	**N**	**E**	**E**	**E**	**E**	**E**	**E**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**						

Life table raw data 生命表原始紀錄 (age 22~43 d)

	Sex	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
1	M	P	P	P	P	P	P	P	M	M	M	M	M	M									
2	F	P	P	P	P	P	F	F	F	F	F	F	F	F	F	F							
3	F	P	P	P	P	P	F	F	F	F	F	F	F	F	F	F							
4	F	P	P	P	P	P	P	F	F	F	F	F	F	F									
5	M	P	P	P	P	P	P	P	M	M	M	M	M										
6	F	P	P	P	P	P	P	P	F	F	F	F	F	F	F	F	F	F	F	F	F	F	
7	M	P	P	P	P	P	P	P	M	M	M	M	M	M	M	M							
8	F	P	P	P	P	F	F	F	F	F	F	F	F	F	F	F							
9	F	P	P	P	P	P	P	P	F	F	F	F	F	F	F	F	F						
10	M	P	P	P	P	P	P	P	M	M	M	M	M	M									
11	M	P	P	P	P	P	P	P	P	M	M	M	M	M	M	M							
12	F	P	P	P	P	P	P	P	P	F	F	F	F	F	F	F	F						
13	F	P	P	P	P	P	P	P	F	F	F	F	F	F	F	F	F	F					
14	M	P	P	P	P	P	P	P	P	M	M	M	M	M	M	M	M						
15	F	P	P	P	P	P	P	P	P	P	F	F	F	F	F	F	F	F	F	F			
16	F	P	P	P	P	P	P	P	P	F	F	F	F	F	F	F	F	F					
17	M	P	P	P	P	P	P	P	P	M	M	M	M	M	M								
18	F	P	P	P	P	P	P	P	P	P	F	F	F	F	F	F							
19	N	P	P	P	P	P																	
20	N																						

Group-reared data?

- If insects are reared in group, you can still use TWOSEX to calculate the population parameters.
- Your data must be collected at the same time interval.
- You will get matrices N and F_{total}.

Advantage of group rearing

- You can save time, space, and labor.
- Females can mate with strong males.
- The probability that a female doesn't produce eggs due to the weakness of its mate is low.
- Insects can help each other to digest food.
- The growth of bacteria will be limited.
- It is more close to the natural condition(?).

Disadvantage of group rearing

- You don’t have data for each individual.
- You don’t have precise developmental time.
- There may be cannibalism.
- There may be competition.
- …

Group-reared data

	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
Eggs															0	15	8	39	26	16	10	0

Group-reared data

	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
Eggs															0	15	8	39	26	16	10	0

Matrix N

F_{total}

Explanation: Group-reared data

Stage	Time (age)																				
	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
Eggs															0	15	8	39	26	16	10	0

Egg,0,5 (Age range of egg stage is 0~5)

10,10,10,4,2,1 **(Survival number at each age)**

Female,14,20 (Age range of female is 14~20)

0,15,8,39,26,16,10 (Daily total eggs laid by surviving females)

Data format life table based on matrices N and F_{total}

"Example of life table raw data"

"Chi, H."

"2009.01.09"

10

3,4

F,Egg,Larva,Pupa,Female

M,Egg,Larva,Pupa,Male

N,Egg,Larva,Pupa,Unknown

Egg,0,5 (age range of egg)

10,10,10,4,2,1 **(survival number)**

Larva,3,12 (age range of larva)

6,8,9,9,9,8,4,3,2,1

Pupa,6,17 (age range of pupal stage)

1,1,2,5,6,7,8,8,7,6,3,2

Female,14,20 (age range of female)

1,1,3,3,3,3,3

Male,16,20 (age range of male)

1,2,3,3,1

Female,14,20 (age range of female)

0,15,8,39,26,16,10 (Daily total eggs)

Data file for life table based on matrices N and F_{total}

```
"Example of life table raw data"
"Jennifer"
"PT"
10
3,4
F,Egg,Larva,Pupa,Female
M,Egg,Larva,Pupa,Male
N,Egg,Larva,Pupa,Unknown
Egg,0,5
10,10,10,4,2,1
Larva,3,12
6,8,9,9,9,8,4,3,2,1
Pupa,6,17
1,1,2,5,6,7,8,8,7,6,3,2
Female,14,20
1,1,3,3,3,3,3
Male,16,20
1,2,3,3,1
Female,14,20
0,15,8,39,26,16,10
```

Group life table data with predation rate

```
"Example of life table raw data"
"Jennifer"
"PT"
10
3,4
F,Egg,Larva,Pupa,Female
M,Egg,Larva,Pupa,Male
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
12,15,15,16,20,16,18,5,4,2
Pupa,6,17
1,1,2,5,6,7,8,8,7,6,3,2,-1
Female,14,20
1,1,3,3,3,3,3,12,14,23,22,25,13,10
Male,16,20
1,2,3,3,1,17,20,23,13,10
Female,14,20
0,15,8,39,26,16,10
```

Using matrix *N* to calculate matrix *S*

Age-stage survival number (Matrix *N*)

Age	Egg	Larva	Pupa	Female	Male
0	20	0	0	0	0
1	20	0	0	0	0
2	20	0	0	0	0
3	20	0	0	0	0
4	20	0	0	0	0
5	20	0	0	0	0
6	0	20	0	0	0
7	0	20	0	0	0
8	0	20	0	0	0
9	0	20	0	0	0
10	0	20	0	0	0
11	0	20	0	0	0
12	0	20	0	0	0
13	0	20	0	0	0
14	0	20	0	0	0
15	0	20	0	0	0
16	0	18	1	0	0
17	0	15	4	0	0
18	0	8	11	0	0
19	0	2	17	0	0
20	0	0	19	0	0

Matrix *S*

Egg	Larva	Pupa	Female	Male
1	0	0	0	0
1	0	0	0	0
1	0	0	0	0
1	0	0	0	0
1	0	0	0	0
1	0	0	0	0
0	1	0	0	0
0	1	0	0	0
0	1			
0	1			
0	1			
0	1			
0	1			
0	1			
0	1	0	0	0
0	1	0	0	0
0	0.9	0.05	0	0
0	0.75	0.2	0	0
0	0.4	0.55	0	0
0	0.1	0.85	0	0
0	0	0.95	0	0

$$s_{xj} = \frac{n_{xj}}{n_{01}}$$

Using matrix *N* to calculate matrix *S*

Age-stage survival number (Matrix *N*)

Age	Egg	Larva	Pupa	Female	Male
20	0	0	19	0	0
21	0	0	19	0	0
22	0	0	19	0	0
23	0	0	19	0	0
24	0	0	19	0	0
25	0	0	19	0	0
26	0	0	18	1	0
27	0	0	15	3	0
28	0	0	14	4	0
29	0	0	7	7	4
30	0	0	2	9	7
31	0	0	0	11	7
32	0	0	0	11	7
33	0	0	0	11	7
34	0	0	0	11	6
35	0	0	0	10	4
36	0	0	0	10	3
37	0	0	0	6	1
38	0	0	0	4	0
39	0	0	0	2	0
40	0	0	0	2	0

Matrix *S*

Egg	Larva	Pupa	Female	Male
0	0	0.95	0	0
0	0	0.95	0	0
0	0	0.95	0	0
0	0	0.95	0	0
0	0	0.95	0	0
0	0	0.95	0	0
0	0	0.9	0.05	0
0	0	0.75	0.15	0
0	0			
0	0			
0	0			
0	0			
0	0			
0	0			
0	0	0	0.55	0.3
0	0	0	0.5	0.2
0	0	0	0.5	0.15
0	0	0	0.3	0.05
0	0	0	0.2	0
0	0	0	0.1	0
0	0	0	0.1	0

$$s_{xj} = \frac{n_{xj}}{n_{01}}$$

Use S and $f_{x,\text{total}}$ to calculate l_x, f_{xj}, m_x

Age	l_x	f(total)	$f_{x,\text{female}}$	m_x	$l_x m_x$			
0	1	0			0			
1	1	0			0			
2	1	0			0			
3	1	0			0			
4	1	0			0			
5	1	0			0			
6	1	0			0			
7	1	0			0			
25	0.95	0			0			
26	0.95	0	0	0	0			
27	0.9	0	0	0	0			
28	0.9	146	36.5	8.111	7.3			
29	0.9	278	39.714	15.44	13.9			
30	0.9	440	48.889	24.44	22			
31	0.9	158	14.364	8.778	7.9			
32	0.9	258	23.455	14.33	12.9			
33	0.9	68	6.1818	3.778	3.4			
34	0.85	35	3.1818	2.059	1.75			
35	0.7	4	0.4	0.286	0.2			
36	0.65	3	0.3	0.231	0.15			
37	0.35	4	0.6667	0.571	0.2			

$$l_x = \sum_{j=1}^{m} s_{xj}$$

$$f_{xj} = \frac{f_{x,\text{total}}}{n_{xj}}$$

$$m_x = \frac{\sum_{j=1}^{m} f_{xj} s_{xj}}{\sum_{j=1}^{m} s_{xj}} = \frac{\sum_{j=1}^{m} f_{xj} s_{xj}}{l_x}$$

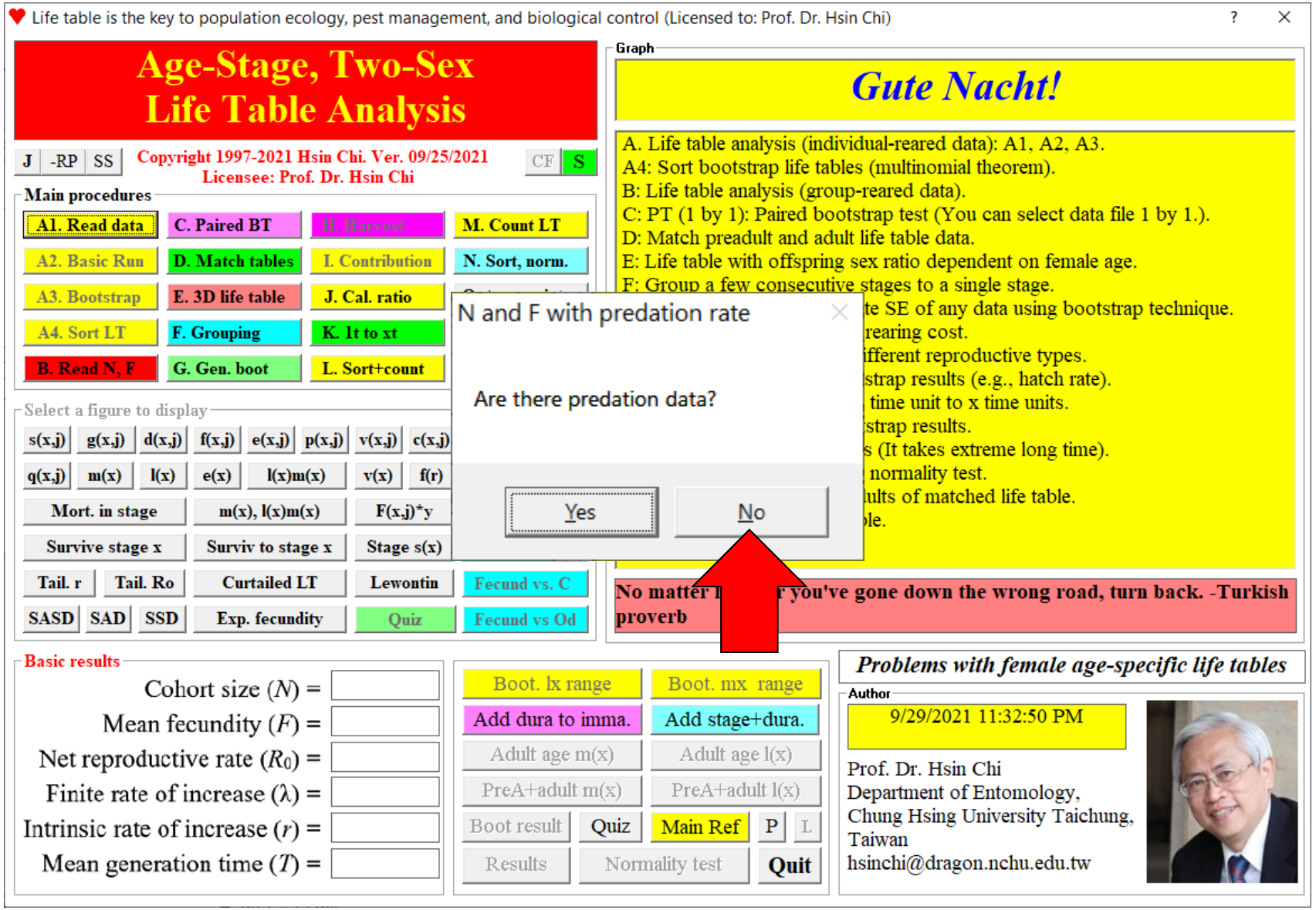
You can calculate the population parameters based on matrices N and F_{total}, but you cannot estimate the standard errors, because you don't know the variability of developmental rate and fecundity among individuals. If you carry out 3 replicates, you can use routine method to calculate the mean and standard error.

Analysis of group-reared life table

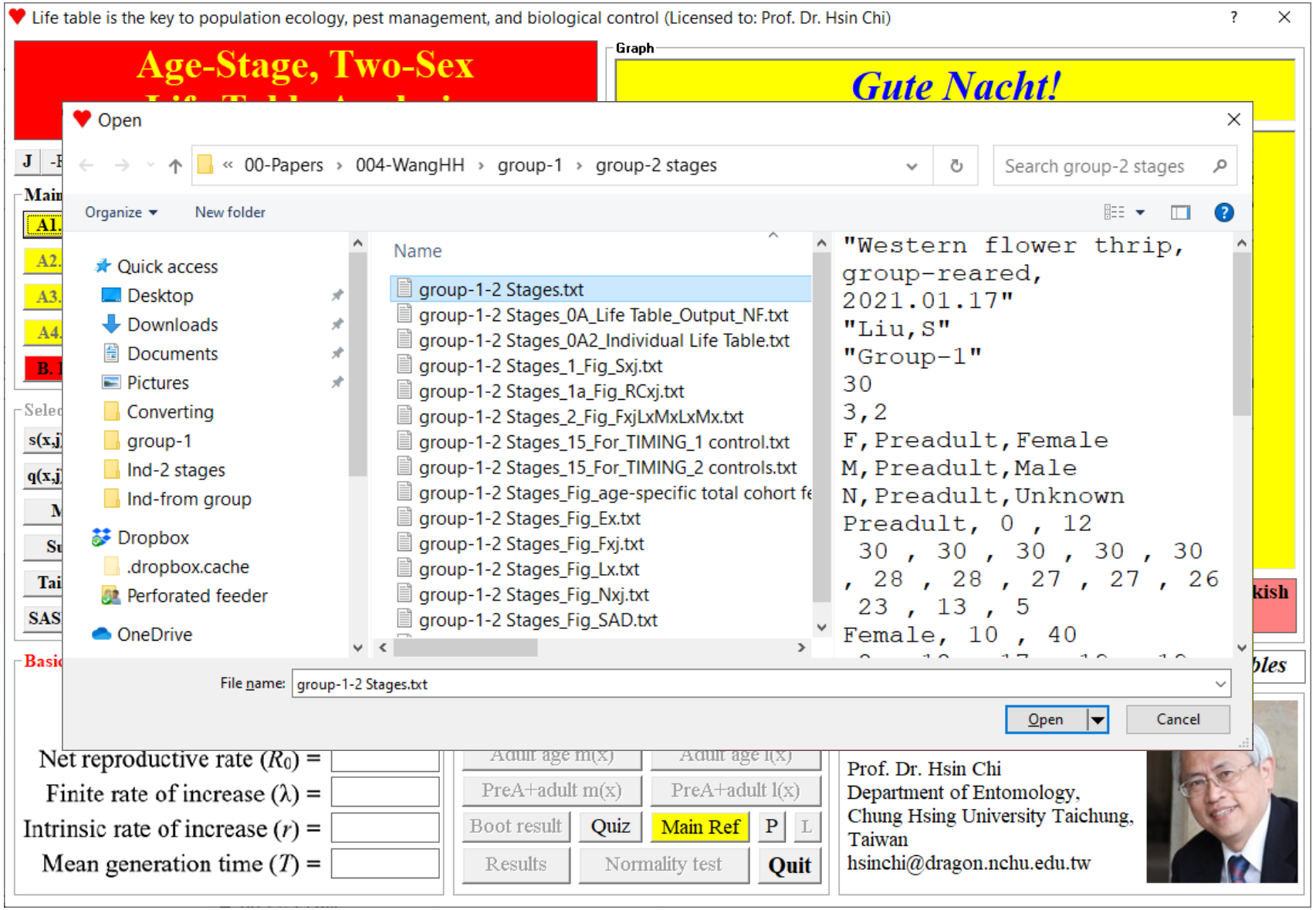
Convert group-reared life table to individual-reared data

- Sometimes, it is possible to convert group-reared life table data to individual-reared life table data. Then you can use the individual reared life table data to run bootstrap.
- Because the mean fecundity will be assigned to each surviving female adults of the same age, the standard errors estimated by using bootstrap will underestimate the real SE.
- If you have 3 replicates of group-reared life table data, it is better to convert them separately. Then pool the 3 converted individual life table data. It gives more realistic results.
- This option is reserved for advanced users only.

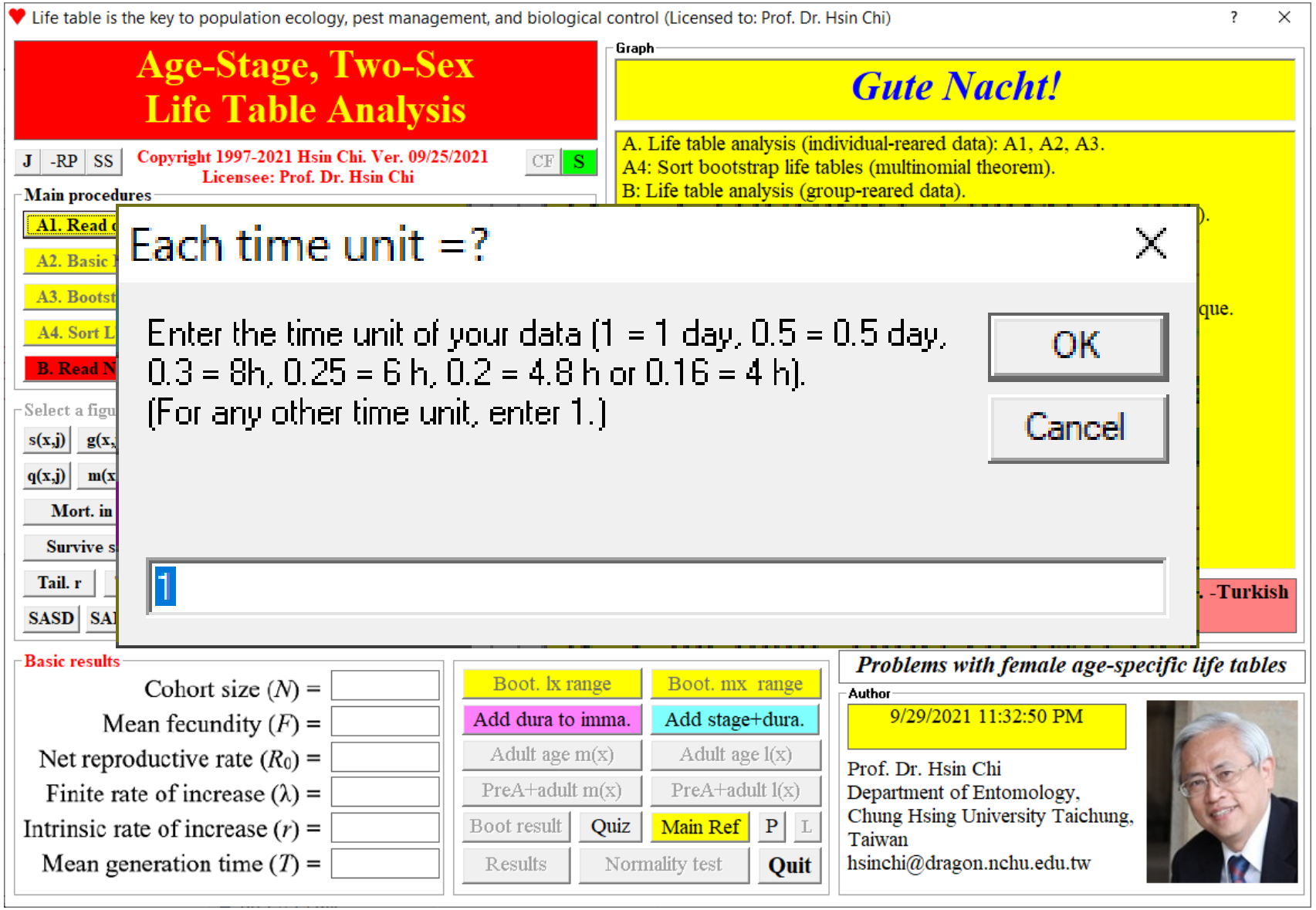
Are there predation data?

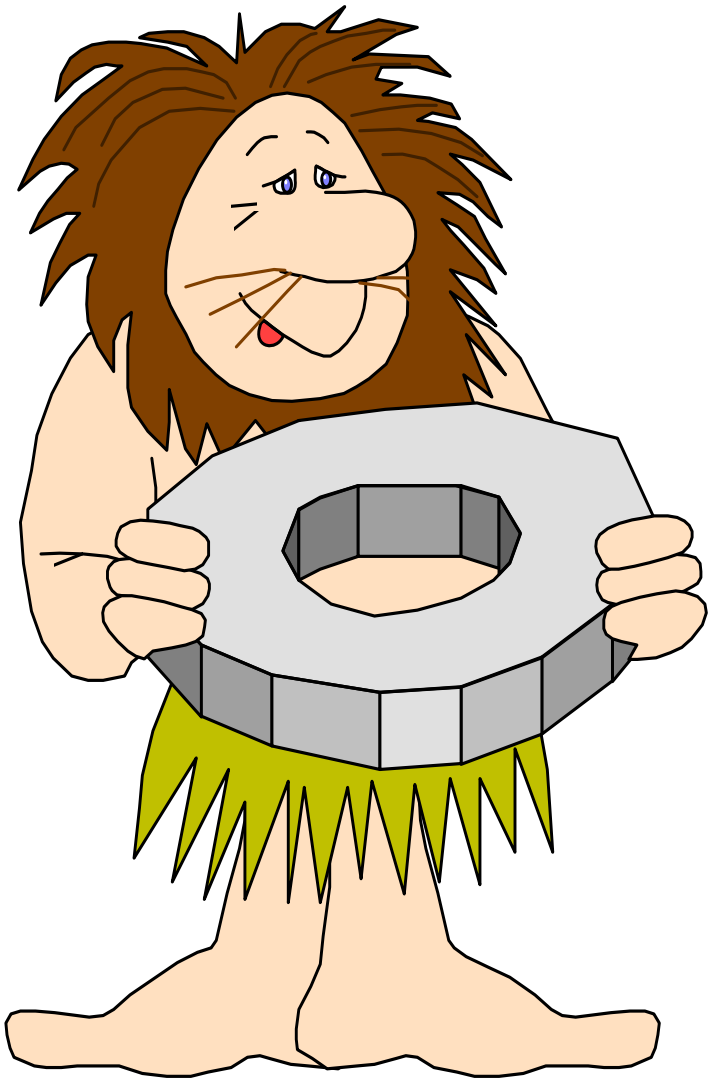


Open group-reared life table data file



Enter the time unit





Teşekkür ederim!

سپاسگزارم

謝謝!

"Å¼Ë˘Ł¼

Děkuji

Danke!

¡Muchas gracias!

Thank you!

ご清聴ありがとうございます！