Chapter 6
TIMING: Population projection

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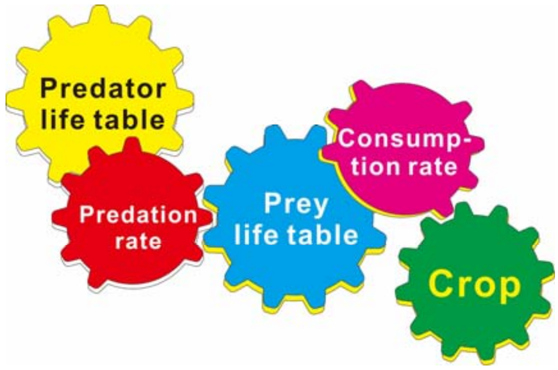
Application of life tables



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Population projection based on age-stage, two-sex life table

TIMING-MSChart

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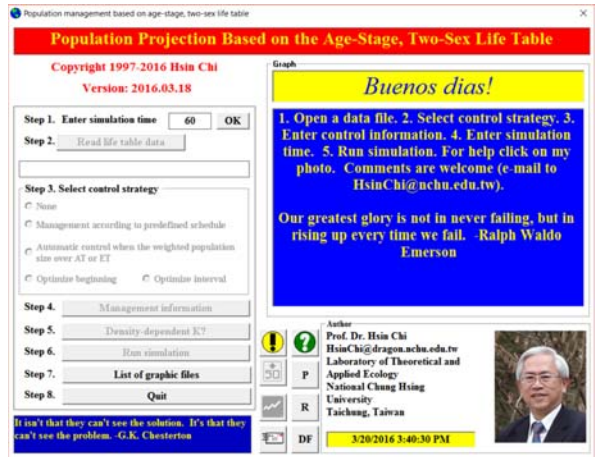

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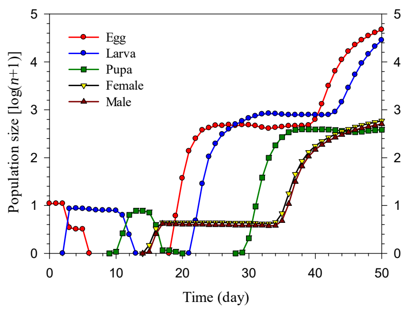
Population Projection by using TIMING-MSChart



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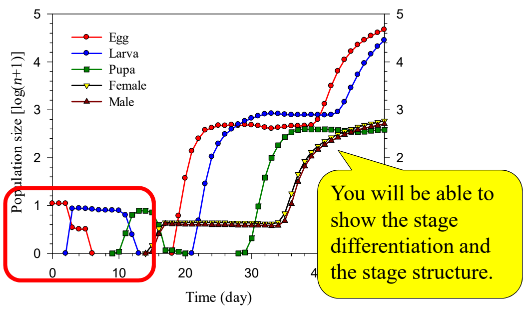
Population Projection by using TIMING-MSChart



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Attention

- If you run projection using the age-stage, two-sex life table and assume the fecundity is zero, you will get exactly the same s_{xj} curves like your life table result.
- It shows that the age-stage, two-sex life table is correct.
- However, if you use the traditional female age-specific life table, your projection result will be different from your life table record.

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A data file for TIMING-MSChart is automatically prepared by TWOSEX.

… _**15**_For_TIMING_program.txt

You should copy it to a new folder.
You can edit the data file. But, you have to be very careful.

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Data format: Basic information

"Description: the next three lines are project, date and user name."
"Example of life table raw data"
"2009.01.09"
"Chi, H."
"Description: Last age group is 20, number of stages is 5"
20,5

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Age interval, stage code, weighting coefficient

"Description: next lines are age intervals, stage name, weighing (cost) coefficient, density-dependent mortality"
0,5,"Egg",.1,.2
3,12,"Larva",.5,.8
6,17,"Pupa",.5,.8
14,20,"Female",.5,.8
16,20,"Male",.5,.8

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

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Female fecundity

"Description: the female stage is 4"
4
"Description: modify the following decrease rate for Timing program to lower the fecundity."
1
"Description: there are 7 fecundity data for female"
0,15,2.6667,13,8.6667,5.3333,3.3333

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Modify the fecundity (matrix *F*)

"Description: modify the following decrease rate for Timing program to lower the fecundity."
1 (e.g., 0.2, 0.5, etc.)
"Description: there are 90 fecundity data for female"
0,0,0,0,0,0,0,0,0,0,2.45,.6,5.8,3.6842,0,.3684,3.9474, 4.6842,4.1053,1.4737, 2.8947,6.1579,1.8421, 4.4737,6.9474,5.3158,3.4211,7.1053,5.3684,10,20.5 263,6.3684,6.1579,8.4737,13.6316,14.9474,11.2

You can change any data, but never delete it.

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Matrix *G*

"Description: modify the following decrease rate for Timing program to lower the growth rate."
1
"Description: the next lines are the growth rates for each stage."
1,1,.4,.5,.5,0
1,1,.8889,1,.8889,.5,.75,.6667,.5,0
1,1,1,1,1,1,1,.875,.8571,.5,.6667,0
1,1,1,.6667,1,1,0
1,1,1,.3333,0

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Matrix *D*

"Description: modify the following decrease rate for Timing program to lower the developmental rate."
1
"Description: next lines are developmental rates"
0,0,.6,.5,.5,1
0,0,.1111,0,.1111,.375,.25,.3333,.5,0
0,0,0,0,0,0,0,.125,0,.3333,0,.5
0,0,0,0,0,0,0,0,0,.1667,.3333,.5

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Modify *G* and *D*

"Description: the next lines are the growth rates for each stage."
1,1,1,.29,1,1,1,1,1,0
.9859,.0143,0
1,.4429,.0938,.6667,.5,1,1,1,1,1,0
.9487,.3485,.2083,1,1,1,.3333,1,.5,1,0

You can change any data, but never delete it. Elements of matrices *G* and *D* are related and should be $0 \le g_{xj} \le 1$, $0 \le d_{xj} \le 1$, and $0 \le d_{xj} + g_{xj} \le 1$.

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Initial population structure

"Description: next lines are initial population structure (age, stage, number), end with 0,0,0"
0,1,10 (age 0, stage 1, 10 individuals)
0,0,0
"Description: Enter time for next release. Zero means no additional release."
0
"Description: Enter population structure (age, stage, number) of next release, end with 0,0,0"
0,0,0

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How to edit the initial population

"Description: next lines are initial population structure (age, stage, number), end with 0,0,0"
0,1,10 (**10 individuals** of age 0 and stage 1).
0,0,0
or
10,4,10 (**10 individuals** of age 10 and stage 4)
10,5,10 (**10 individuals** of age 10 and stage 5)
0,0,0

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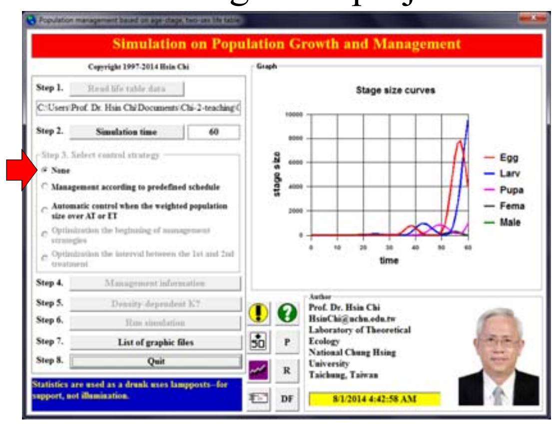
Unlimited growth projection



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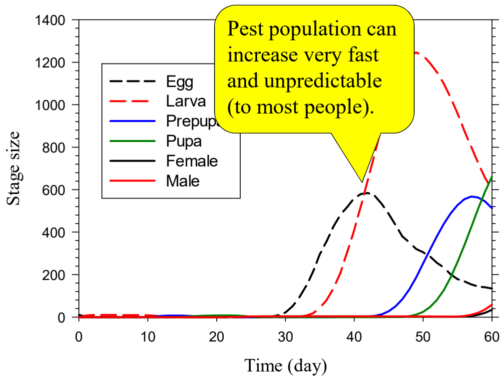
Stage size



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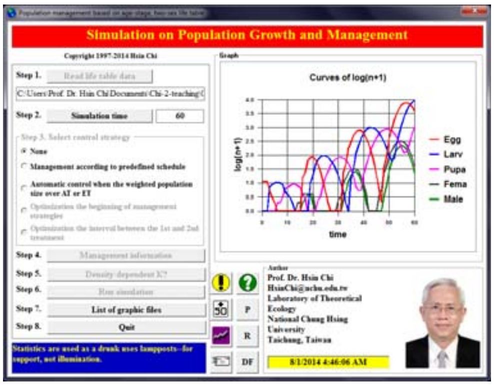
Use log(n+1) to show details



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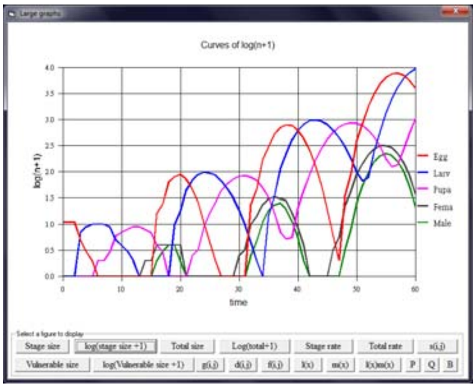
Large graph



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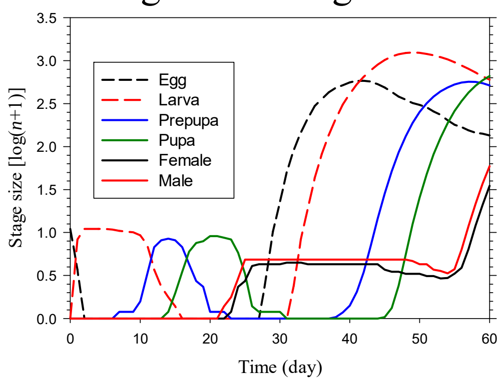
Stage size in log scale



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Creative thinking

- In field, we cannot sample all life stages of an insect population. In most cases, only individuals of a specific life stage is sampled.
- How can we calculate the growth rate of a specific stage (e.g., larval stage)?

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Stage growth rate in log or ln scale

$$\phi_{j,t} = \frac{\log(n_{j,t+1}+1)}{\log(n_{j,t}+1)}$$

$$r_{j,t} = \ln\left(\frac{n_{j,t+1}+1}{n_{j,t}+1}\right) = \ln(n_{j,t+1}+1) - \ln(n_{j,t}+1)$$

J. Econ. Entomol. 108(4): 1466–1478 (2015) **(Forum)**

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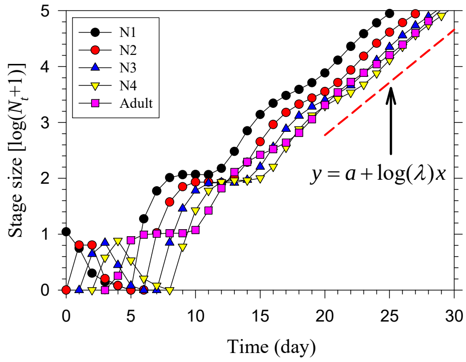
$$r_{j,t} = \frac{\log(n_{j,t+1}+1)}{\log(n_{j,t}+1)} \approx \frac{\log(n_{j,t+1})}{\log(n_{j,t})} = \log\lambda$$



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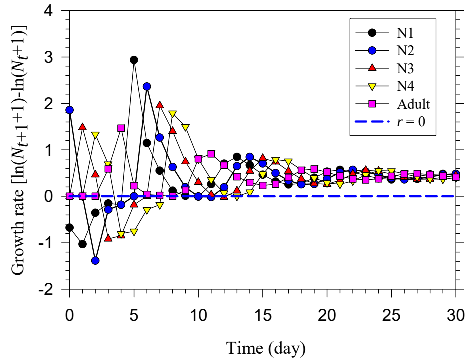
$$r_{j,t} = \ln\left(\frac{n_{j,t+1}+1}{n_{j,t}+1}\right) = \ln(n_{j,t+1}+1) - \ln(n_{j,t}+1) \approx \ln(e^r) = r$$



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Attention!

- If you simulate the population growth for 60 days, then you will get the population size from 0 to 60 d (61 data). But you will only get the growth rate data for time 0 to 59 (60 growth rate).
- If you need the growth rate data point at 60 d for the figure of growth rate, you have to run the simulation to 61 d.

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Stage-specific weighting coefficient

$$w_j = \frac{c_j}{c_{highest}}$$

$C_{highest}$: the highest stage mean **daily** consumption rate

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Cumulative insect-days (stage-days)

$$CumSD = \sum_{t=0}^{T}\sum_{j=1}^{m}\sum_{x=0}^{\infty} n_{xj}(t)$$

T : the simulation time
m: number of life stages
n_{xj} : number of individuals of age x and stage j

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Weighted insect-day at time t

$$n_w(t) = \sum_{j=1}^{m}\left(\sum_{x=0}^{\infty} n_{xj}(t)\cdot w_j\right)$$

Weighted insect-day shows the weighted effect of insect population to crop (or predator to pest) by taking the different consumption rate into account.

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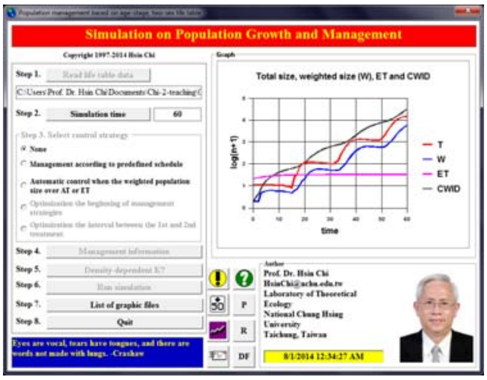
Cumulative weighted insect-days

$$CumWSD=\sum_{t=0}^{T}\left[n_w(t)\right]$$

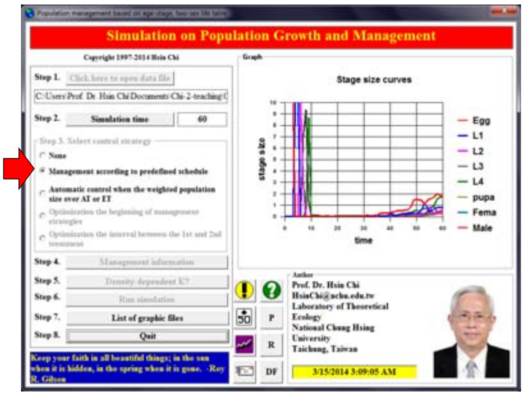
CWID (cumulative weighted insect-days), total population size (T), W (weighted population size), ET (economic threshold)



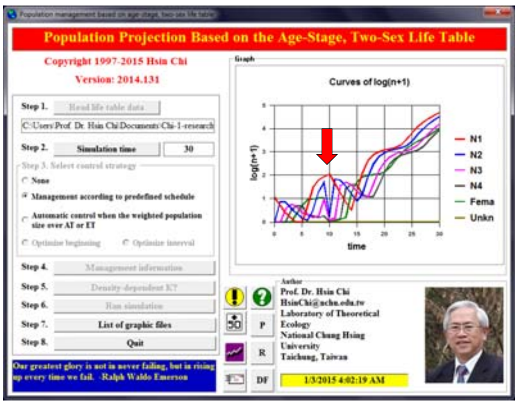
Pest control information

"Description: no. treatment = 1 (If there are 2 …"
1
"Description: first treatment at 10th day"
10
"Description: Critical cumu. insect day is on 15th day"
15
"Line A: Code, effective duration, time to next treatment "
"DDT",1,10
"Description: stage mortality due to treatment"
0 , 0.9 , 0.9 , 0.9 , 0.9 , 0.9

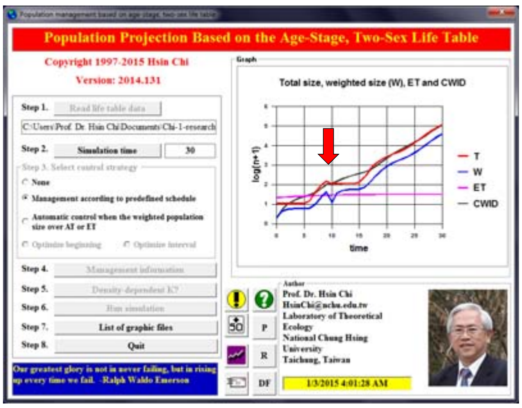
Pest control according to predefined schedule



One control



One control



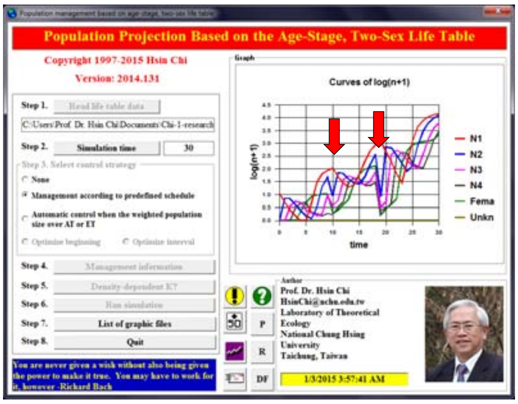
Two treatments

"Description: Density-dependent mortality coefficient for density below K and over K"
.2,1
"Description: number of treatment = 1"
2
"Description: first treatment at 10th day"
10

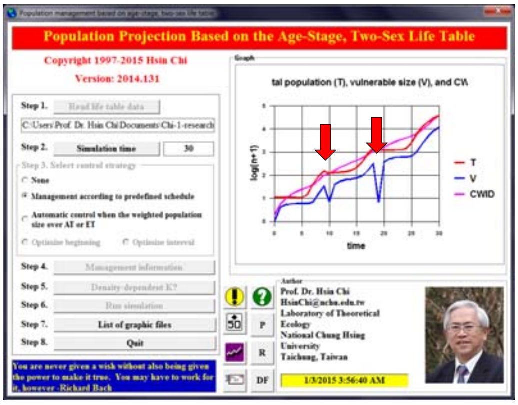
Control information for 2 treatments

"Description: Code treatment is DDT, effective duration is one day, interval to next treatment is 10 days"
"DDT",1,10
"Description: stage mortality due to treatment"
0 , 0.9 , 0 , 0.9 , 0.9
"Description: Code treatment is Spinosad, effective duration is one day, interval to next treatment is 10 days"
"Spinosad",1,10
"Description: stage mortality due to treatment"
0 , 0.9 , 0 , 0.9 , 0.9

Two controls



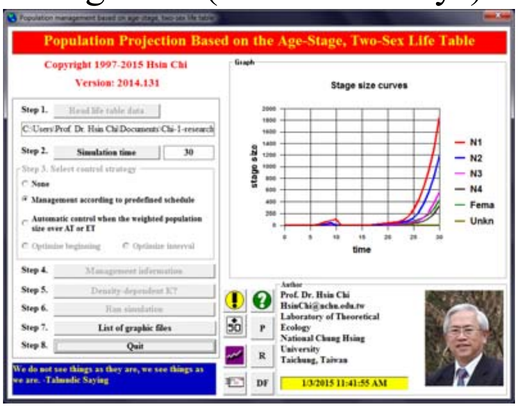
Two controls



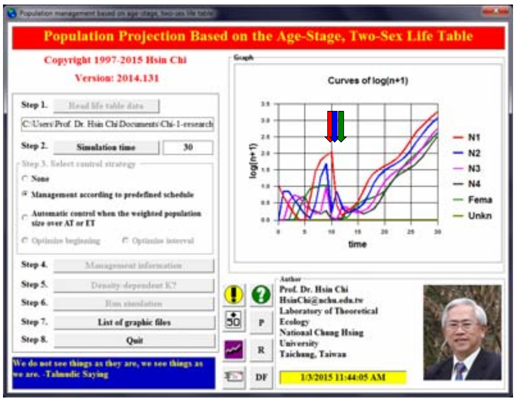
One treatment, 3 effective days

"Description: Code treatment is DDT, effective duration is one day, interval to next treatment is 10 days"
"DDT",**3**,10
"Description: stage mortality due to treatment"
0 , 0.9 , 0.9 , 0.9 , 0.9
0 , 0.8 , 0.7 , 0.7 , 0.6
0 , 0.5 , 0.5 , 0.4 , 0.3
"Description: Code treatment is DDT, effective duration is one day, interval to next treatment is 10 days"
"DDT",1,10
"Description: stage mortality due to treatment"
0 , 0.9 , 0.9 , 0.9 , 0.9

Stage size (3 effective days)



log Stage size (3 effective days)



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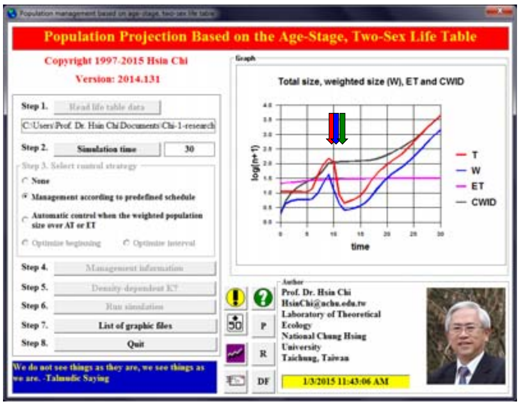
CWID, T, W, ET (3 effective days)



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How to edit the weighting coefficients

"Description: next lines are age intervals, stage name, **weighting coefficient**, density-dependent mortality"

0,9,"Egg", **0**,.2 (eggs don't cause damage)

4,6,"L1",**0.1**,.8 (L1 equals **0.1** of L4)

5,15,"L2", **0.4**,.8 (L2 equals **0.4** of L4)

You can also use the real "consumption rate", "injury rate", rearing cost, etc. for weighting coefficients.

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Please prepare following graphs

- Population structure vs. time.
- Log(population structure) vs. time.
- Weighted population size vs. time.
- Stage size vs. time.
- Stage size every 10 days vs. time.

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Advantages to Using the Age-Stage, Two-sex Life Table

- Because age-stage, two-sex life table can take the stage differentiation into consideration, it can be used to simulate the effect of stage-specific mortality properly, while the female age-specific life table is incapable in this.
- Population projection based on age-stage, two-sex life table can simulate the population growth under pesticide control.

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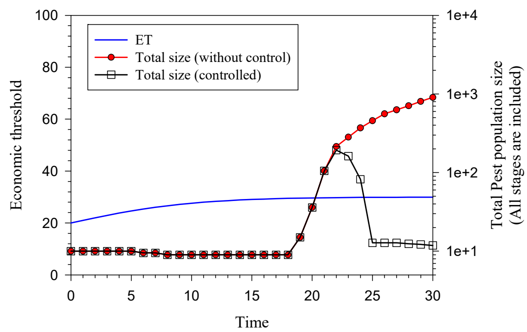
Computer simulation: Timing Control (TIMING-MSChart)



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Simulation with two releases

"Description: next lines are initial population "

3,1,10

0,0,0

"Description: Enter time for next release. Zero means no additional release."

10 (The second release is on day 10)

"Description: Enter population structure (age, stage, number) of next release, end with 0,0,0"

3,1,10

0,0,0

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Life table + predation rate → predator-prey relationship and biological control

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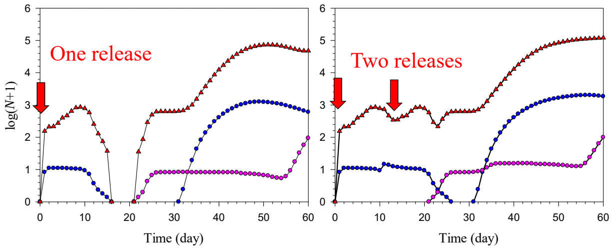
Timing the release of predators: filling up the predation gap



Journal of Economic Entomology 106(1): 1-9.

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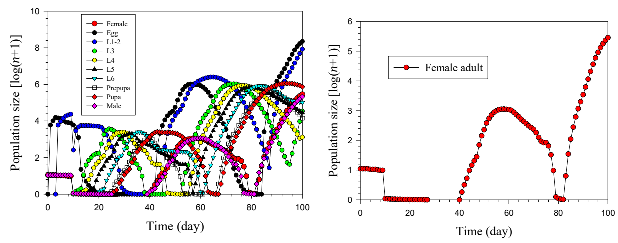
Difference between reality and sampling

Complete reality Simplified reality



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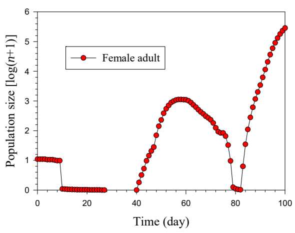
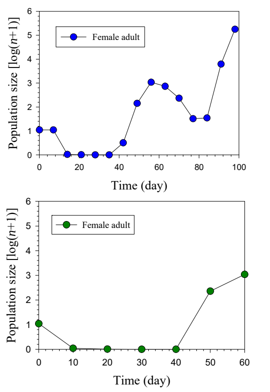
Difference between reality and sampling

Reality





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Fitting sampling data?

- Many entomologists fit the field sampling data by using polynomial regression or multiple regression. Because most field samplings are carried out at interval and there are many missing data, you should be cautious.

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Imagination, reality, and theory

- Imagination and reality have little in common - Amour (2012)
- Theory and reality have lots in common. Theory is the soul of reality. Reality is composed of theories and case-specific data – Chi.

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Life table + consumption rate →ET, timing of pesticide application?

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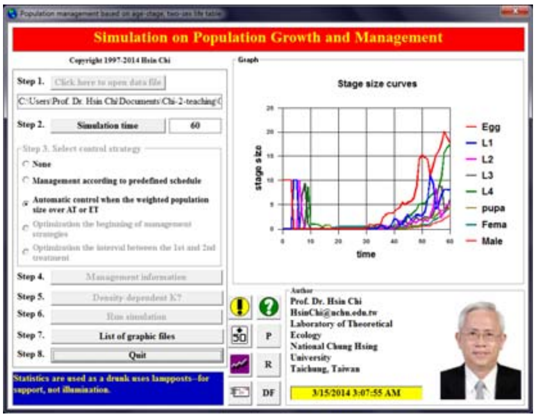
Auto-control based on weighted *N* and AT (ET)



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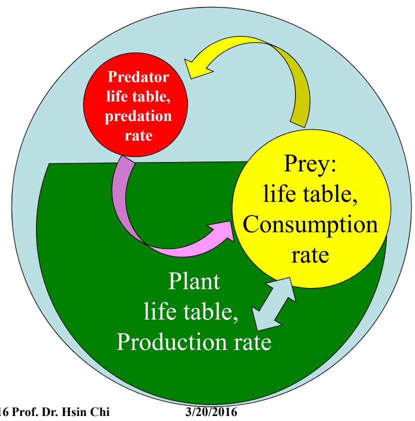
System ecology and ecosystem



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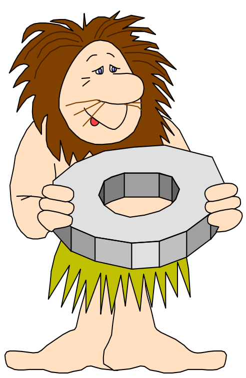

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سپاسگزارم
謝謝!
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Děkuji
Danke!
¡Muchas gracias!
Thank you!
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