Summer School

Climate Impacts Modelling for Developing countrie
Water, Agriculture and Health

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IPM
Integrated Pest Management

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Application and Use of Phenology Modeling for Integrated Pest Management

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Outline

Introduction

- Expected impacts of CC to pests
- Observed and modeled effects of CC to pests
- Temperature-based phenology modeling

Methodology

- Data collection and data analysis using ILCYM software

Results

- Model parameterization and validation
- Risk mapping worldwide and for the Andean region under different climate change scenarios

Conclusions

Impacts of CC on Pests

An increase in extreme climate events, changes in moisture conditions, temperature rise, elevated CO_2 concentrations, are expected to magnify pest pressure on agricultural systems through:

- Range expansion of existing pests and invasion by new pests.
- Accelerated pest development leading to more pest cycles per season.
- Disruption of the temporal and geographical synchronization of pests and beneficial insects that increase risk of pest outbreaks.
- Promotion of minor pests to primary pests brought about by reduction in host tolerance and changes in landscape characteristics and land-use practices.
- Increase damage potential from invasive alien species.
- Susceptibility to pests increases in drought stressed plants.

(adapted from Padgham, 2009; Discussion paper - The World Bank)

Observed and modeled effects of CC on insect pests

Pest	Climate Dimension	Cropping System/Region	Reference
INSECTS			
Brown locust (*Locustana pardalina)**	Increased outbreaks during ENSO events.	Crop/rangeland, S-Africa	Todd et al. 2002
Leaf miner (*Caloptilia* sp.)	Range expansion projected.	Coffee, Brazil	Magrin et al. 2007
Southern pink bollworm (*Pectinophora gossypiella*)	Increased winter temperatures predicted to increase range and damage potential.	Cotton, SW-US	Gutierrez et al. 2006
Southern pine beetle (*Dendroctonus frontalis*)	Increased winter/spring temperatures predicted to increase range and damage potential.	Forests, S-US	Gan 2004
White fly (*Bemisia tabaci,* and *B. afer*)*	Increased outbreaks during ENSO events.	Tuber crops, Andean region	Shapiro et al. 2007
Potato tuber moth (*Phthorimaea operculella*)	Temperature increase of 2℃–3℃ expands distribution by 400–800 km to the north and accelerates damage intensity.	Potato, globally	Sporleder et al. 2007

(Padgham 2009)

Pest infestation in potato/sweetpotato in the Cañete Valley of Peru before, during and after the El Niño year in 1997.

1 = absent; 2 = slight; 3 = medium; 4 = severe; 5 = extreme infestation. - = no information

Name	Scientific name	Degree of infestation		
Potato		1996	1997	1998
Leafminer fly	***Liriomyza huidobrensis***	4	2	4
Bud midge	***Prodiplosis longifila***	2	5	3
Broad mite	***Polyphagotarsonemus latus***	3	4	3
Potato tuber moth	***Phthorimaea operculella***	2	3	2
Soybean Looper	***Pseudoplusia includens***	1	3	1
Sweetpotato				
White fly	***Bemisia tabaci***	2	4	5
Leafhopper	***Empoasca* spp.**	2	3	4
Aphids	***Myzus persicae***	2	3	3
Red spider mite	***Paraponychus incanus***	2	3	2
Sweet potato weevil	***Euscepes postfasciatus***	3	4	4
White grubs	***Bothynus* spp. / *Anomala* spp.**	3	4	4

(Cisneros and Mujica 1999)

Yields (in t or quintal for cotton) in different crops, Cañete Valley, Peru, before, during and after the El Niño year in 1997 and related yield losses (%) due to increased pest severity

Crop	1996	1997	1998	Yield loss (1996-1998)
Potato	27 (18-35)	12 (1.5-21)	15 (5-20)	**55**
Sweetpotato	28 (10-40)	16 (2-40)	15 (2-20)	**54**
Cotton	50 (45-110)	25 (1-60)	35 (10-70)	**50**
Maize	-	6.5 (5-8)	3.5 (2-4)	**46**
Citrus	-	60	24 (14-30)	**60**
Asparagus	8	7	2	**70**

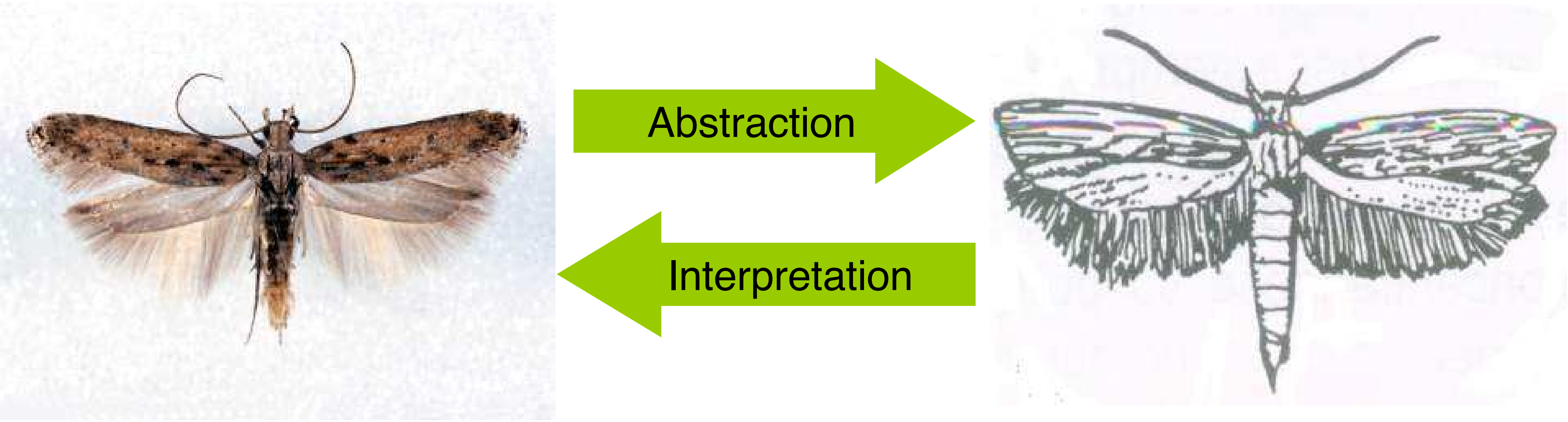
(Cisneros and Mujica 1999)

Our approach

To support farmers and national programs to cope with CC and alternating pest problems by:

- Understanding the effects of temperature increase on key pests and related beneficial insects in agro-ecosystems by using phenology modeling.
- Developing risk maps for major pests for current and future scenarios according to temperature indicating major future pest hot spots.
- Providing tools for pest risk assessments and adaptation planning.
- Identifying IPM strategies to enhance resilience of vulnerable agro-systems to CC.
- Developing human scientific capacity to work in pest risks assessments and adaptive pest management strategies to cope with new emerging pest problems.
- Increasing awareness of the impact of CC on pests to improve national pest management and quarantine programs.

Models as analytical tools



Real system

Model

Abstraction

Interpretation

A model is a tool. It should not be considered as the ultimate objective in ecological studies.

No model is perfect but it can be very useful.

Temperature-based insect phenology modeling

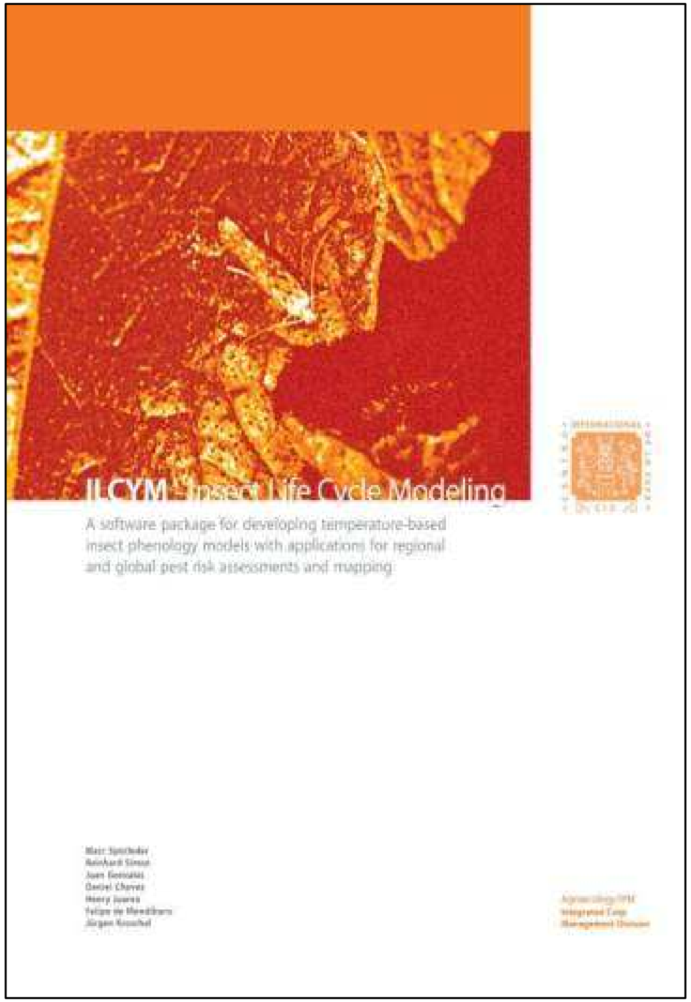
Analytical tools for predicting, evaluating and understanding the dynamics of insect populations in agroececosystems.

- Phytosanitary pest risk assessments / Climate change
- Integrated Pest Management
  - Classical biocontrol: identification of potential release sites for parasitoids
  - Simulation of field performance of biopesticides and application frequencies

Insect Life Cycle Modeling (ILCYM)

Software package for developing temperature-based insect phenology models with applications for regional and global pest risk assessments and mapping.

- Collecting life cycle data under constant and fluctuating temperature regimes
- Analyzing the data using ILCYM
  - Fitting functions for describing temperature-driven development processes under constant temperatures, i.e. development rate, mortality and reproduction ("Model Builder")
  - Validating the model using life table data established under fluctuating temperature
- Generate risks maps using ILCYM in an GIS environment
  - Establishment index
  - Generation index
  - Activity index



ILCYM: Insect Life Cycle Modeling

A software package for developing temperature-based insect phenology models with applications for regional and global pest risk assessments and mapping

(www.cipotato.org/ilcym)

Use of ILCYM

✓ ILCYM offers advanced modeling techniques for insect populations and tools for analyzing models; users do not need to be experts in the field.

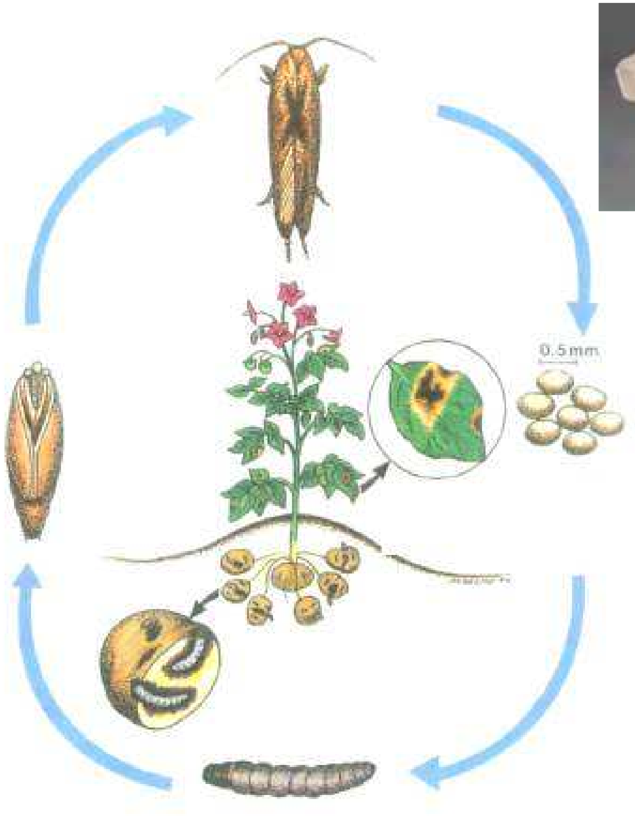
✓ ILCYM guides the user interactively through the steps developing a phenology/population model and facilitates spatial pest risk mapping.

✓ User do not need to learn programming languages.

✓ However, ILCYM restricts users to certain model designs and might not provide solutions for every problem.

Data collection

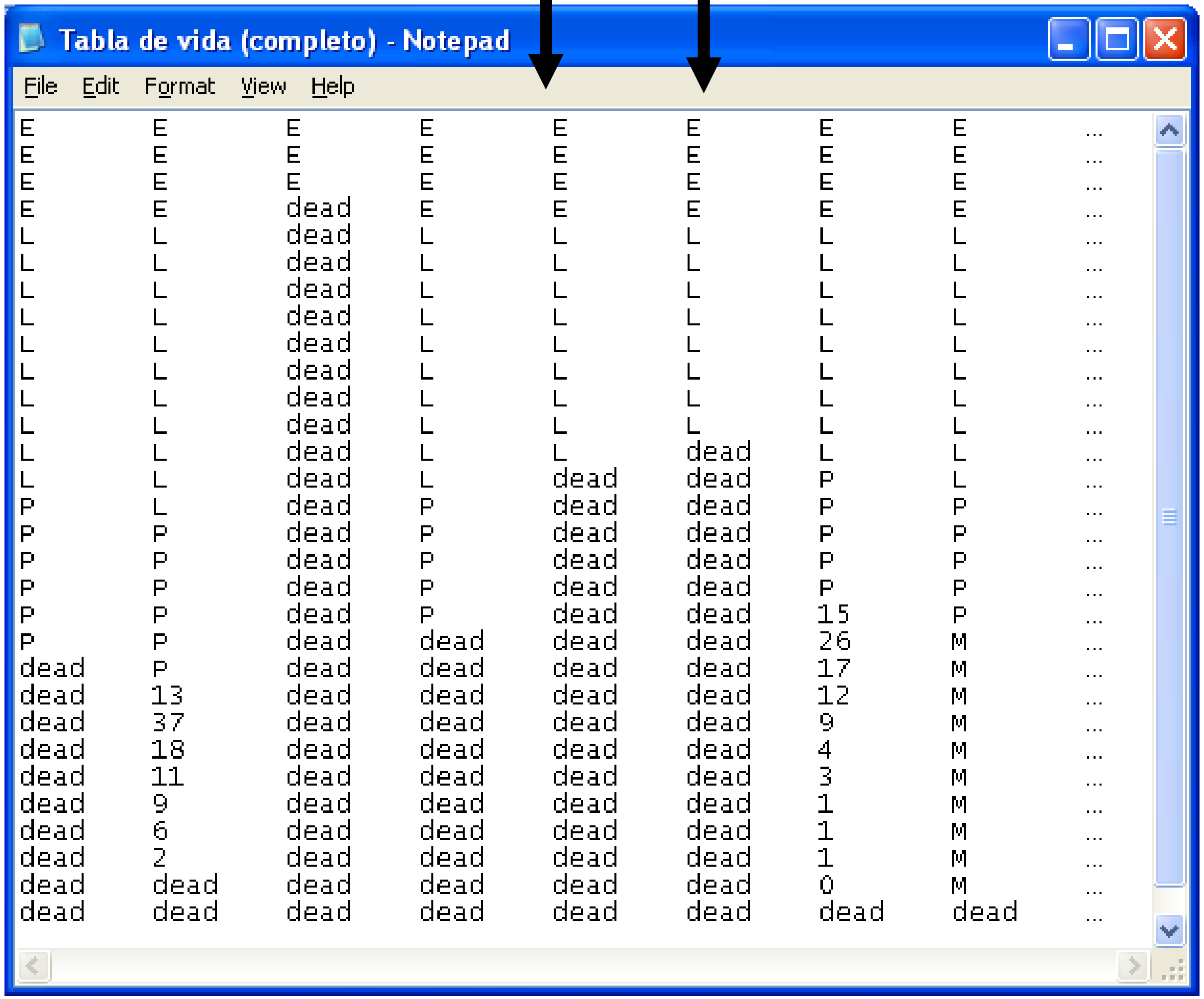
- Oviposition
- Survival time
  (male and female)



Constant
temperatures

- Development time
- Mortality

Life table data (complete)



```
E       E       E       E       E       E       E       E       ...
E       E       E       E       E       E       E       E       ...
E       E       E       E       E       E       E       E       ...
E       E       dead    E       E       E       E       E       ...
L       L       dead    L       L       L       L       L       ...
L       L       dead    L       L       L       L       L       ...
L       L       dead    L       L       L       L       L       ...
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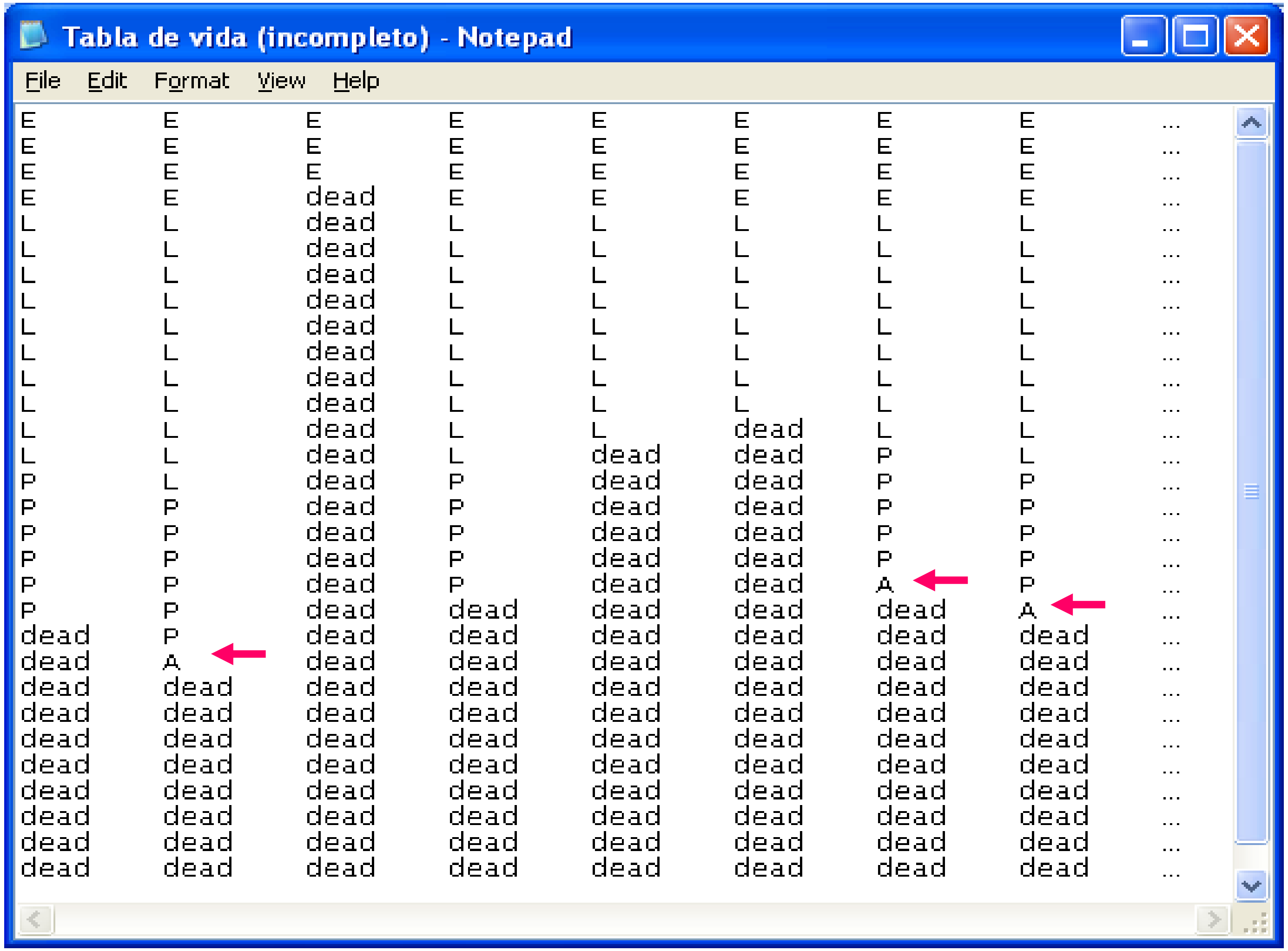
L       L       dead    L       dead    dead    P       L       ...
P       L       dead    P       dead    dead    P       P       ...
P       P       dead    P       dead    dead    P       P       ...
P       P       dead    P       dead    dead    P       P       ...
P       P       dead    P       dead    dead    P       P       ...
P       P       dead    P       dead    dead    15      P       ...
P       P       dead    dead    dead    dead    26      M       ...
dead    P       dead    dead    dead    dead    17      M       ...
dead    13      dead    dead    dead    dead    12      M       ...
dead    37      dead    dead    dead    dead    9       M       ...
dead    18      dead    dead    dead    dead    4       M       ...
dead    11      dead    dead    dead    dead    3       M       ...
dead    9       dead    dead    dead    dead    1       M       ...
dead    6       dead    dead    dead    dead    1       M       ...
dead    2       dead    dead    dead    dead    1       M       ...
dead    dead    dead    dead    dead    dead    0       M       ...
dead    dead    dead    dead    dead    dead    dead    dead    ...
```

Each column represent one individual

Each line represent one evaluation interval (days)

Life table data (complete)



```
E       E       E       E       E       E       E       E       ...
E       E       E       E       E       E       E       E       ...
E       E       E       E       E       E       E       E       ...
E       E       dead    E       E       E       E       E       ...
L       L       dead    L       L       L       L       L       ...
L       L       dead    L       L       L       L       L       ...
L       L       dead    L       L       L       L       L       ...
L       L       dead    L       L       L       L       L       ...
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L       L       dead    L       L       dead    L       L       ...
L       L       dead    L       dead    dead    P       L       ...
P       L       dead    P       dead    dead    P       P       ...
P       P       dead    P       dead    dead    P       P       ...
P       P       dead    P       dead    dead    P       P       ...
P       P       dead    P       dead    dead    P       P       ...
P       P       dead    P       dead    dead    A       P       ...
P       P       dead    dead    dead    dead    dead    A       ...
dead    P       dead    dead    dead    dead    dead    dead    ...
dead    A       dead    dead    dead    dead    dead    dead    ...
dead    dead    dead    dead    dead    dead    dead    dead    ...
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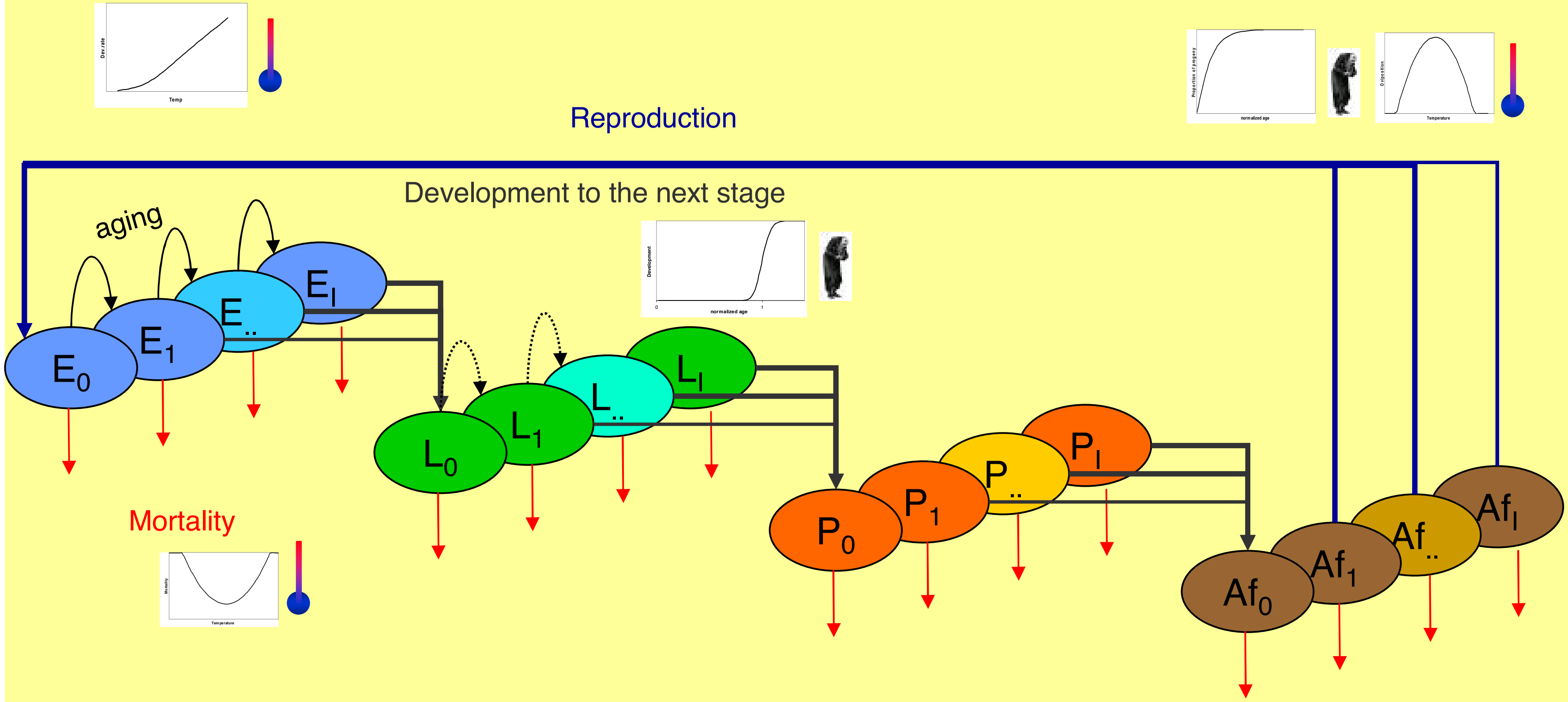
Instead of “numbers” for oviposited eggs or “M” for males you indicate “A” for adult or “F” and “M” for “female” and “male”

Model Implementation


Reproduction

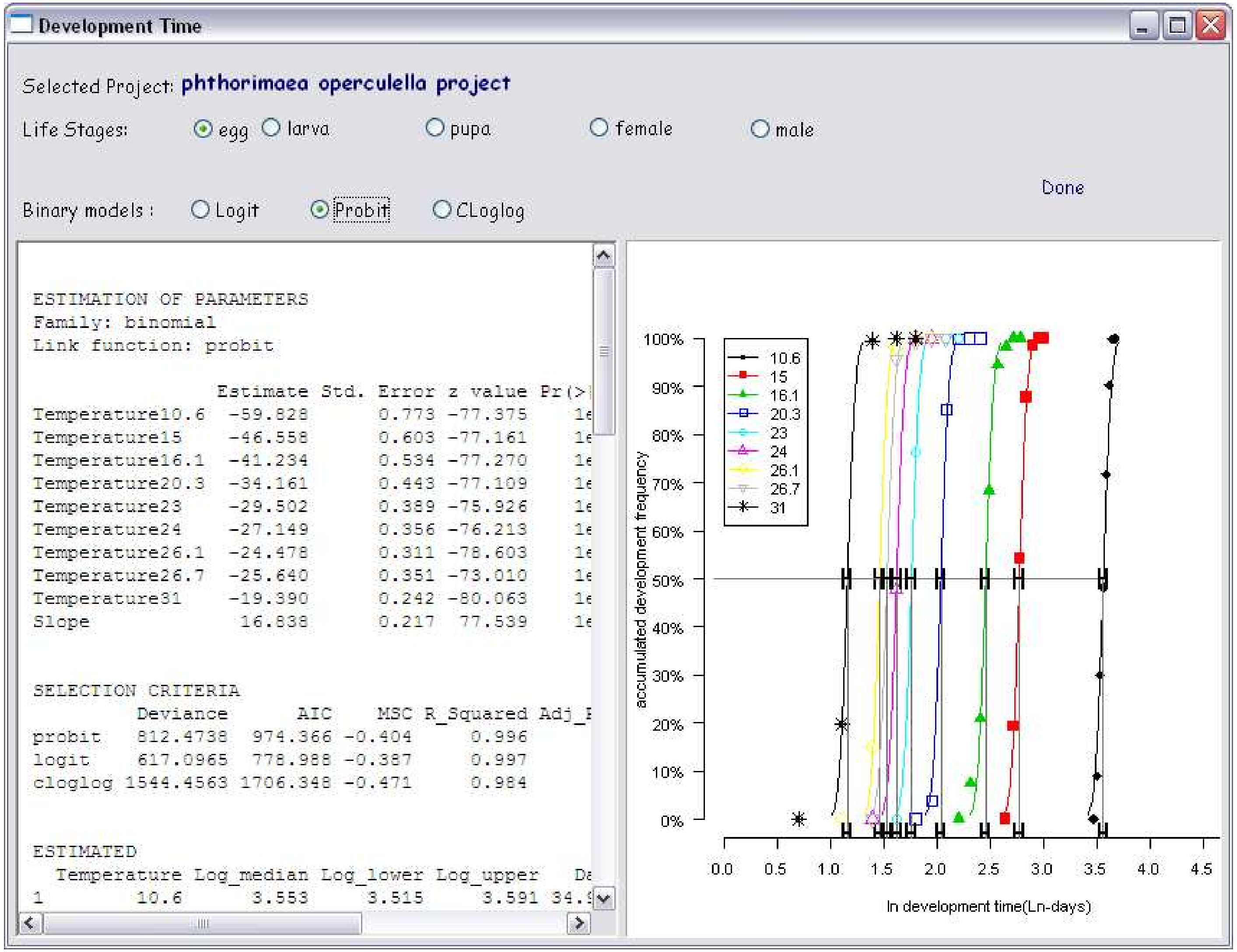
Development to the next stage

aging

Mortality

Functions generated in ILCYM

Development Time



Selected Project: **phthorimaea operculella project**

Life Stages: ● egg ○ larva ○ pupa ○ female ○ male

Binary models : ○ Logit ● Probit ○ CLoglog

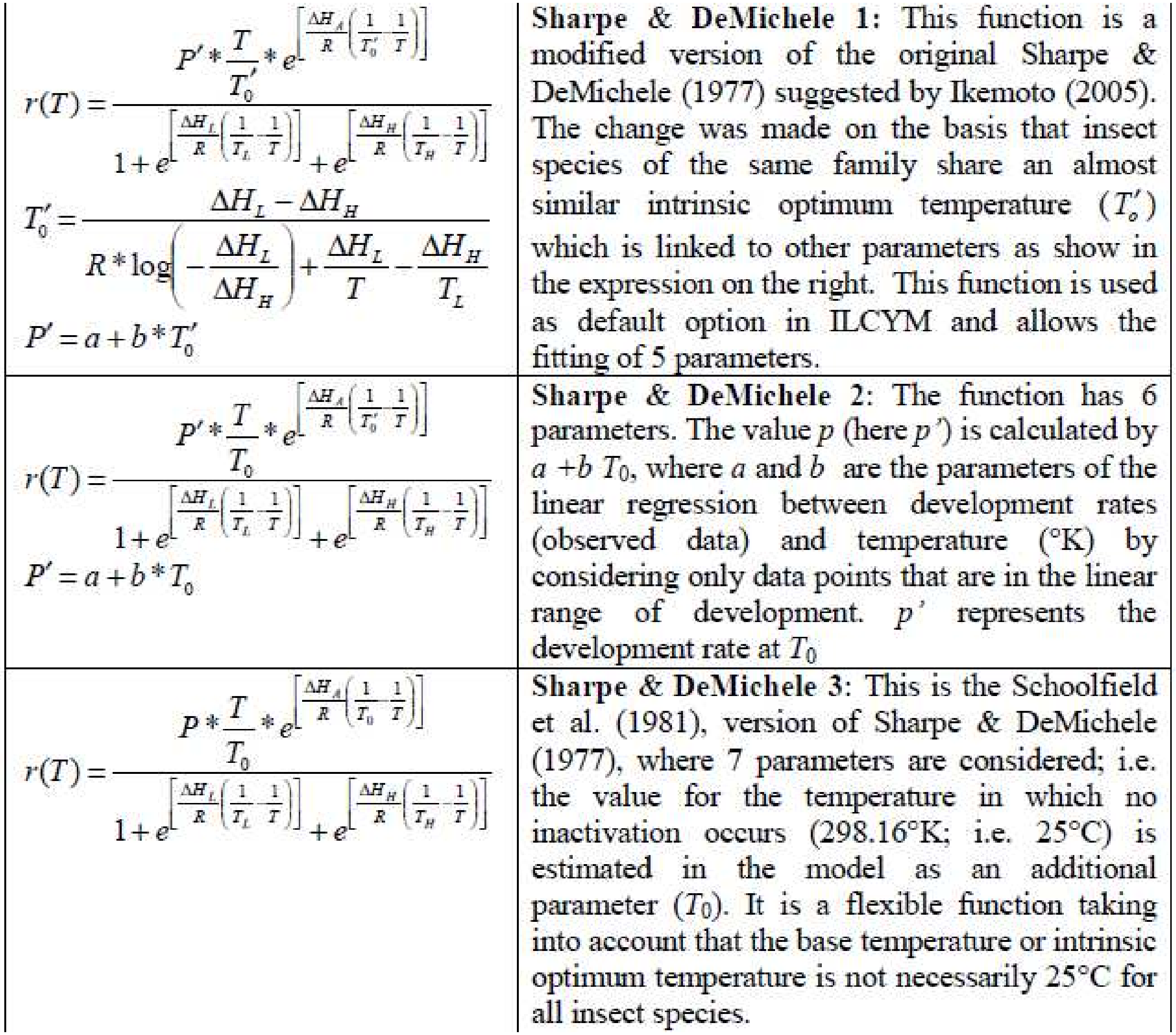
```
ESTIMATION OF PARAMETERS
Family: binomial
Link function: probit

                  Estimate Std. Error z value Pr(>
Temperature10.6   -59.828      0.773 -77.375    1e
Temperature15     -46.558      0.603 -77.161    1e
Temperature16.1   -41.234      0.534 -77.270    1e
Temperature20.3   -34.161      0.443 -77.109    1e
Temperature23     -29.502      0.389 -75.926    1e
Temperature24     -27.149      0.356 -76.213    1e
Temperature26.1   -24.478      0.311 -78.603    1e
Temperature26.7   -25.640      0.351 -73.010    1e
Temperature31     -19.390      0.242 -80.063    1e
Slope              16.838      0.217  77.539    1e


SELECTION CRITERIA
         Deviance      AIC    MSC R_Squared Adj_
probit   812.4738  974.366 -0.404     0.996
logit    617.0965  778.988 -0.387     0.997
cloglog 1544.4563 1706.348 -0.471     0.984


ESTIMATED
  Temperature Log_median Log_lower Log_upper   Da
1        10.6      3.553     3.515     3.591 34.
```

Few Sharpe & DeMichelle Development rate Functions in ILCYM

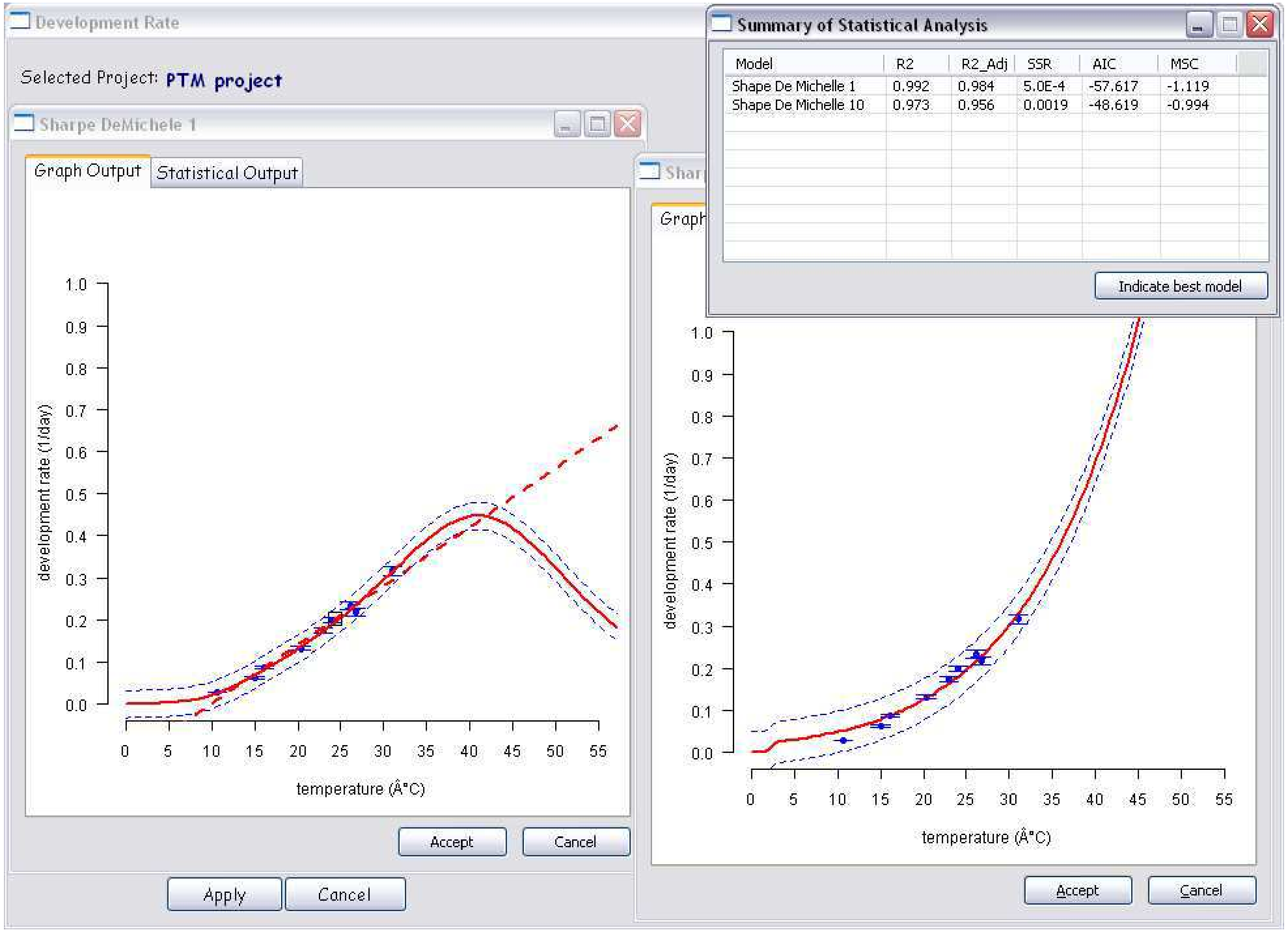


$r(T)=\dfrac{P'*\dfrac{T}{T'_0}*e^{\left[\frac{\Delta H_A}{R}\left(\frac{1}{T'_0}-\frac{1}{T}\right)\right]}}{1+e^{\left[\frac{\Delta H_L}{R}\left(\frac{1}{T_L}-\frac{1}{T}\right)\right]}+e^{\left[\frac{\Delta H_H}{R}\left(\frac{1}{T_H}-\frac{1}{T}\right)\right]}}$ $T'_0=\dfrac{\Delta H_L-\Delta H_H}{R*\log\left(-\dfrac{\Delta H_L}{\Delta H_H}\right)+\dfrac{\Delta H_L}{T}-\dfrac{\Delta H_H}{T_L}}$ $P'=a+b*T'_0$	**Sharpe & DeMichele 1:** This function is a modified version of the original Sharpe & DeMichele (1977) suggested by Ikemoto (2005). The change was made on the basis that insect species of the same family share an almost similar intrinsic optimum temperature (T'_o) which is linked to other parameters as show in the expression on the right. This function is used as default option in ILCYM and allows the fitting of 5 parameters.
$r(T)=\dfrac{P'*\dfrac{T}{T_0}*e^{\left[\frac{\Delta H_A}{R}\left(\frac{1}{T'_0}-\frac{1}{T}\right)\right]}}{1+e^{\left[\frac{\Delta H_L}{R}\left(\frac{1}{T_L}-\frac{1}{T}\right)\right]}+e^{\left[\frac{\Delta H_H}{R}\left(\frac{1}{T_H}-\frac{1}{T}\right)\right]}}$ $P'=a+b*T_0$	**Sharpe & DeMichele 2:** The function has 6 parameters. The value p (here p') is calculated by $a+b\ T_0$, where a and b are the parameters of the linear regression between development rates (observed data) and temperature (°K) by considering only data points that are in the linear range of development. p' represents the development rate at T_0
$r(T)=\dfrac{p*\dfrac{T}{T_0}*e^{\left[\frac{\Delta H_A}{R}\left(\frac{1}{T_0}-\frac{1}{T}\right)\right]}}{1+e^{\left[\frac{\Delta H_L}{R}\left(\frac{1}{T_L}-\frac{1}{T}\right)\right]}+e^{\left[\frac{\Delta H_H}{R}\left(\frac{1}{T_H}-\frac{1}{T}\right)\right]}}$	**Sharpe & DeMichele 3:** This is the Schoolfield et al. (1981), version of Sharpe & DeMichele (1977), where 7 parameters are considered; i.e. the value for the temperature in which no inactivation occurs (298.16°K; i.e. 25°C) is estimated in the model as an additional parameter (T_0). It is a flexible function taking into account that the base temperature or intrinsic optimum temperature is not necessarily 25°C for all insect species.

- *r(T)* developmental rate at temperature *T* (°K),
- *R* universal gas constant (1.987 cal degree-1 mol-1),
- *RHO25* developmental rate at 25°C (298.16°K) assuming no enzyme inactivation,
- ∆*HA* enthalpy of activation of the reaction that is catalyzed by the enzymes (cal mol-1);
- ∆*HL,H* change in enthalpy associated with low (*L*) and hot (*H*) temperatures (cal mol-1);
- *TL* and *TH* temperatures (°K) at which the enzyme is half active at low and hot temperatures, respectively

Functions generated in ILCYM

Development Rate



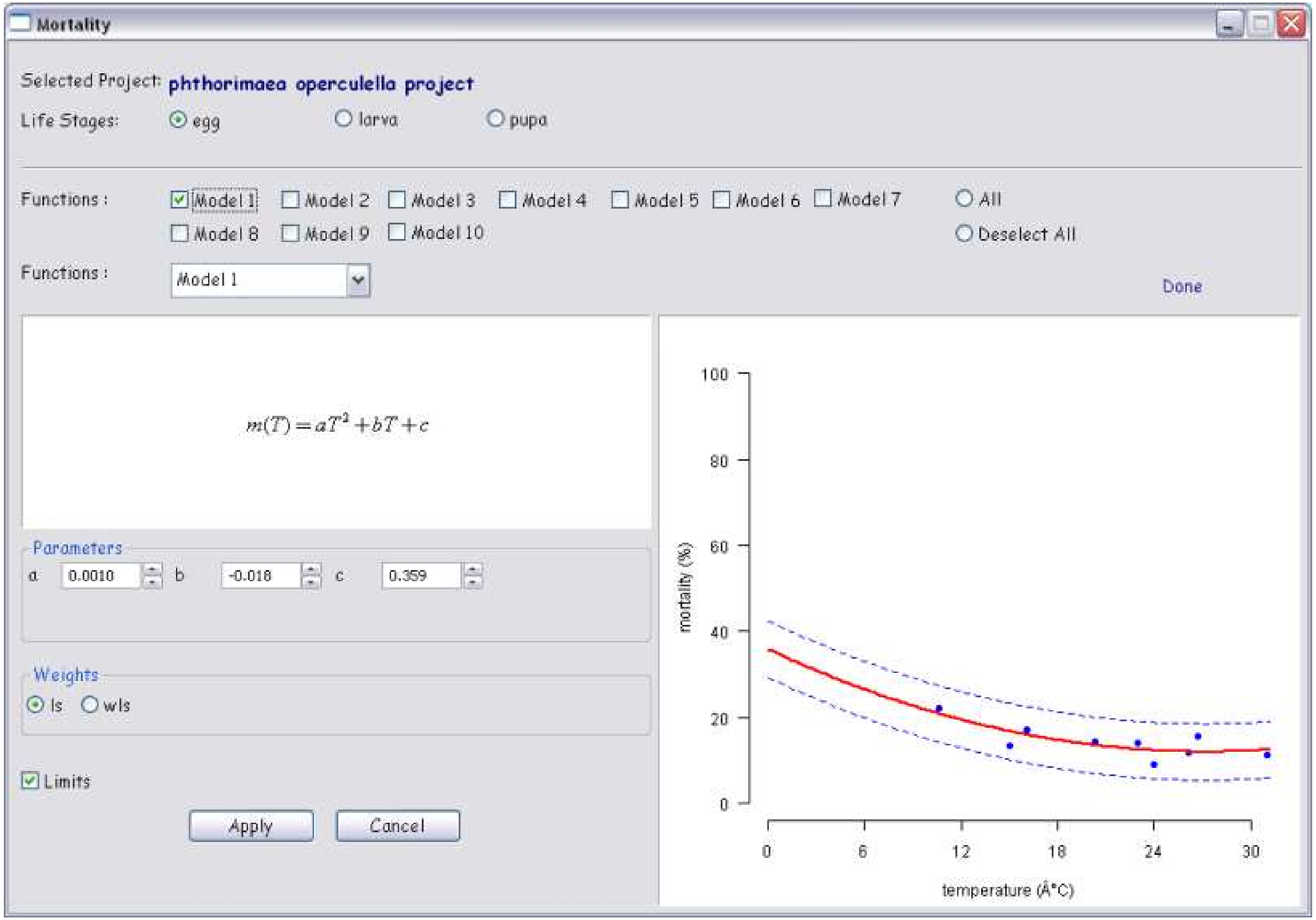
Selected Project: **PTM project**

Summary of Statistical Analysis

Model	R2	R2_Adj	SSR	AIC	MSC
Shape De Michelle 1	0.992	0.984	5.0E-4	-57.617	-1.119
Shape De Michelle 10	0.973	0.956	0.0019	-48.619	-0.994

Functions generated in ILCYM

Mortality



Selected Project: **phthorimaea operculella project**

Life Stages: ● egg ○ larva ○ pupa

Functions : ☑ Model 1 ☐ Model 2 ☐ Model 3 ☐ Model 4 ☐ Model 5 ☐ Model 6 ☐ Model 7 ○ All
☐ Model 8 ☐ Model 9 ☐ Model 10 ○ Deselect All

Functions : Model 1

$$m(T) = aT^2 + bT + c$$

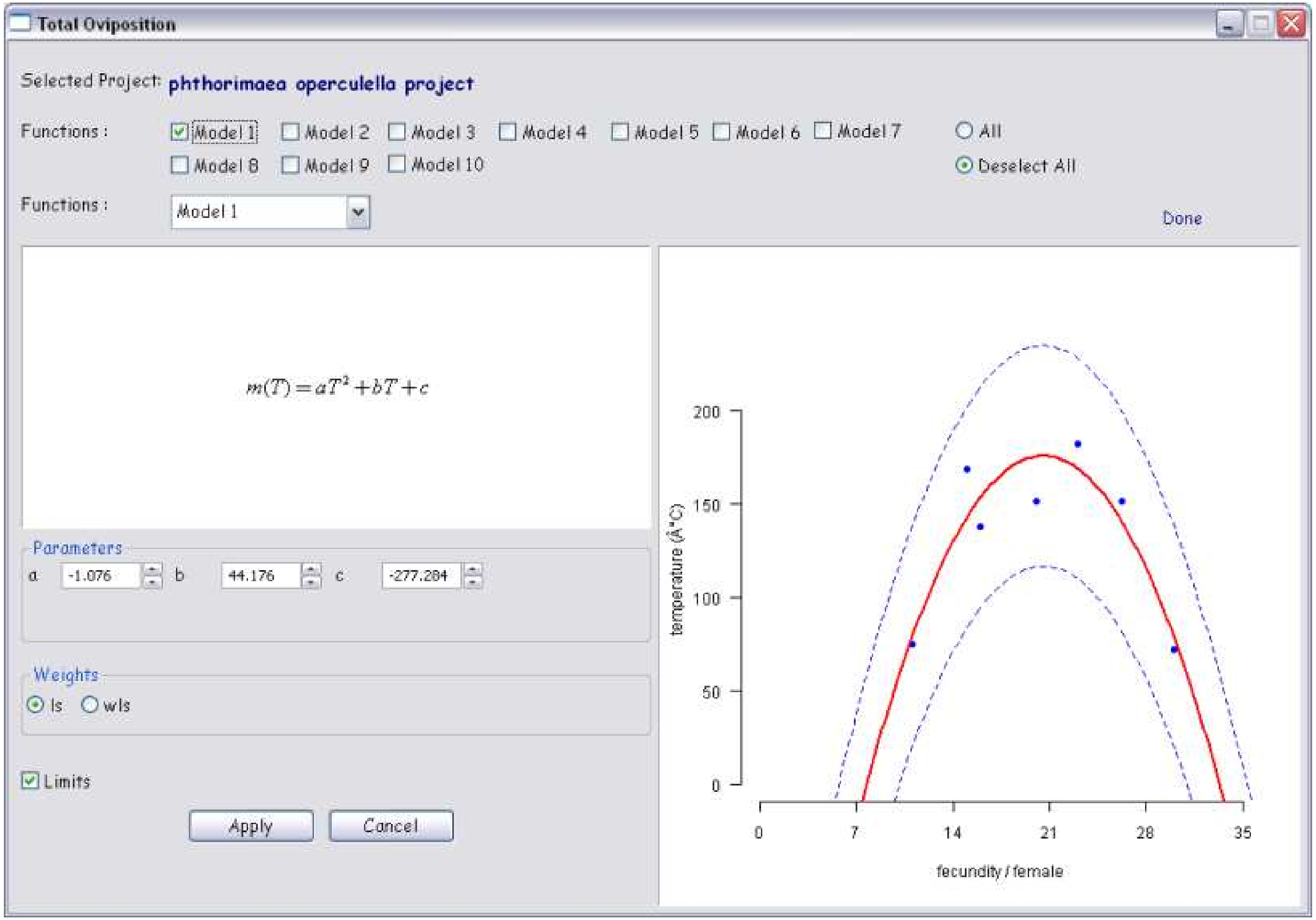
Parameters
a 0.0010 b -0.018 c 0.359

Weights
● ls ○ wls

☑ Limits

Functions generated in ILCYM

Total oviposition



Total Oviposition

Selected Project: **phthorimaea operculella project**

Functions : ☑ Model 1 ☐ Model 2 ☐ Model 3 ☐ Model 4 ☐ Model 5 ☐ Model 6 ☐ Model 7 ○ All
☐ Model 8 ☐ Model 9 ☐ Model 10 ● Deselect All

Functions : Model 1

$$m(T) = aT^2 + bT + c$$

Parameters

a: -1.076 b: 44.176 c: -277.284

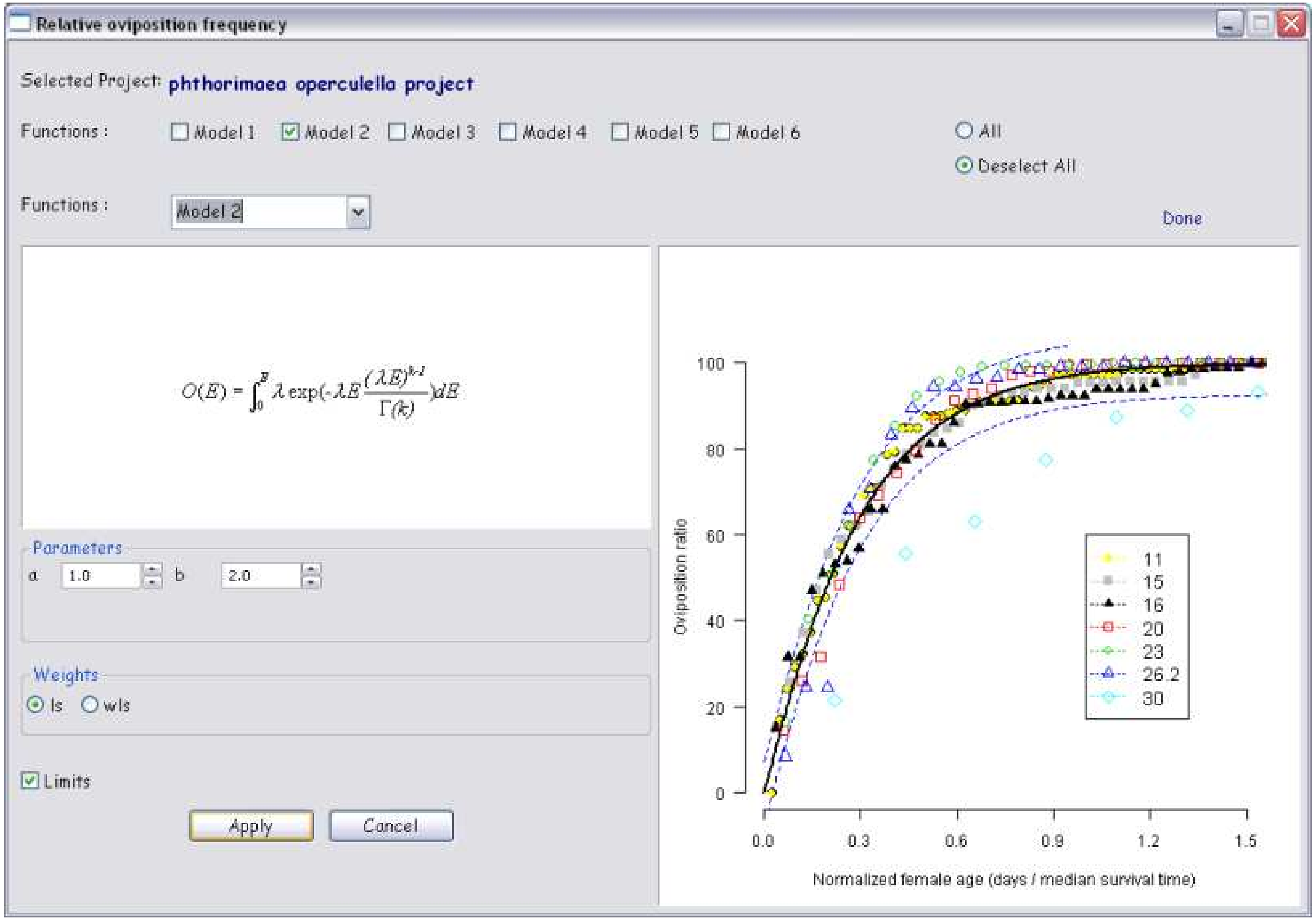
Weights

● ls ○ wls

☑ Limits

Functions generated in ILCYM

Relative oviposition



Relative oviposition frequency

Selected Project: **phthorimaea operculella project**

Functions : ☐ Model 1 ☑ Model 2 ☐ Model 3 ☐ Model 4 ☐ Model 5 ☐ Model 6

○ All
● Deselect All

Functions : Model 2

$$O(E) = \int_0^E \lambda \exp(-\lambda E \frac{(\lambda E)^{k-1}}{\Gamma(k)})dE$$

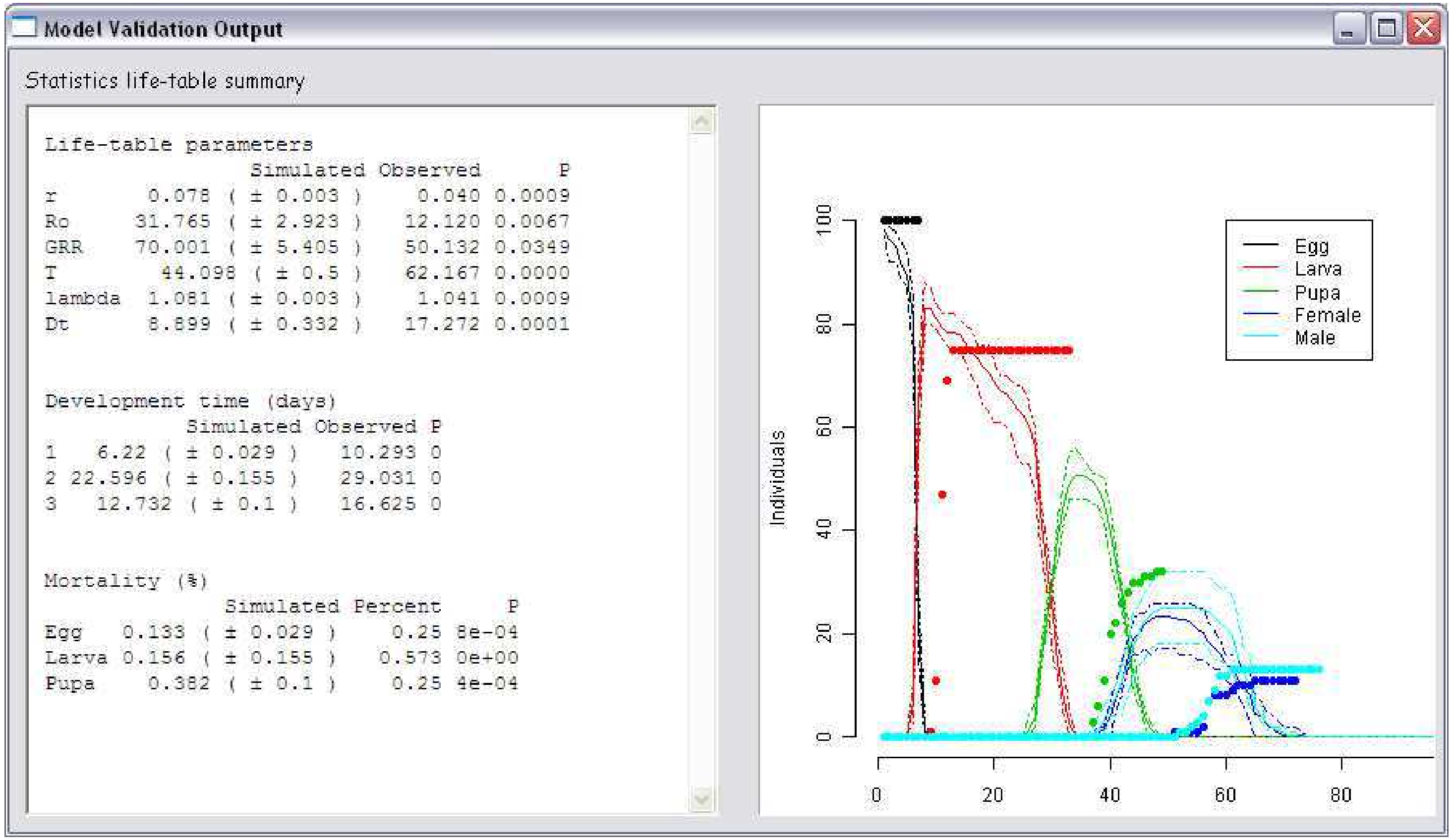
Parameters
a 1.0 b 2.0

Weights
● ls ○ wls

☑ Limits

Phenology Model validation

The phenology model is stochastically simulated and compared to life table obtained from fluctuating temperature



```
Life-table parameters
                Simulated Observed      P
r        0.078  ( ± 0.003 )    0.040 0.0009
Ro      31.765  ( ± 2.923 )   12.120 0.0067
GRR     70.001  ( ± 5.405 )   50.132 0.0349
T         44.098 ( ± 0.5 )    62.167 0.0000
lambda   1.081  ( ± 0.003 )    1.041 0.0009
Dt       8.899  ( ± 0.332 )   17.272 0.0001


Development time (days)
           Simulated Observed P
1   6.22 ( ± 0.029 )   10.293 0
2 22.596 ( ± 0.155 )   29.031 0
3   12.732 ( ± 0.1 )   16.625 0


Mortality (%)
              Simulated Percent     P
Egg   0.133 ( ± 0.029 )    0.25 8e-04
Larva 0.156 ( ± 0.155 )   0.573 0e+00
Pupa    0.382 ( ± 0.1 )    0.25 4e-04
```

Life table parameters

Net reproduction rate: R_0 (♀/♀)

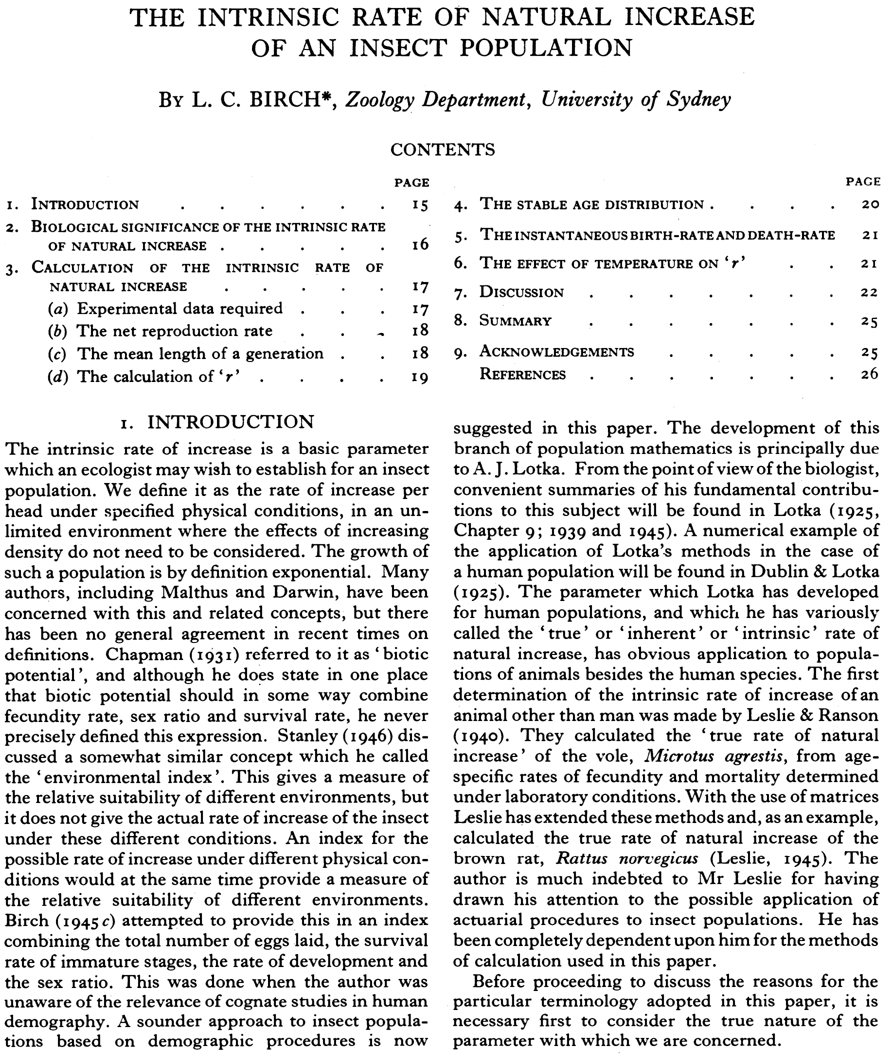
Mean generation time: *T* (days)

Intrinsic rate of increase: r_m

Finite rate of increase: $\lambda = e^{r_m}$

Doubling time: $Dt = Ln(2)/r_m$

Foundation Insect Population Modeling



THE INTRINSIC RATE OF NATURAL INCREASE OF AN INSECT POPULATION

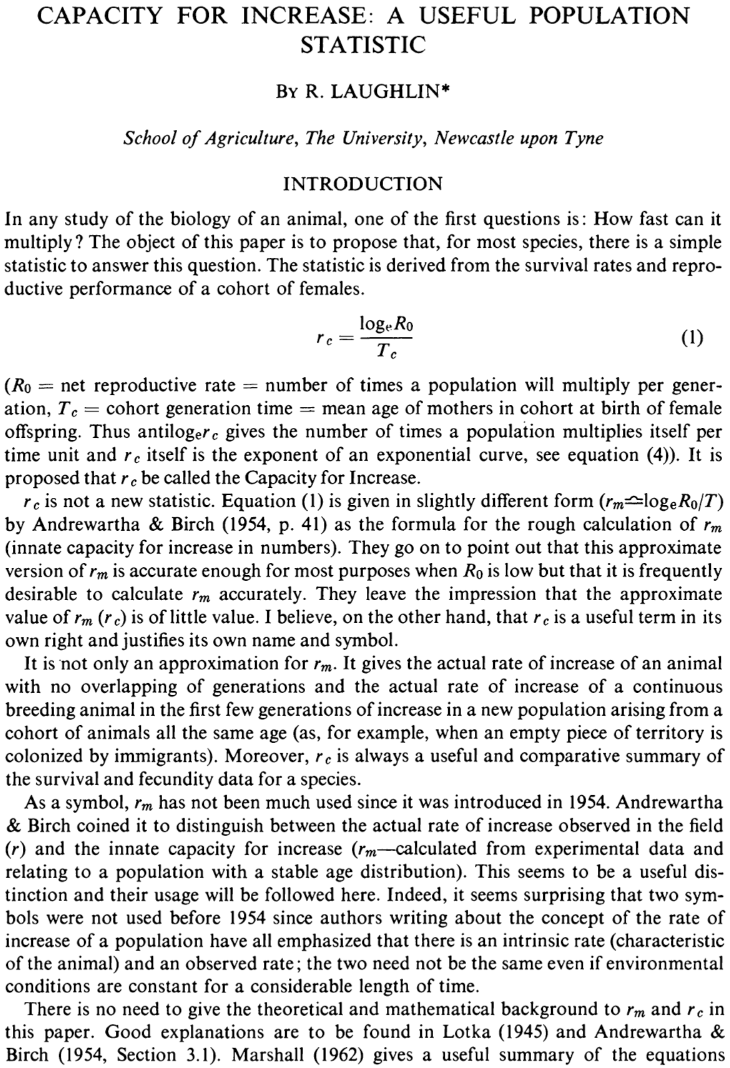
By L. C. BIRCH*, *Zoology Department, University of Sydney*

CONTENTS

1. INTRODUCTION

The intrinsic rate of increase is a basic parameter which an ecologist may wish to establish for an insect population. We define it as the rate of increase per head under specified physical conditions, in an unlimited environment where the effects of increasing density do not need to be considered. The growth of such a population is by definition exponential. Many authors, including Malthus and Darwin, have been concerned with this and related concepts, but there has been no general agreement in recent times on definitions. Chapman (1931) referred to it as 'biotic potential', and although he does state in one place that biotic potential should in some way combine fecundity rate, sex ratio and survival rate, he never precisely defined this expression. Stanley (1946) discussed a somewhat similar concept which he called the 'environmental index'. This gives a measure of the relative suitability of different environments, but it does not give the actual rate of increase of the insect under these different conditions. An index for the possible rate of increase under different physical conditions would at the same time provide a measure of the relative suitability of different environments. Birch (1945*c*) attempted to provide this in an index combining the total number of eggs laid, the survival rate of immature stages, the rate of development and the sex ratio. This was done when the author was unaware of the relevance of cognate studies in human demography. A sounder approach to insect populations based on demographic procedures is now suggested in this paper. The development of this branch of population mathematics is principally due to A. J. Lotka. From the point of view of the biologist, convenient summaries of his fundamental contributions to this subject will be found in Lotka (1925, Chapter 9; 1939 and 1945). A numerical example of the application of Lotka's methods in the case of a human population will be found in Dublin & Lotka (1925). The parameter which Lotka has developed for human populations, and which he has variously called the 'true' or 'inherent' or 'intrinsic' rate of natural increase, has obvious application to populations of animals besides the human species. The first determination of the intrinsic rate of increase of an animal other than man was made by Leslie & Ranson (1940). They calculated the 'true rate of natural increase' of the vole, *Microtus agrestis*, from age-specific rates of fecundity and mortality determined under laboratory conditions. With the use of matrices Leslie has extended these methods and, as an example, calculated the true rate of natural increase of the brown rat, *Rattus norvegicus* (Leslie, 1945). The author is much indebted to Mr Leslie for having drawn his attention to the possible application of actuarial procedures to insect populations. He has been completely dependent upon him for the methods of calculation used in this paper.

Before proceeding to discuss the reasons for the particular terminology adopted in this paper, it is necessary first to consider the true nature of the parameter with which we are concerned.



CAPACITY FOR INCREASE: A USEFUL POPULATION STATISTIC

By R. LAUGHLIN*

School of Agriculture, The University, Newcastle upon Tyne

INTRODUCTION

In any study of the biology of an animal, one of the first questions is: How fast can it multiply? The object of this paper is to propose that, for most species, there is a simple statistic to answer this question. The statistic is derived from the survival rates and reproductive performance of a cohort of females.

$$r_c = \frac{\log_e R_0}{T_c} \qquad (1)$$

(R_0 = net reproductive rate = number of times a population will multiply per generation, T_c = cohort generation time = mean age of mothers in cohort at birth of female offspring. Thus antilog$_e r_c$ gives the number of times a population multiplies itself per time unit and r_c itself is the exponent of an exponential curve, see equation (4)). It is proposed that r_c be called the Capacity for Increase.

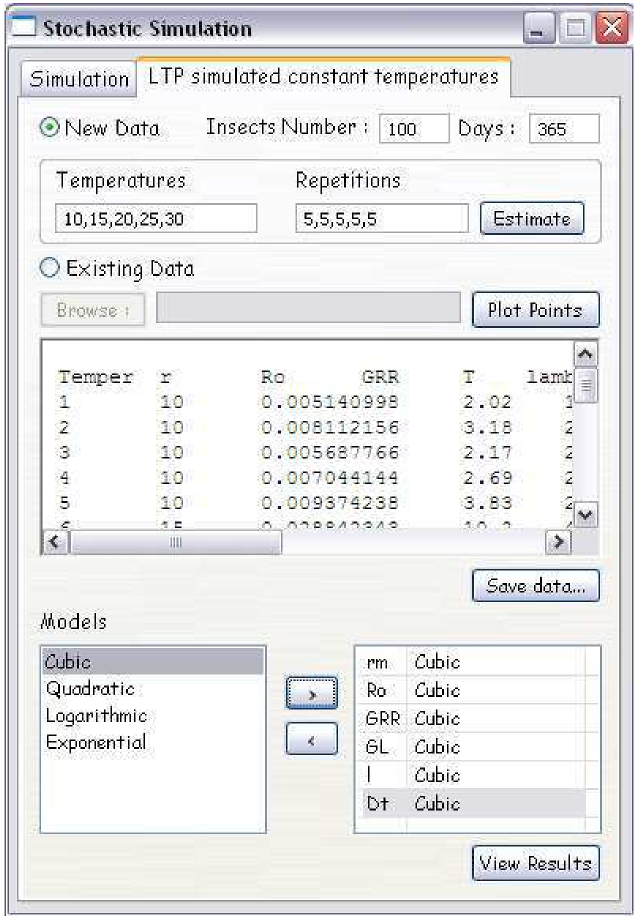
r_c is not a new statistic. Equation (1) is given in slightly different form ($r_m \simeq \log_e R_0/T$) by Andrewartha & Birch (1954, p. 41) as the formula for the rough calculation of r_m (innate capacity for increase in numbers). They go on to point out that this approximate version of r_m is accurate enough for most purposes when R_0 is low but that it is frequently desirable to calculate r_m accurately. They leave the impression that the approximate value of r_m (r_c) is of little value. I believe, on the other hand, that r_c is a useful term in its own right and justifies its own name and symbol.

It is not only an approximation for r_m. It gives the actual rate of increase of an animal with no overlapping of generations and the actual rate of increase of a continuous breeding animal in the first few generations of increase in a new population arising from a cohort of animals all the same age (as, for example, when an empty piece of territory is colonized by immigrants). Moreover, r_c is always a useful and comparative summary of the survival and fecundity data for a species.

As a symbol, r_m has not been much used since it was introduced in 1954. Andrewartha & Birch coined it to distinguish between the actual rate of increase observed in the field (r) and the innate capacity for increase (r_m—calculated from experimental data and relating to a population with a stable age distribution). This seems to be a useful distinction and their usage will be followed here. Indeed, it seems surprising that two symbols were not used before 1954 since authors writing about the concept of the rate of increase of a population have all emphasized that there is an intrinsic rate (characteristic of the animal) and an observed rate; the two need not be the same even if environmental conditions are constant for a considerable length of time.

There is no need to give the theoretical and mathematical background to r_m and r_c in this paper. Good explanations are to be found in Lotka (1945) and Andrewartha & Birch (1954, Section 3.1). Marshall (1962) gives a useful summary of the equations

Simulated life table parameters



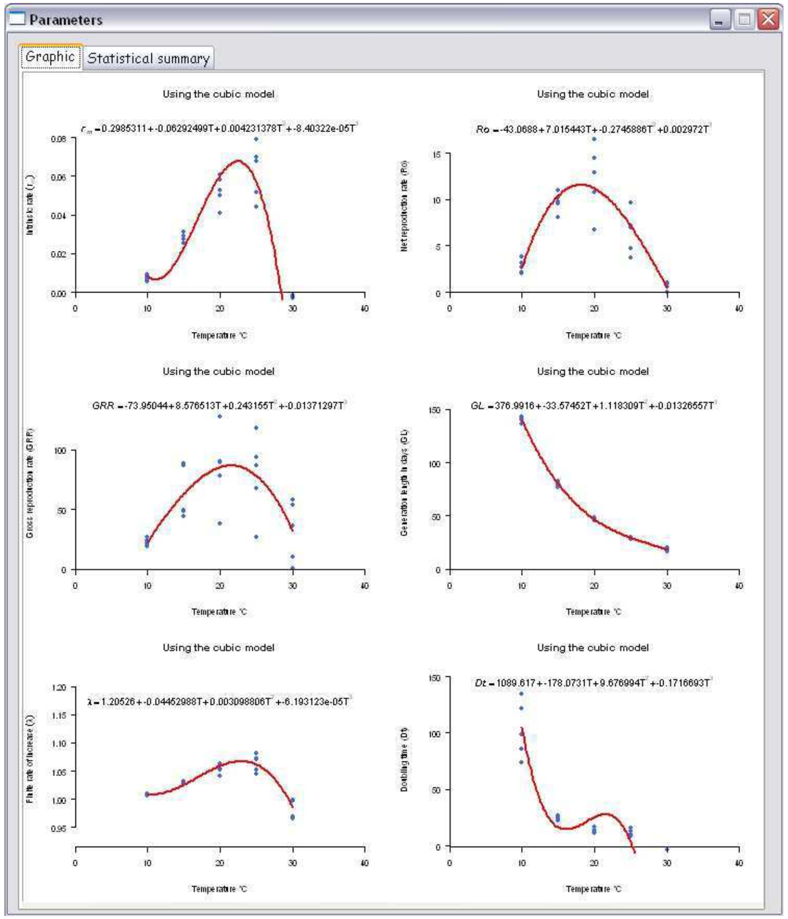
● New Data Insects Number : 100 Days : 365

Temperatures: 10,15,20,25,30

Repetitions: 5,5,5,5,5

```
Temper  r      Ro           GRR     T      lamb
1       10     0.005140998          2.02   1
2       10     0.008112156          3.18   2
3       10     0.005687766          2.17   2
4       10     0.007044144          2.69   2
5       10     0.009374238          3.83   2
```

rm	Cubic
Ro	Cubic
GRR	Cubic
GL	Cubic
l	Cubic
Dt	Cubic



LTP are simulated stochastically or deterministically
at constant or fluctuating temperature

ILCYM Geographical Simulation

approximated LTP

i) Generation length in days (T) = $(1/d_1) + (1/d_2) + \ldots\ldots + (1/d_K) + (1/s_F) \times TR_{50\%}$

where d_k is the median development rate for the immature life stages, k, s_F is the median senescence time for female adults and $TR_{50\%}$ is the normalized age of females until median oviposition.

ii) Net reproduction rate (R_0) = $f \times IS \times FR$

where f is the fecundity per female, IS is the immature survival rate ($= \prod 1\text{-}m_k$), and FR is the female rate in the progeny.

iii) Intrinsic rate of increase (r_m) = $\ln(R_0) / T$

iv) Finite rate of increase (λ) = $\exp(r_m)$

v) Doubling time (Dt) = $\ln(2) / r_m$

Risk indices

1 Establishment risk index (Survival risk index):

$$EI = (1-x_{Egg}) \times (1-x_{Larva}) \times (1-x_{Pupa})$$

x is percentage of days a specific life-stage does not survive

2 Generation Index:

$$GI = \frac{\sum 365/T_x}{365}$$

the average number of generations within one year

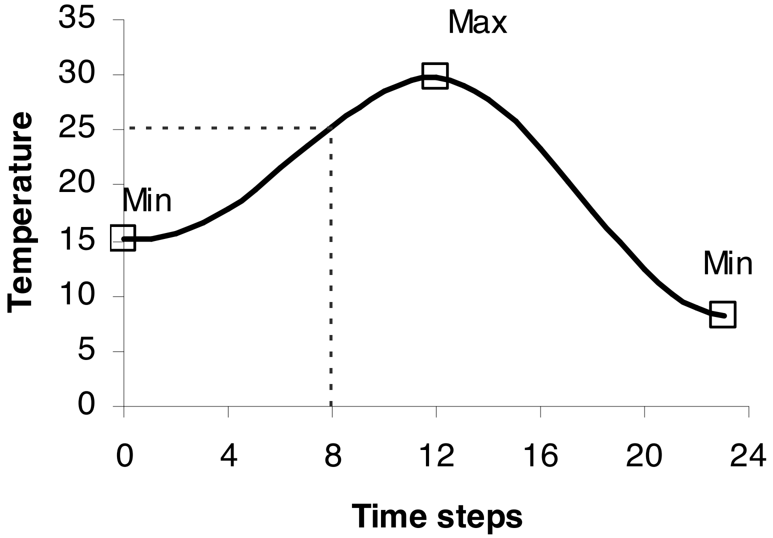
3 Activity Index:

$$AI = \text{Log} \prod \text{finite rate of population increase } (\lambda)$$

this index not only highlights the risk of establishment but also the spread potential

Temperature inclusion in the model

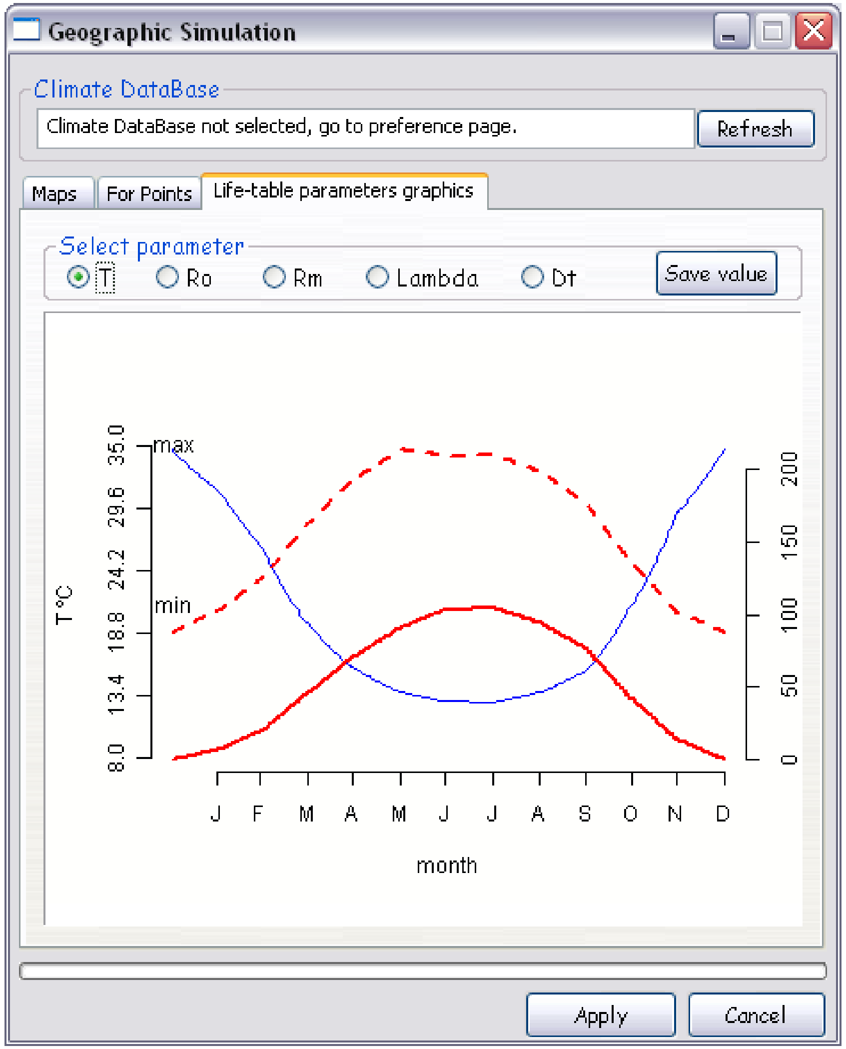
$$T_i = \frac{(Max - Min)}{2} \times \cos\left(\frac{\pi \times (i + 0.5)}{48}\right) + \frac{(Max - Min)}{2}$$



1) **Present scenario:**
   Interpolated temperature data obtained from WorldClim available at http://www.worldclim.org/.
   documented in Hijmans et al. (2005).

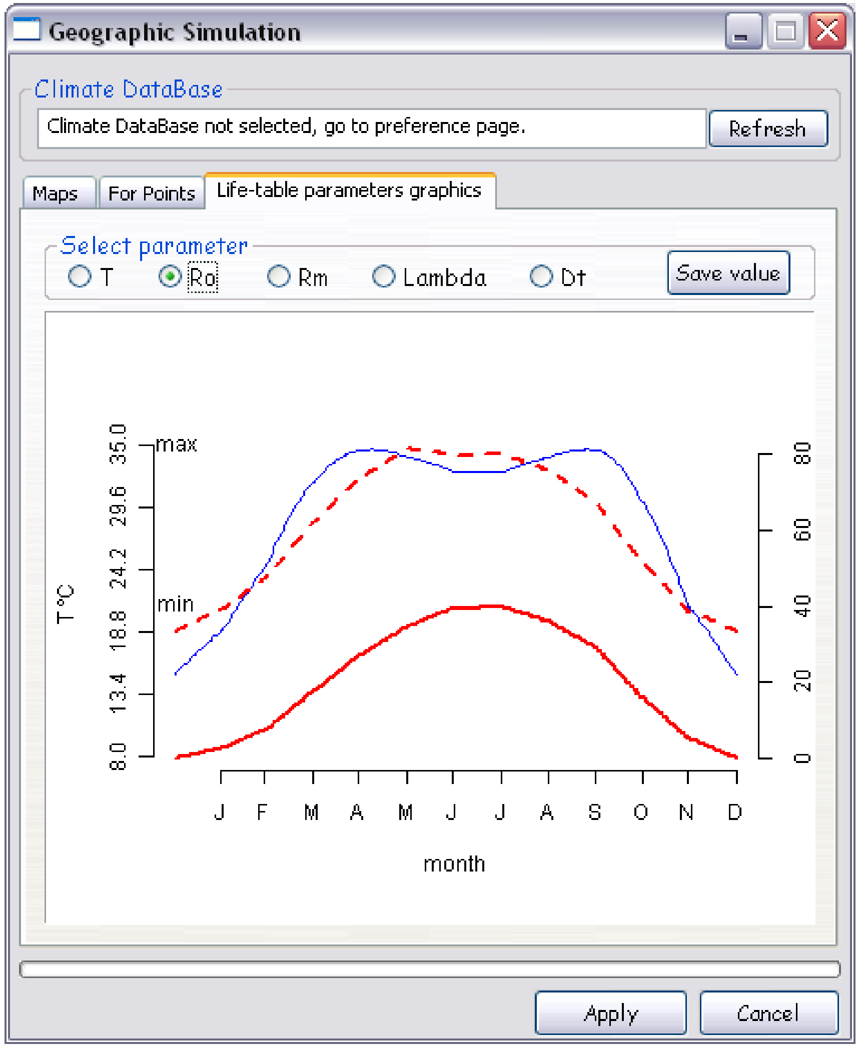
2) **2050 scenario:**
   Downscaled SRES-A1B scenario
   Ramirez and Jarvis (2010)

Geographic simulation in ILCYM



Climate DataBase not selected, go to preference page.

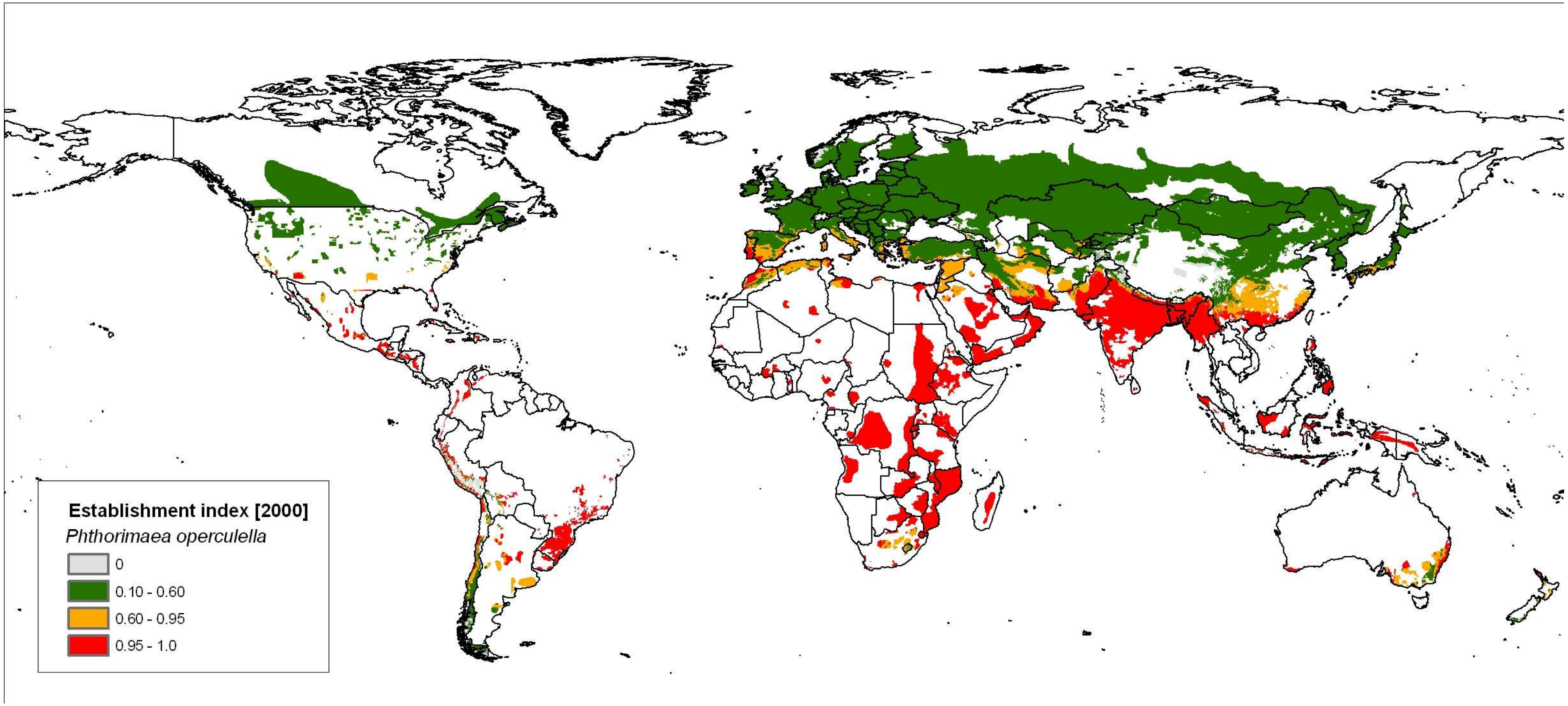
Select parameter: ● T ○ Ro ○ Rm ○ Lambda ○ Dt



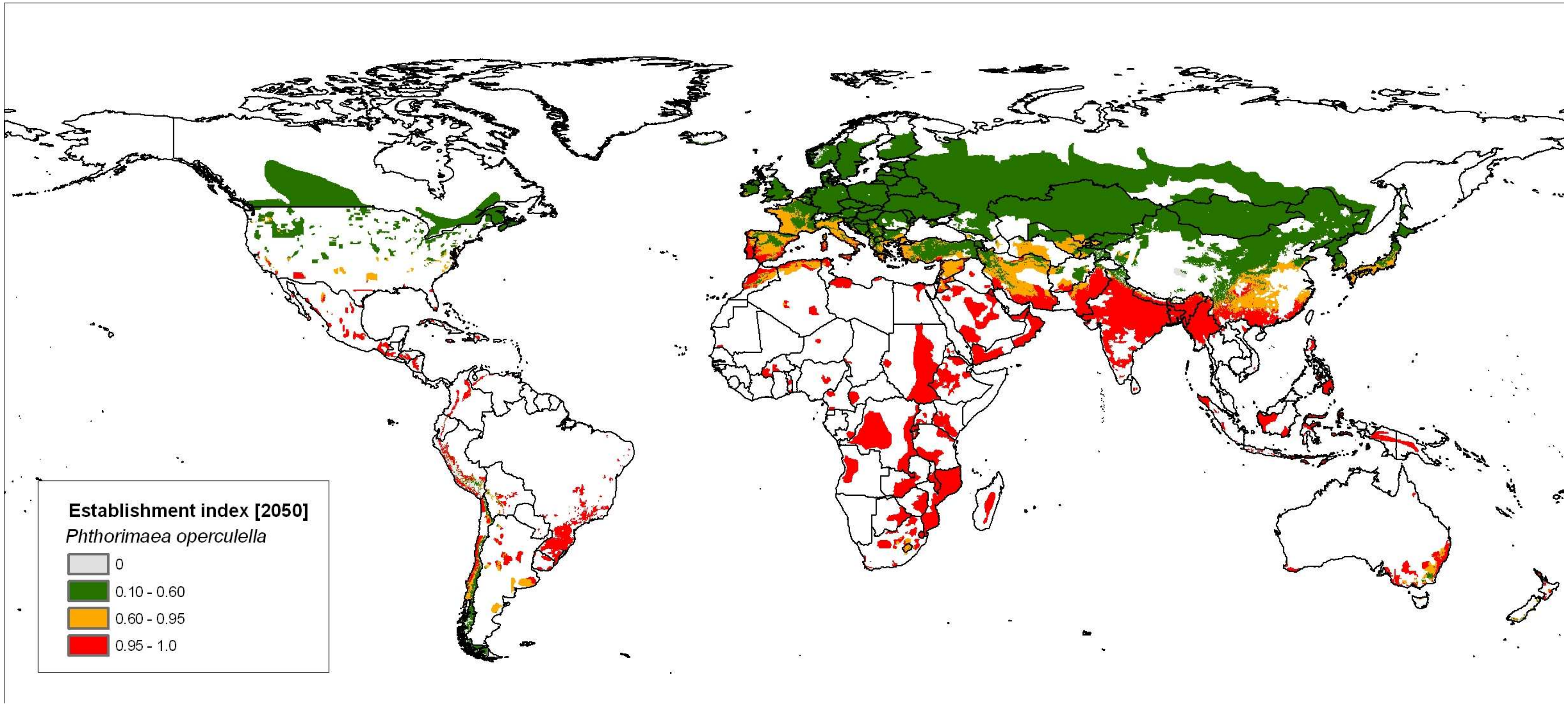
Climate DataBase not selected, go to preference page.

Select parameter: ○ T ● Ro ○ Rm ○ Lambda ○ Dt

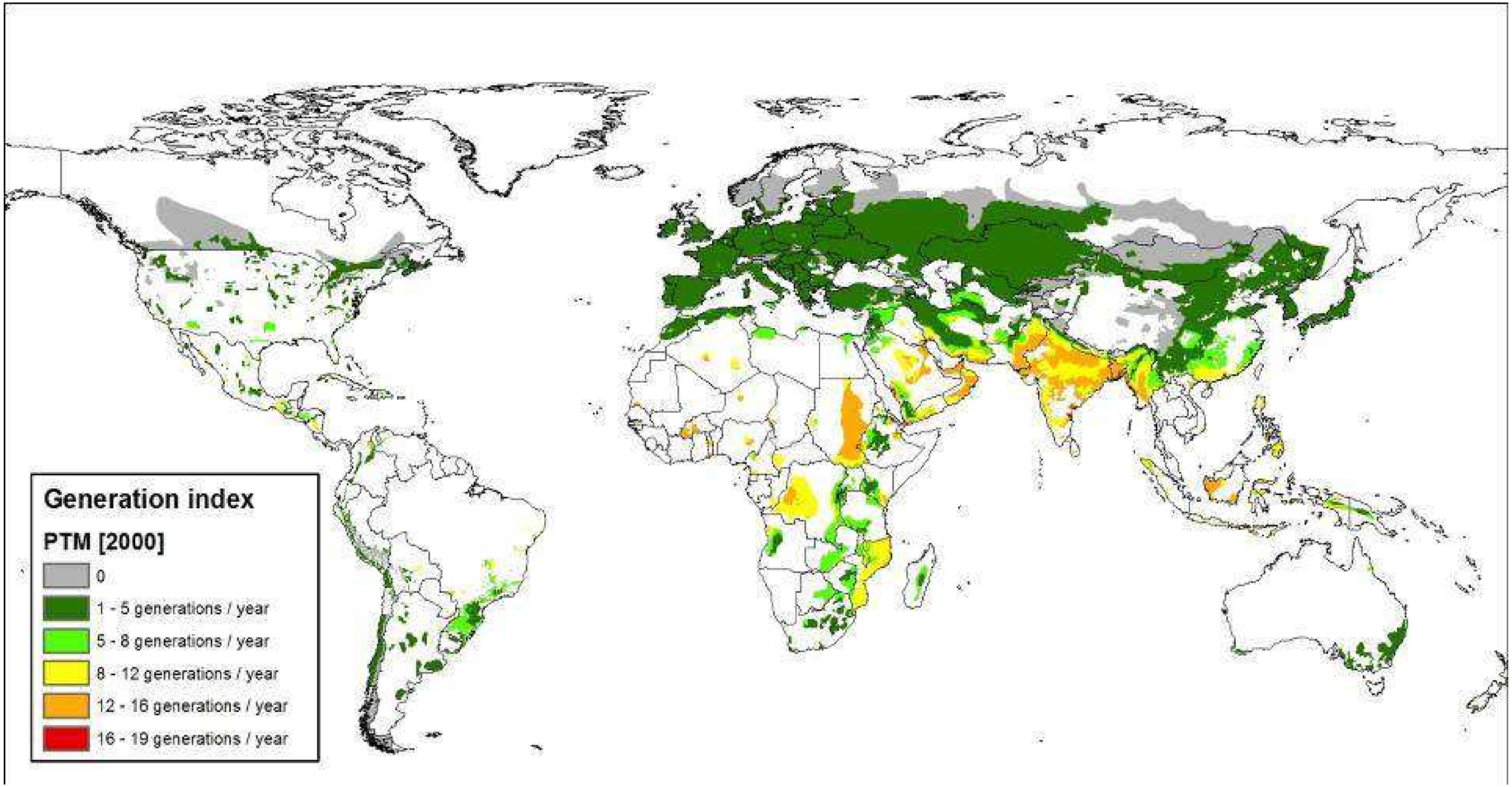
Establishment risk index 2000



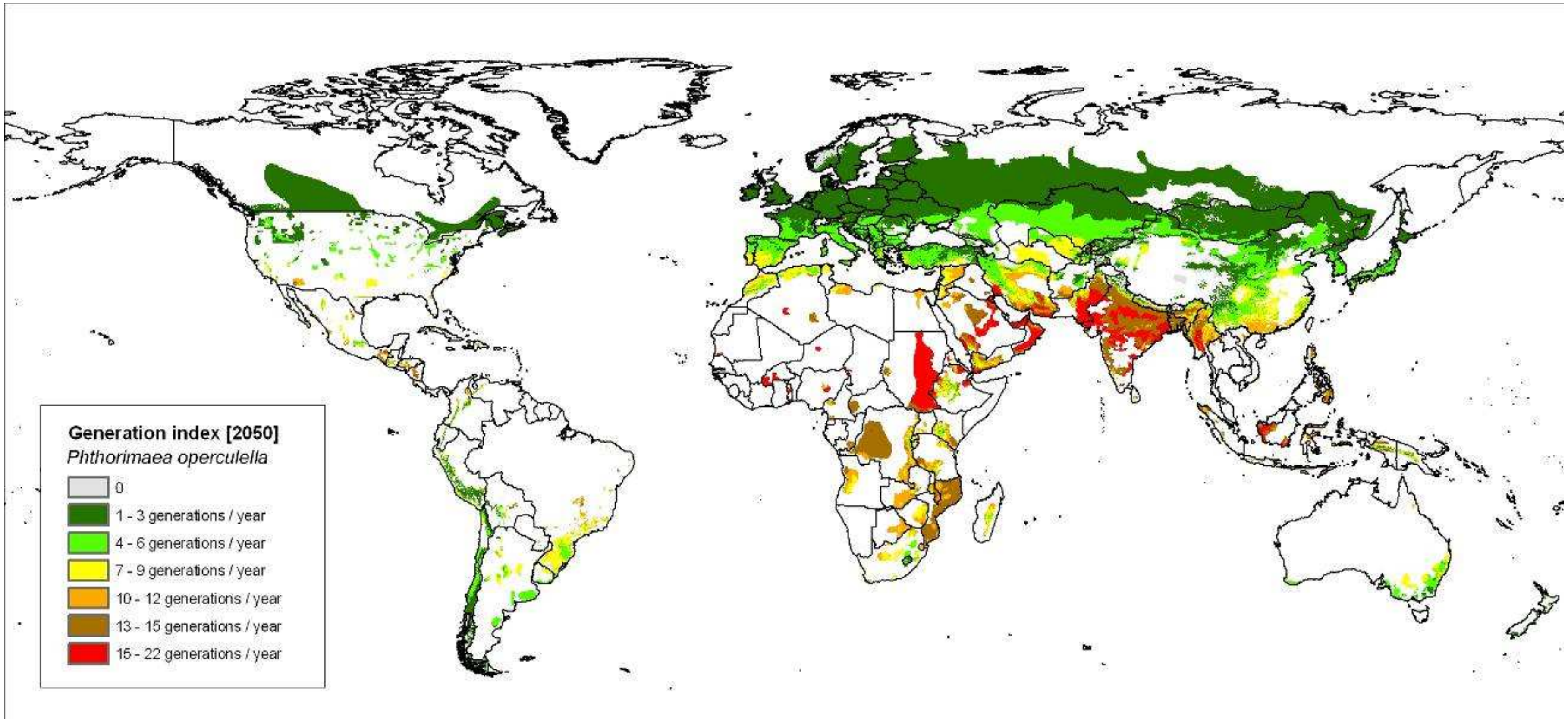
Establishment risk index 2050



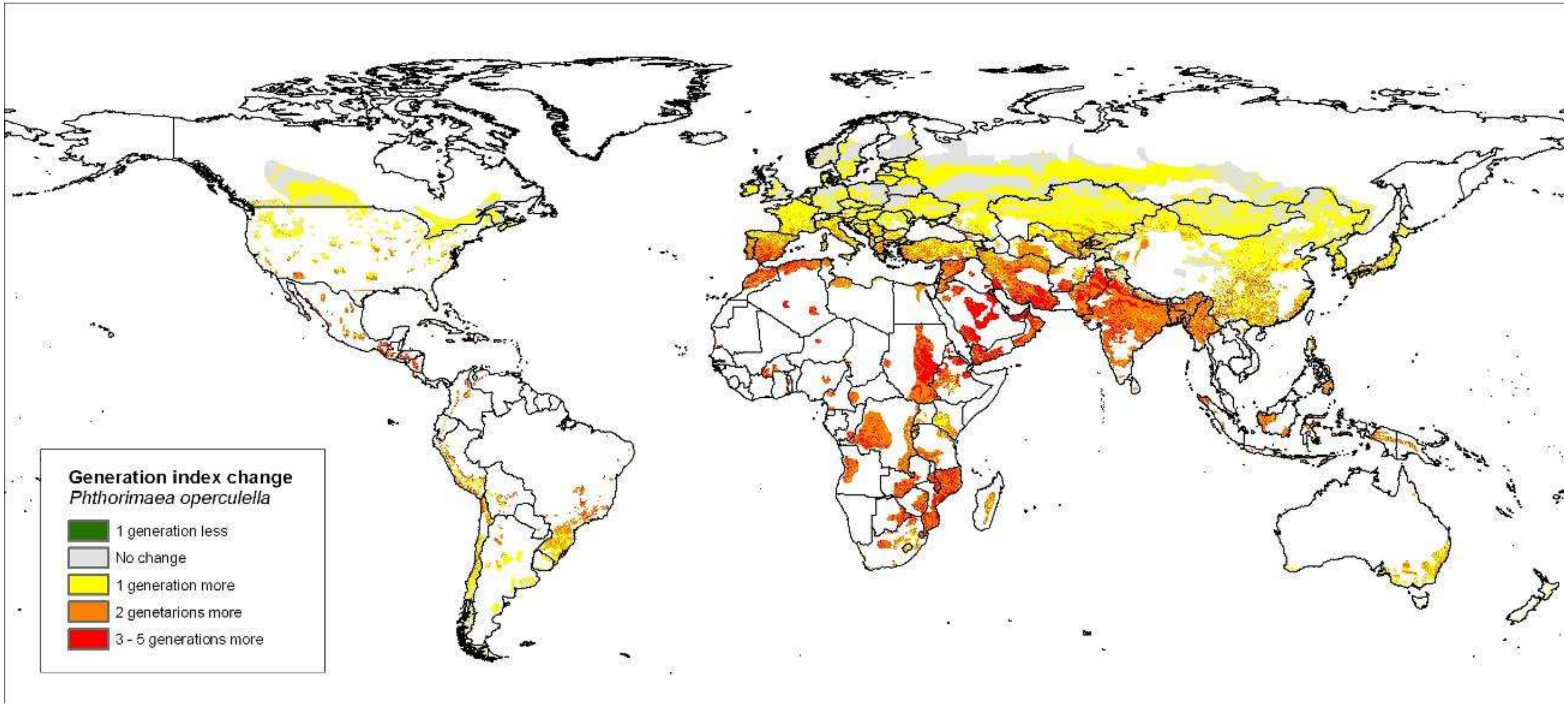
Generation index 2000



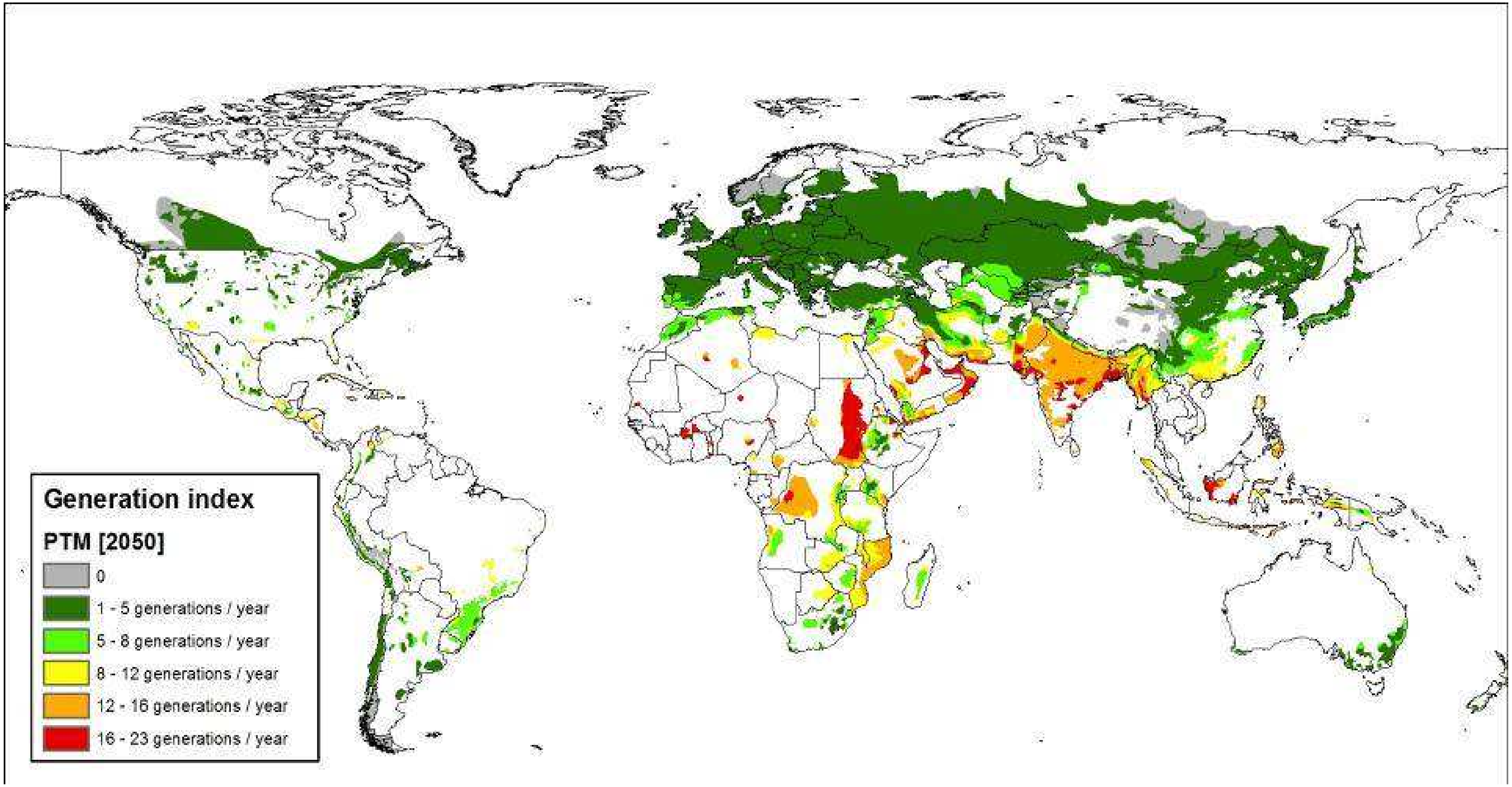
Generation index 2050



Generation index change

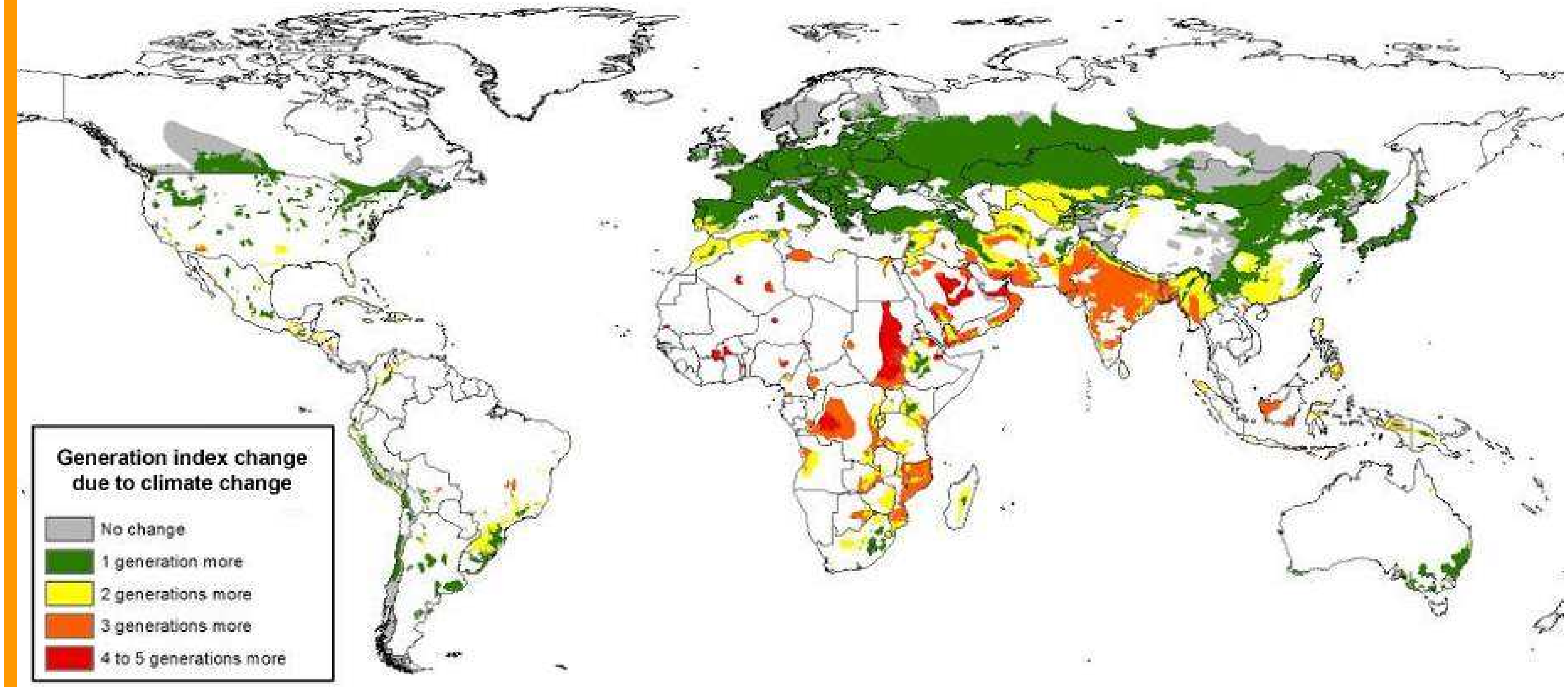


Global risks of potato tuber moth in potato: 2000 - 2050



Absolute generation index change due to effect of climate change: 2000 - 2050

Expansion to the North and to higher altitudes!

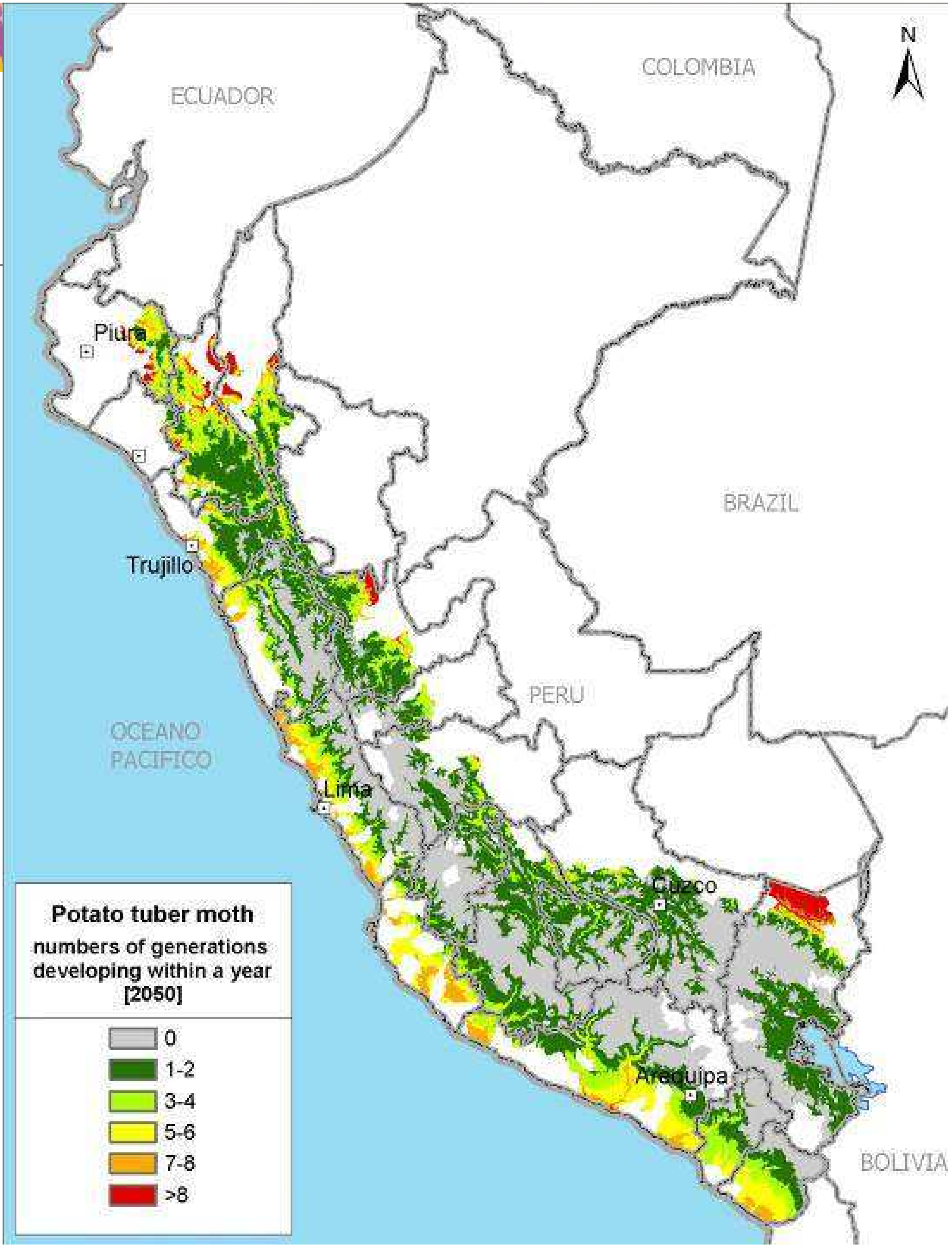


Risk of potato tuber moth in Peruvian highlands

☐ Total potato production area in Peru in 2007: 267,000 ha.

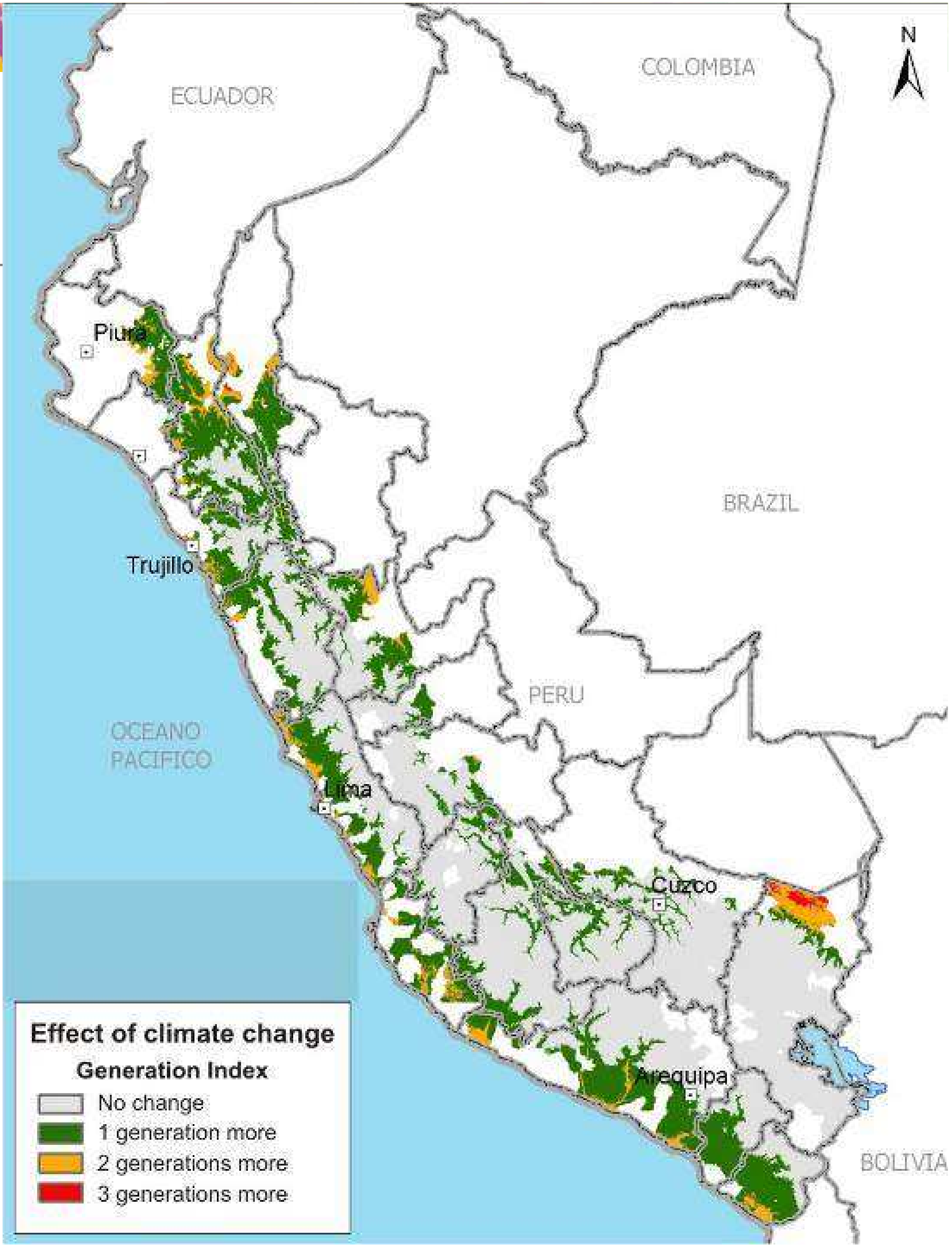
☐ Potato tuber moth is reported from the coast and Inter-Andean valleys.

☐ It is estimated that today 120,398 ha of potato are affected by the potato tuber moth (45% of the total potato area).



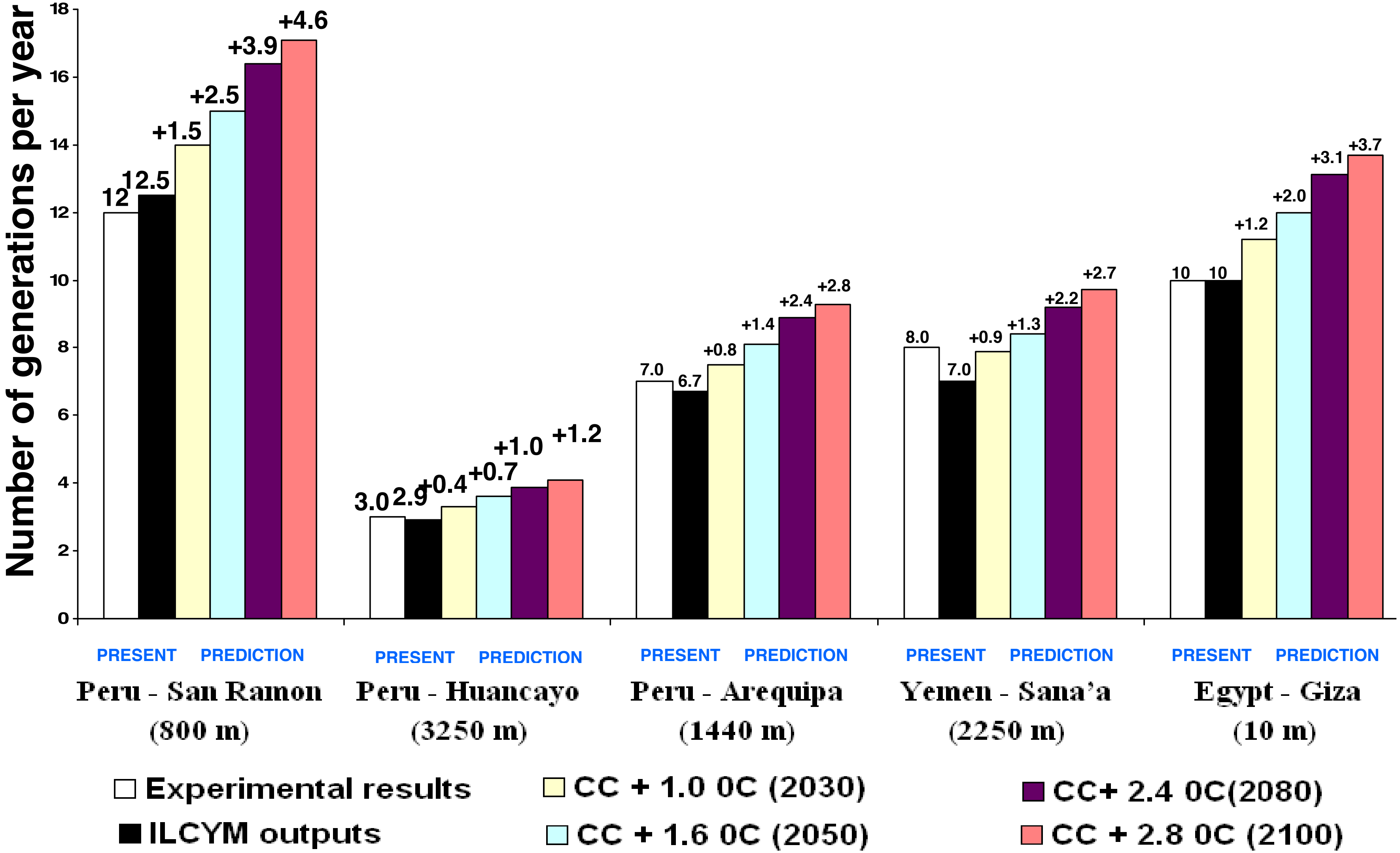
Absolute generation index change due to effect of climate change: 2000 - 2050

- It is estimated that due to CC, the potato tuber moth will affect potato at higher elevations and will increase the total area of infestation from 120,398 ha to 179,178 ha (67% of the total potato area).



Effect of climate change scenarios on the number of generations at different locations

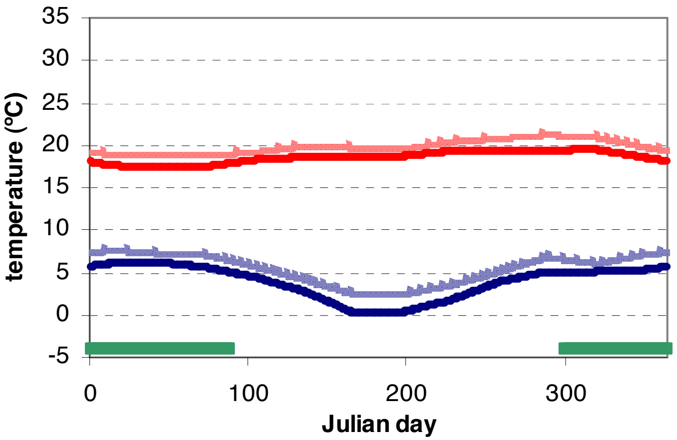
(point by point validation)



Huancayo, Peru
3283 masl
-12.03 Lat
Ø 11.1℃ => 12.7℃

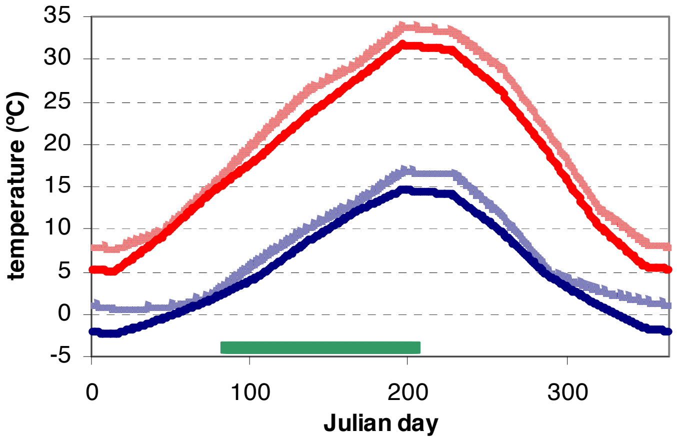
potential activity increase

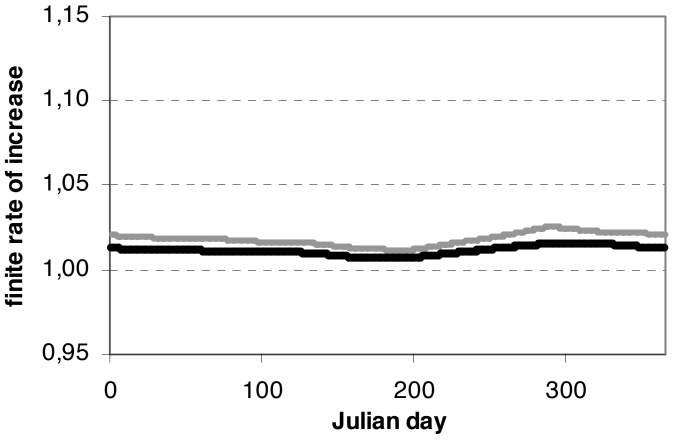
Hermiston, OR (CRB)
144 masl
45.84 Lat
Ø 11.9℃ => 14.0℃



Year
EI: 1 => 1
GI: 2.6 => 3.3
AI: 1.7 => 2.9
1338%

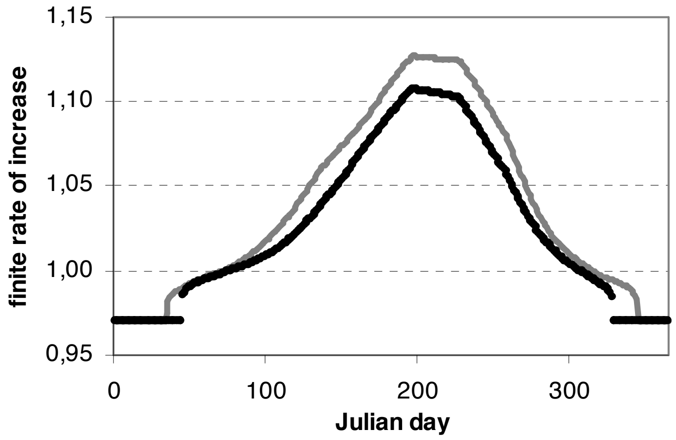
Veg. Period
AI: 0.8 => 1.3
328%





Year
EI: 0.78 => 0.85
GI: 4.1 => 5.1
AI: 3.8 => 5.7
6523%

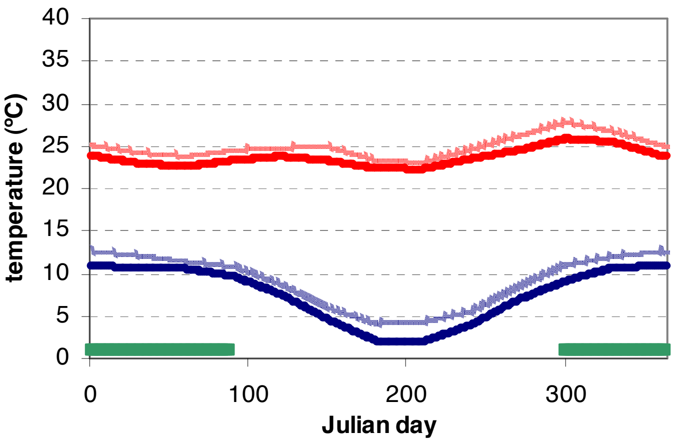
Veg. Period
AI: 2.6 => 3.4
665%



Cochabamba, Bolivia
2531 masl
-17.45 Lat
Ø 15.3℃ => 16.9℃

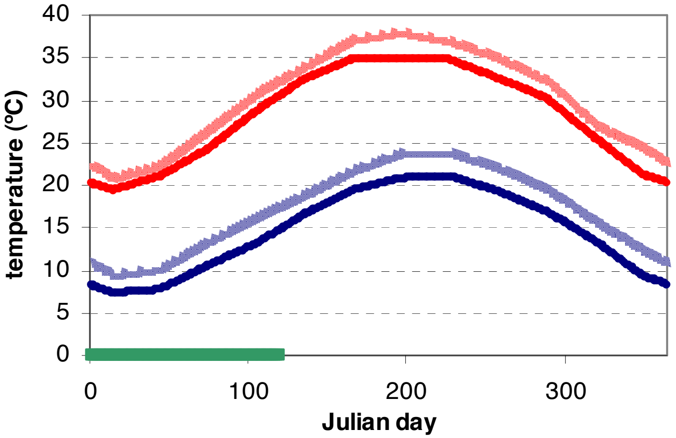
potential activity increase

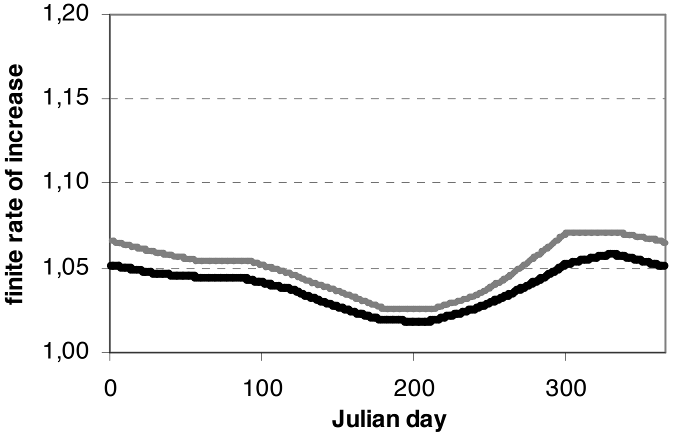
Al Buhayrah, Egypt
10 masl
30.4 Lat
Ø 21.5℃ => 23.8℃



Year
EI: 1 => 1
GI: 5.0 => 5.9
AI: 5.9 => 7.7
5730%

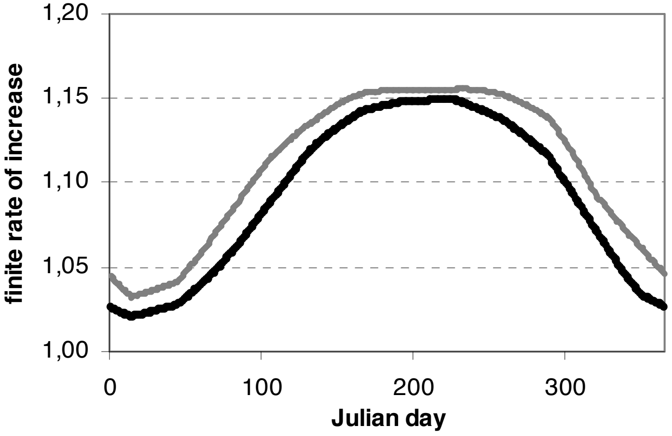
Veg. Period
AI: 3.2 => 4.1
709%





Year
EI: 1 => 1
GI: 9.6 => 11.8
AI: 13.9 => 16.4
>33000%

Veg. Period
AI: 2.4 => 3.4
951%



Conclusions and challenges

- Phenology modeling and GIS risk mapping might be an appropriate framework for assessing insect related effects of CC, but:
  - Uncertainties in climate change predictions.
  - Worldclim data provide monthly aggregated temperature data; interpolation of weather data.
  - Regional meteorological data could have higher accuracy.
  - Other factors: e.g., precipitation.
  - Interaction of pests and natural enemies

CIP's Modeling Group

Marc Sporleder

Jürgen Kroschel

The team is composed by:
-specialists in Agroecology/IPM
- insect modeling and statistics, and
- application of GIS.

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Henri Tonnang

Henry Juarez

Juan Carlos Gonzalo

Pablo Carhuapoma