

# Analysis of group-reared life table

## 群體飼育生命表分析

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# 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							

# 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	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	F		
16	F	P	P	P	P	P	P	P	P	F	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

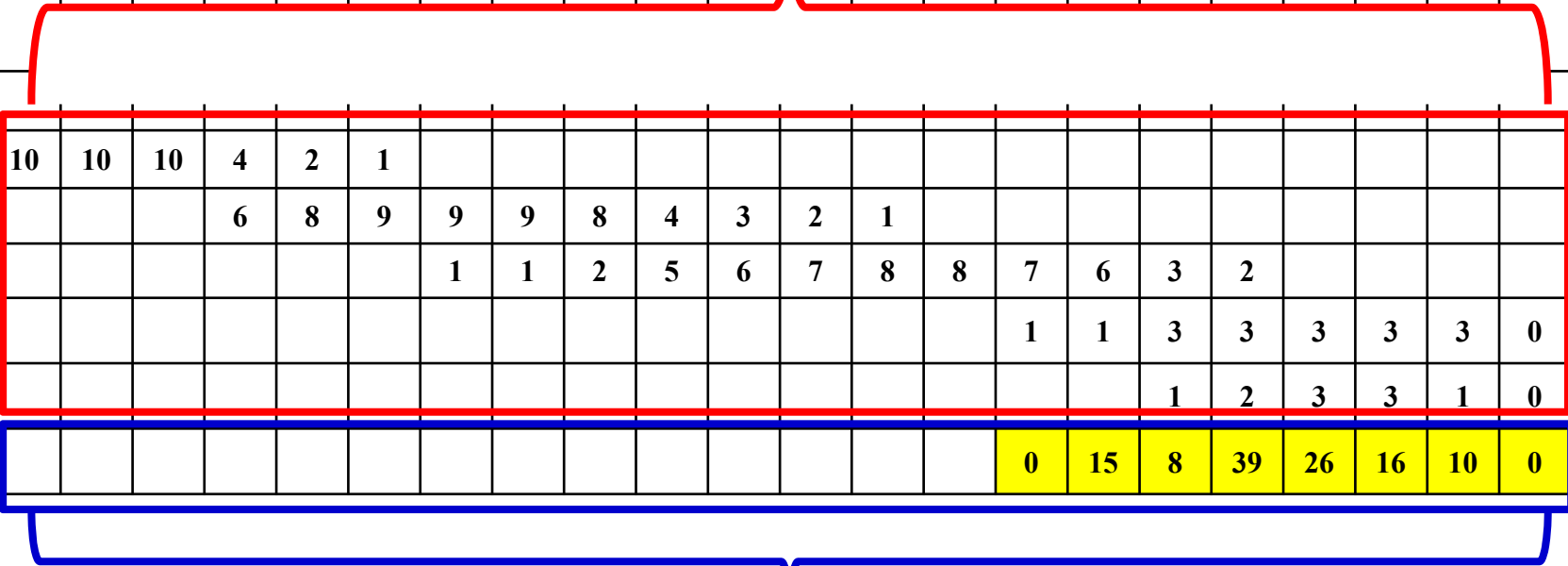
- You don't have data for each individual.
- You don't have precise developmental time.
- There may be cannibalism.
- There may be competition.
- ...



# 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

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"	Larva,3,12 (age range of larva)
"Chi, H."	6,8,9,9,9,8,4,3,2,1
"2009.01.09"	Pupa,6,17 (age range of pupal stage)
10	
3,4	1,1,2,5,6,7,8,8,7,6,3,2
F,Egg,Larva,Pupa,Female	Female,14,20 (age range of female)
M,Egg,Larva,Pupa,Male	1,1,3,3,3,3,3
N,Egg,Larva,Pupa,Unknown	Male,16,20 (age range of male)
Egg,0,5 (age range of egg)	1,2,3,3,1
10,10,10,4,2,1 (survival number)	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	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	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	0.7	0.2	0
0	0	0.6	0.3	0
0	0	0.5	0.4	0
0	0	0.4	0.5	0
0	0	0.3	0.6	0
0	0	0.2	0.7	0
0	0	0.1	0.8	0
0	0	0.1	0.9	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	$l_x$	$f(\text{total})$	$f_{x,\text{female}}$	$m_x$	$l_x m_x$			
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

♥ Life table is the key to population ecology, pest management, and biological control (Licensed to: Prof. Dr. Hsin Chi) ? X

## Age-Stage, Two-Sex Life Table Analysis

J -RP SS
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Licensee: Prof. Dr. Hsin Chi
CF S

**Main procedures**

A1. Read data	C. Paired BT	H. Harvest	M. Count LT
A2. Basic Run	D. Match tables	I. Contribution	N. Sort, norm.
A3. Bootstrap	E. 3D life table	J. Cal. ratio	O. + overwinter
A4. Sort LT	F. ...	K. It to xt	P. Spec. boot
B. Read N, F	L. Sort+count	Q. Cartesian	

Select a figure to display

s(x,j)	g(x,j)	d(x,j)	f(x,j)	e(x,j)	p(x,j)	v(x,j)	c(x,j)	r( $\delta$ )	f( $\lambda$ )
q(x,j)	m(x)	l(x)	e(x)	l(x)m(x)	v(x)	f(r)	Cumu. Ro(x)		
Mort. in stage	m(x), l(x)m(x)		F(x,j)*y		Fecund vs L				
Survive stage x	Surviv to stage x		Stage s(x)		Fecund vs AL				
Tail. r	Tail. Ro	Curtailed LT		Lewontin		Fecund vs. C			
SASD	SAD	SSD	Exp. fecundity		Quiz	Fecund vs Od			

**Basic results**

Cohort size ( $N$ ) =	<input type="text"/>
Mean fecundity ( $F$ ) =	<input type="text"/>
Net reproductive rate ( $R_0$ ) =	<input type="text"/>
Finite rate of increase ( $\lambda$ ) =	<input type="text"/>
Intrinsic rate of increase ( $r$ ) =	<input type="text"/>
Mean generation time ( $T$ ) =	<input type="text"/>

Boot. lx range	Boot. mx range
Add dura to imma.	Add stage+dura.
Adult age m(x)	Adult age l(x)
PreA+adult m(x)	PreA+adult l(x)
Boot result	Quiz
Results	Normality test
	Main Ref
	P
	L
	Quit

**Problems with female age-specific life tables**

Author

9/29/2021 11:32:50 PM

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Gute Nacht!

A. Life table analysis (individual-reared data): A1, A2, A3.  
A4: Sort bootstrap life tables (multinomial theorem).  
B: Life table analysis (group-reared data).  
C: PT (1 by 1): Paired bootstrap test (You can select data file 1 by 1.).  
D: Match preadult and adult life table data.  
E: Life table with offspring sex ratio dependent on female age.  
F: Group a few consecutive stages to a single stage.  
G: General bootstrap: Estimate SE of any data using bootstrap technique.  
H: Calculate harvest rate and rearing cost.  
I: Calculate contribution of different reproductive types.  
J: Calculate ratio of two bootstrap results (e.g., hatch rate).  
K: Change life table data of 1 time unit to x time units.  
L: Read, sort and count bootstrap results.  
M: Count bootstrap life tables (It takes extreme long time).  
N: Sort bootstrap results and normality test.  
O: Add overwinter time to adults of matched life table.  
P: Write specific boot life table.  
Q: Cartesian product.

No matter how far you've gone down the wrong road, turn back. -Turkish proverb

## 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?

♥ Life table is the key to population ecology, pest management, and biological control (Licensed to: Prof. Dr. Hsin Chi) ? X

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A3. Bootstrap	E. 3D life table	J. Cal. ratio	
A4. Sort LT	F. Grouping	K. It to xt	
B. Read N, F	G. Gen. boot	L. Sort+count	

Select a figure to display

s(x,j)	g(x,j)	d(x,j)	f(x,j)	e(x,j)	p(x,j)	v(x,j)	c(x,j)
q(x,j)	m(x)	l(x)	e(x)	l(x)m(x)	v(x)	f(r)	
Mort. in stage	m(x), l(x)m(x)		F(x,j)*y				
Survive stage x	Surviv to stage x		Stage s(x)				
Tail. r	Tail. Ro	Curtailed LT		Lewontin	Fecund vs. C		
SASD	SAD	SSD	Exp. fecundity	Quiz	Fecund vs Od		

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Mean generation time ( $T$ ) =	<input type="text"/>

Boot. lx range	Boot. mx range
Add dura to imma.	Add stage+dura.
Adult age m(x)	Adult age l(x)
PreA+adult m(x)	PreA+adult l(x)
Boot result	Quiz
Results	Normality test
	Main Ref
	P
	L
	Quit

**Problems with female age-specific life tables**

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**Graph**

### Gute Nacht!

A. Life table analysis (individual-reared data): A1, A2, A3.  
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N and F with predation rate

Are there predation data?

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# Open group-reared life table data file

Life table is the key to population ecology, pest management, and biological control (Licensed to: Prof. Dr. Hsin Chi)

**Age-Stage, Two-Sex** **Gute Nacht!**

Open

00-Papers > 004-WangHH > group-1 > group-2 stages

Search group-2 stages

Name	Content
group-1-2 Stages.txt	"Western flower thrip, group-reared, 2021.01.17" "Liu, S" "Group-1" 30 3, 2 F, Preadult, Female M, Preadult, Male N, Preadult, Unknown Preadult, 0, 12 30, 30, 30, 30, 30 , 28, 28, 27, 27, 26 23, 13, 5 Female, 10, 40
group-1-2 Stages_OA_Life Table_Output_NF.txt	
group-1-2 Stages_OA2_Individual Life Table.txt	
group-1-2 Stages_1_Fig_Sxj.txt	
group-1-2 Stages_1a_Fig_RCxj.txt	
group-1-2 Stages_2_Fig_FxjLxMxLxMx.txt	
group-1-2 Stages_15_For_TIMING_1 control.txt	
group-1-2 Stages_15_For_TIMING_2 controls.txt	
group-1-2 Stages_Fig_age-specific total cohort fe	
group-1-2 Stages_Fig_Ex.txt	
group-1-2 Stages_Fig_Fxj.txt	
group-1-2 Stages_Fig_Lx.txt	
group-1-2 Stages_Fig_Nxj.txt	
group-1-2 Stages_Fig_SAD.txt	

File name: group-1-2 Stages.txt

Open Cancel

Net reproductive rate ( $R_0$ ) =

Finite rate of increase ( $\lambda$ ) =

Intrinsic rate of increase ( $r$ ) =

Mean generation time ( $T$ ) =


Adult age m(x)    Adult age l(x)

PreA+adult m(x)    PreA+adult l(x)

Boot result    Quiz    **Main Ref**    P    L

Results    Normality test    **Quit**

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# Enter the time unit

♥ Life table is the key to population ecology, pest management, and biological control (Licensed to: Prof. Dr. Hsin Chi) ? X

## Age-Stage, Two-Sex Life Table Analysis

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J -RP SS CF S

**Main procedures**

- A1. Read d
- A2. Basic
- A3. Bootst
- A4. Sort L
- B. Read N

Select a figure

s(x,j) g(x,j)

q(x,j) m(x,j)

Mort. in

Survive s

Tail. r

SASD SA

Gute Nacht!

A. Life table analysis (individual-reared data): A1, A2, A3.  
A4: Sort bootstrap life tables (multinomial theorem).  
B: Life table analysis (group-reared data).

### Each time unit =?

Enter the time unit of your data (1 = 1 day, 0.5 = 0.5 day,  
0.3 = 8h, 0.25 = 6 h, 0.2 = 4.8 h or 0.16 = 4 h).  
(For any other time unit, enter 1.)

1

**Basic results**

Cohort size ( $N$ ) =

Mean fecundity ( $F$ ) =

Net reproductive rate ( $R_0$ ) =

Finite rate of increase ( $\lambda$ ) =

Intrinsic rate of increase ( $r$ ) =

Mean generation time ( $T$ ) =

Boot. lx range    Boot. mx range

Add dura to imma.    Add stage+dura.

Adult age m(x)    Adult age l(x)

PreA+adult m(x)    PreA+adult l(x)

Boot result    Quiz    Main Ref    P    L


Results    Normality test    Quit

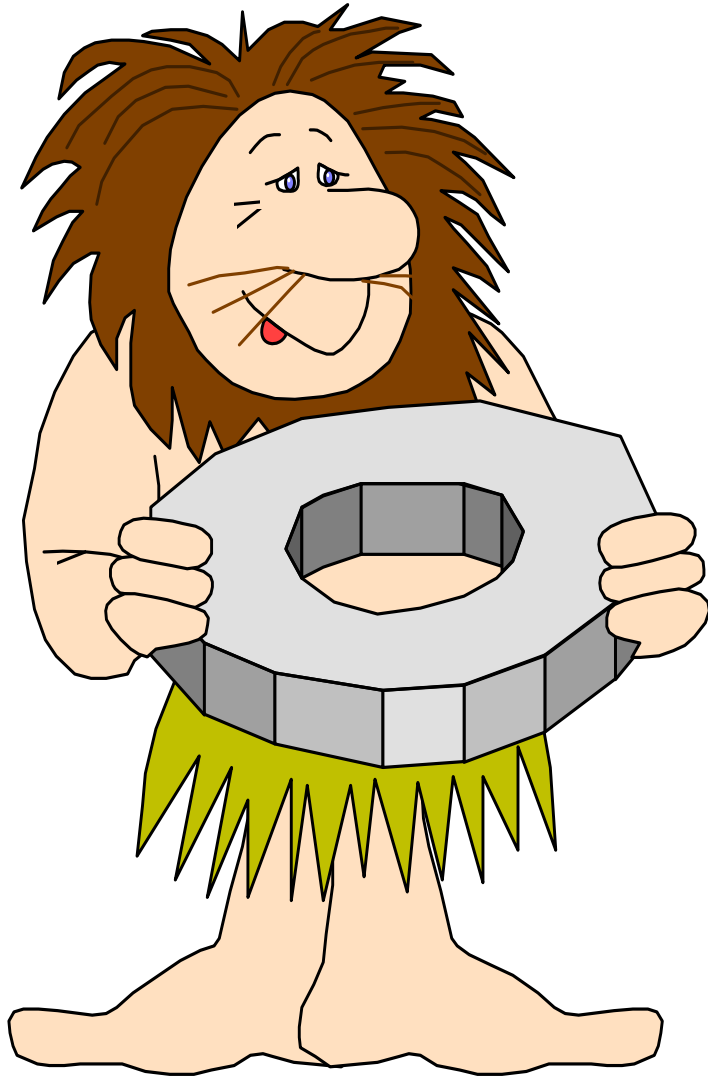
**Problems with female age-specific life tables**

Author

9/29/2021 11:32:50 PM

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Teşekkür ederim!

سپاسگزارم

謝謝!

“À¼É¼İ¼

Děkuji

Danke!

¡Muchas gracias!

Thank you!

ご清聴ありがとうございます  
います!