Un modèle de dynamique de population de limace avec deux classes d’âge

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Formation Introduction à la modélisation pour la protection intégrée des cultures.

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Modèle simple de dynamique de population

Choi *et al.,* 2004

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Modelling *Deroceras reticulatum* (Gastropoda) population dynamics based on daily temperature and rainfall

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Abstract

A simple mathematical model was developed, using ordinary differential equations, to understand the dynamics of *Deroceras reticulatum* populations. Field data from a long term experiment were interpolated to give daily data for the numbers of slugs m^{-2}. Using a model calibration procedure, rates estimated from interpolated data were found to be different from the laboratory rates used to initialise the model. The calibrated model explained 81.2% of the total variation in the interpolated data. Calibration results indicated that rainfall and temperature influenced each rate and affected adults and juveniles differently. Juvenile mortality appeared to be only affected by temperature, whilst the juvenile recruitment rate and the rate of adult mortality were found to be more dependent upon rainfall. The model was then simulated over a three and a half year period for comparison with the interpolated data for the same period. Qualitative changes in the interpolated slug abundance were well described by the model. The results suggest that with a better understanding of between year and site factors, and the inclusion of time delays and egg laying, this model could provide a more accurate forecast of slug abundance.

Deux équations différentielles

- X_J : nombre d'individus juvéniles
- X_A : nombre d'individus adultes

$$\frac{\mathrm{d}X_{\mathrm{J}}(t)}{\mathrm{d}t} = \alpha(t) - (\delta_{\mathrm{J}}(t) + \rho(t))X_{\mathrm{J}}(t),$$

$$\frac{\mathrm{d}X_{\mathrm{A}}(t)}{\mathrm{d}t} = \rho(t)X_{\mathrm{J}}(t) - \delta_{\mathrm{A}}(t)X_{\mathrm{A}}(t),$$

Effet climatique

$$f(T) = \begin{cases} 0.5\left(1 + \cos\left(\frac{T - T_0}{c}\pi\right)\right), & \text{when } T_L < T < T_U, \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

with T being the temperature at time t, T_L and T_U the lower and upper threshold values for temperature, T_0 the location of the peak of the cosine function, π/c the angular frequency for the function, and

$$g(R) = \begin{cases} 0.5\left(1 + \cos\left(\frac{R - R_0}{d}\pi\right)\right), & \text{when } 0 < R < R_U, \\ 0 & \text{otherwise.} \end{cases} \tag{3}$$

R being the rainfall at time t, R_U the upper threshold value for rainfall, R_0 the rainfall maxima, π/d the

Les étapes d’une simulation

On peut décrire l’algorithme de simulation d’un modèle dynamique ainsi :

- **Initialiser toutes les variables d'état, les paramètres** et autres variables nécessaires pour effectuer les calculs.
- **Propager, à chaque pas de temps** (par exemple, jour). Boucle sur les 2 étapes suivantes jusqu’à la fin de la simulation.
  - **Calculer les taux de changement des variables d'état** ou les changements dans ces variables d'état qui ont lieu à chaque pas de temps.
  - **Mettre à jour les variables d'état** pour le nouveau pas de temps en ajoutant le taux de changement, multiplié par le pas de temps à la valeur de la variable d'état à partir du pas de temps précédent. C'est ce qu'on appelle l'intégration d’Euler.

    (par exemple : $TT(j+1) = TT(j) + \Delta TT(j)$).
- **Enregistrer les résultats** des simulations dans une table pour une analyse ultérieure, en conservant la dynamique des variables d’état.

paramètres : initiaux et calibration

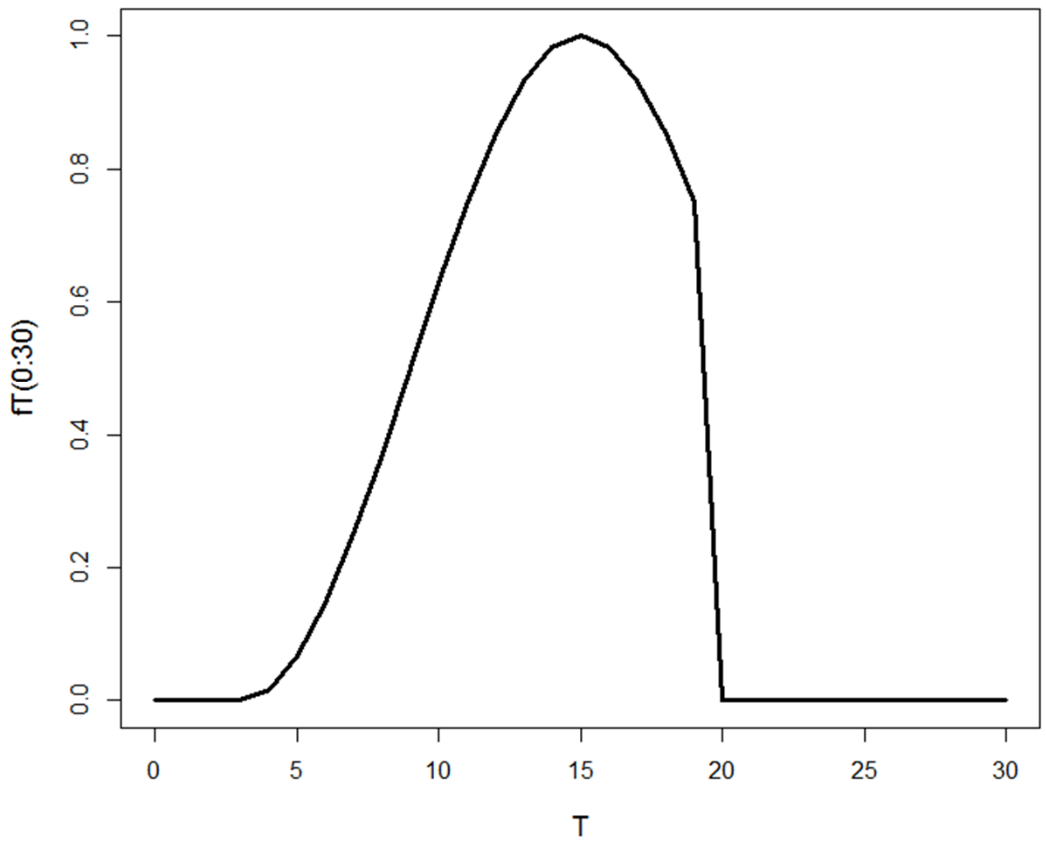
Table 2
The parameter values given in Eqs. (4) and (5) according to their initialisation in Table 1, their calibrated values with standard errors and references

	Initialised values	Calibrated values	S.E.	References
Recruitment a_α	20	30.09	1.39	Carrick (1942) and Judge (1972)
Recruitment b_α	0	0	*	Carrick (1942) and Judge (1972)
Growth rate a_ρ	0.0365	0	*	South (1982)
Growth rate b_ρ	0.0111	0.0299	0.0022	South (1982)
Juvenile mortality rate l_J	0.3220	0.1147	0.0074	Pearl and Miner (1935) and South (1989)
Juvenile mortality rate m_J	0.0111	0	*	Pearl and Miner (1935) and South (1989)
Adult mortality rate l_A	0.1980	0.0902	0.0109	Pearl and Miner (1935) and South (1989)
Adult Mortality rate m_A	0.0020	0.0254	0.0069	Pearl and Miner (1935) and South (1989)
p_{δ_J}	0.5000	1	*	N/A
$p_{\alpha\delta_A}$	0.5000	0.1819	0.0301	N/A

* No standard error available, parameters fixed at 0 or 1.

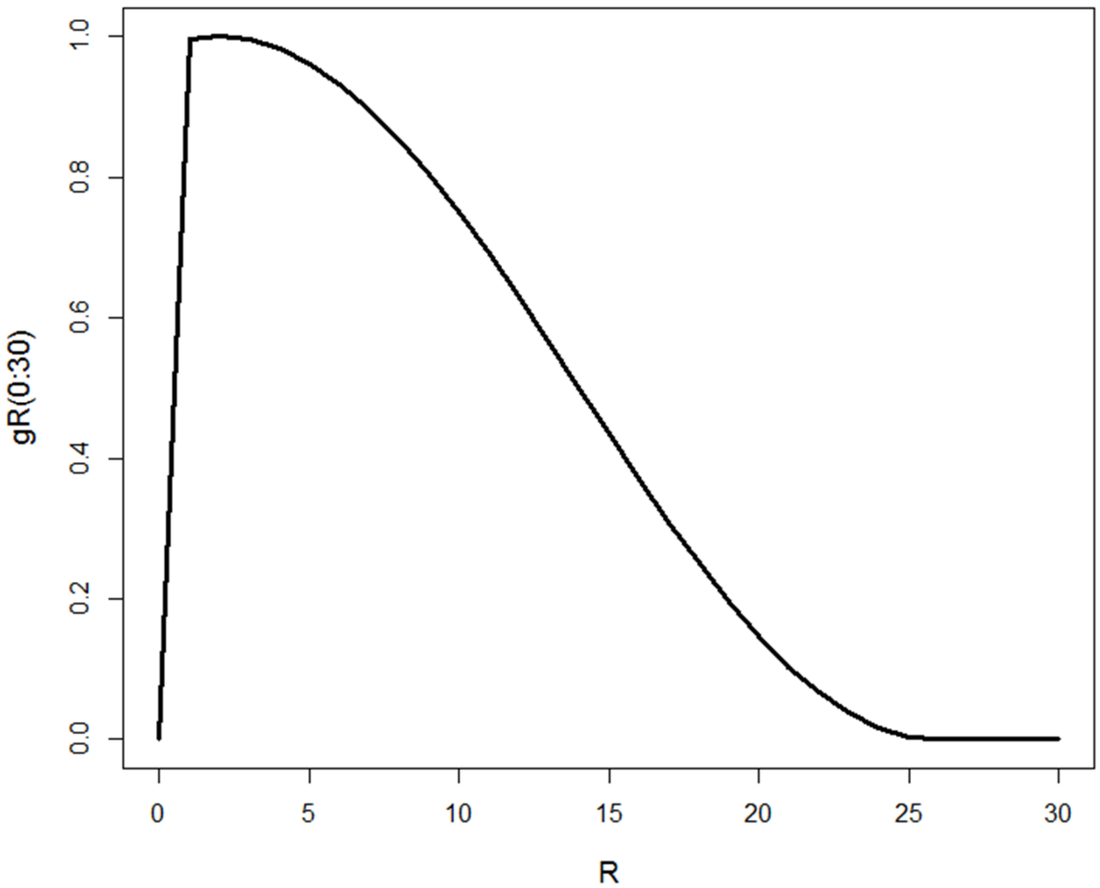
Effet de la température

```
fT=function(Temp, T0=15, c=12, TL=3,TU=20){
    res=0.5*(1+cos((Temp-T0)/c*pi))
    res[(Temp<=TL | Temp>=TU)]=0
    return(res)
}
```



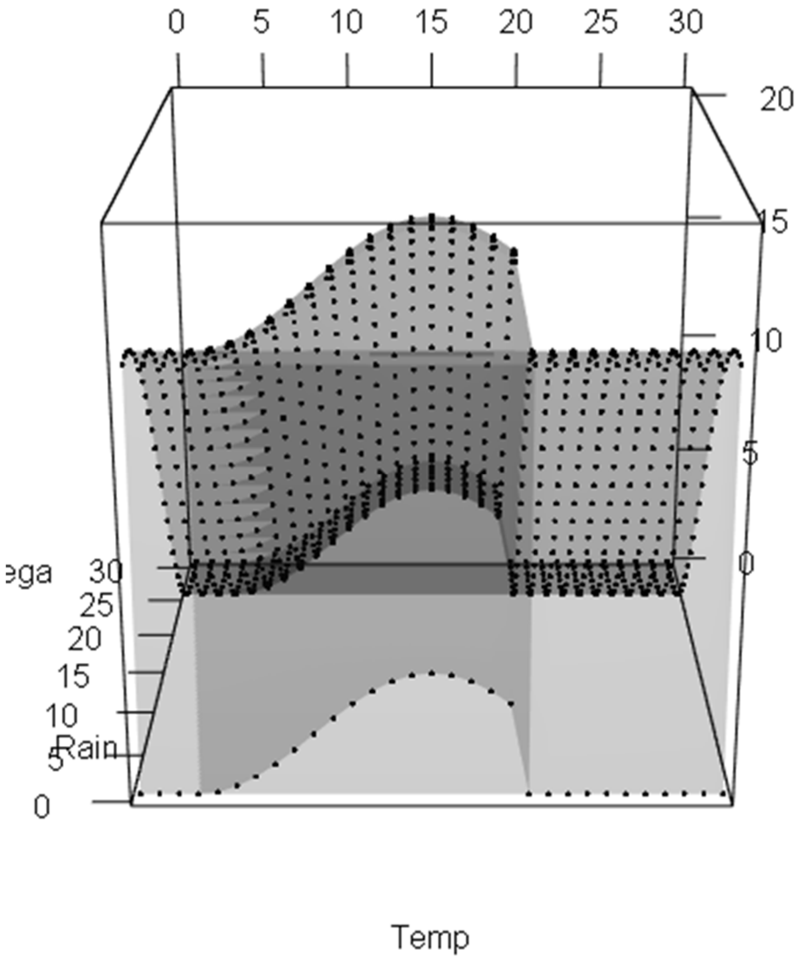
Effet de la pluie

```
gR=function(Rain, R0=2, d=24, RL=0,RU=26){
    res=0.5*(1+cos((Rain-R0)/d*pi))
    res[(Rain<=RL | Rain>=RU)]=0
    return(res)
}
```



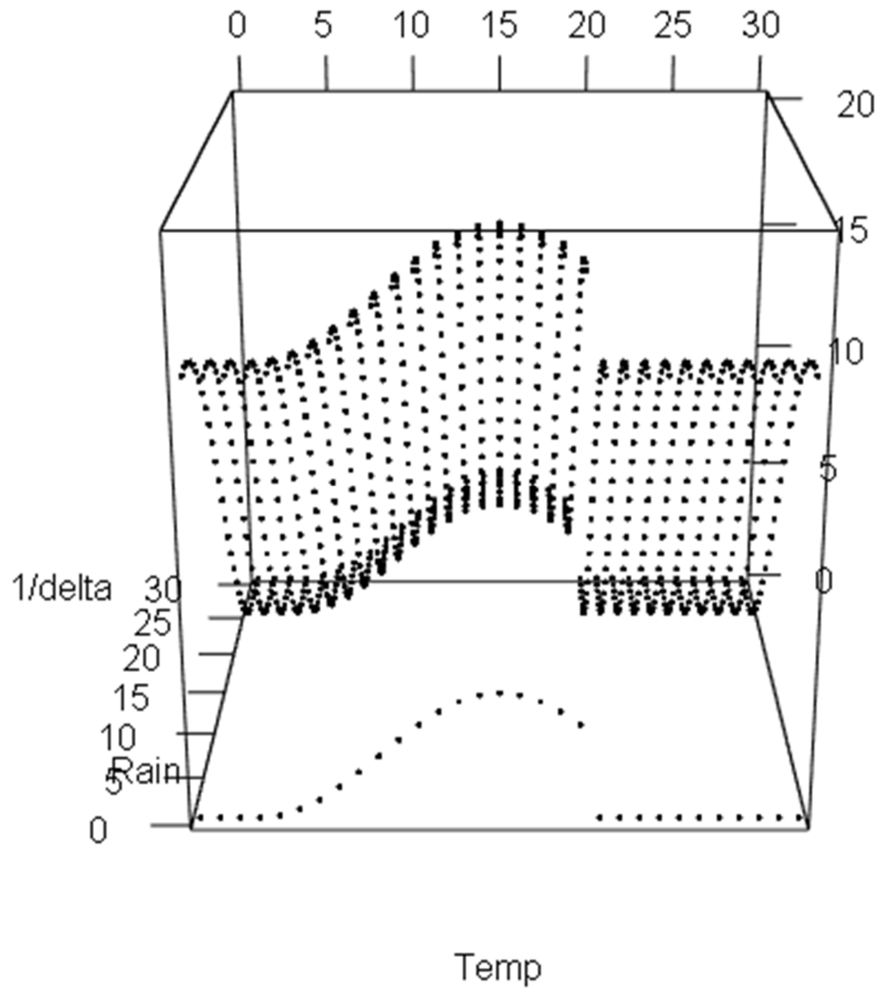
Croissance=f(T,pluie)

```
for growth and recruitment
omega=function(Temp, Rain, a,b, p){
  a *(p*fT(Temp) + (1-p)*gR(Rain)) + b
}
```



mortalité=f(T,pluie)

```
delta=function(Temp, Rain, l,m, p){
    l *(1 - (p*fT(Temp) + (1-p)*gR(Rain))) + m
}
```

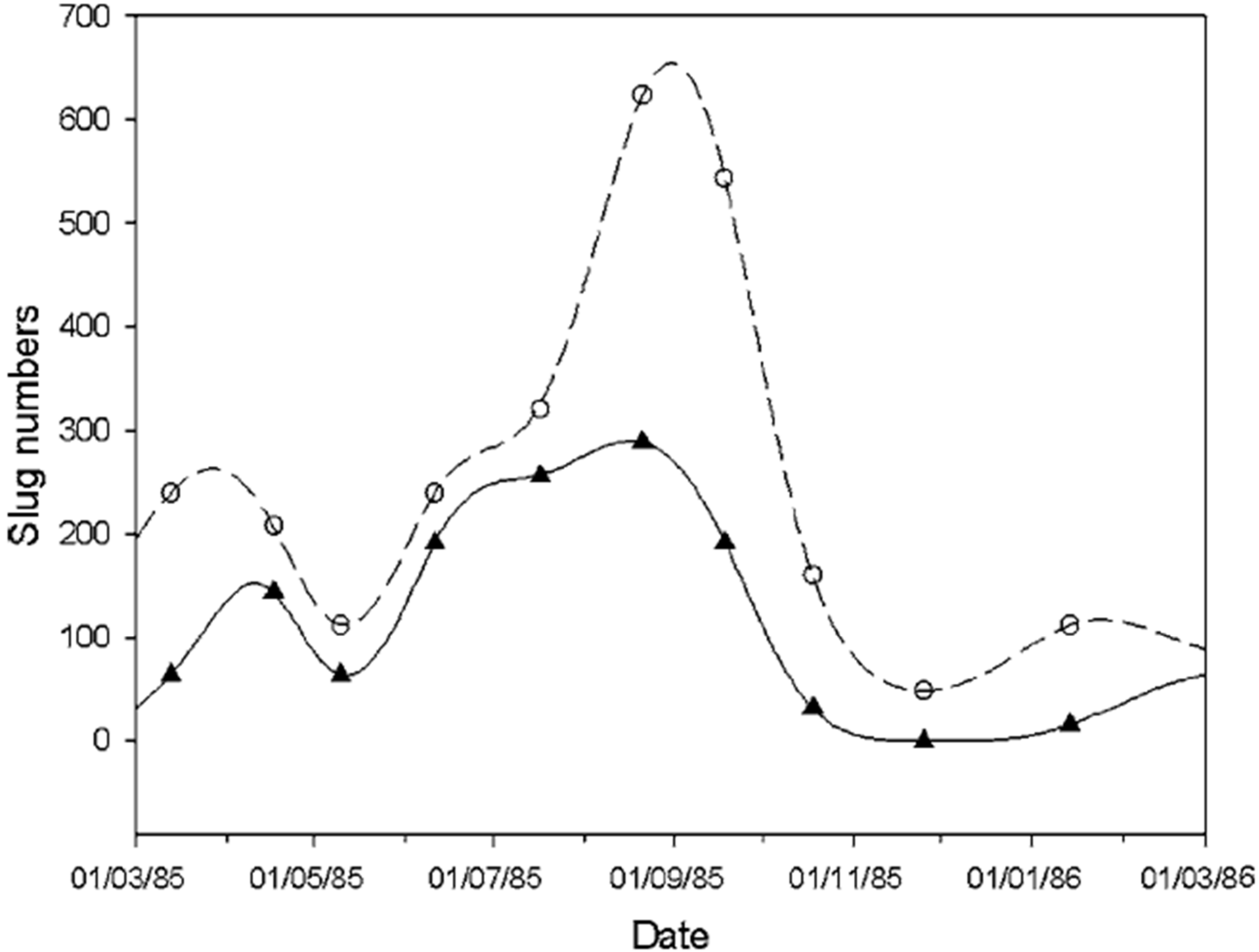


Fonction du modèle

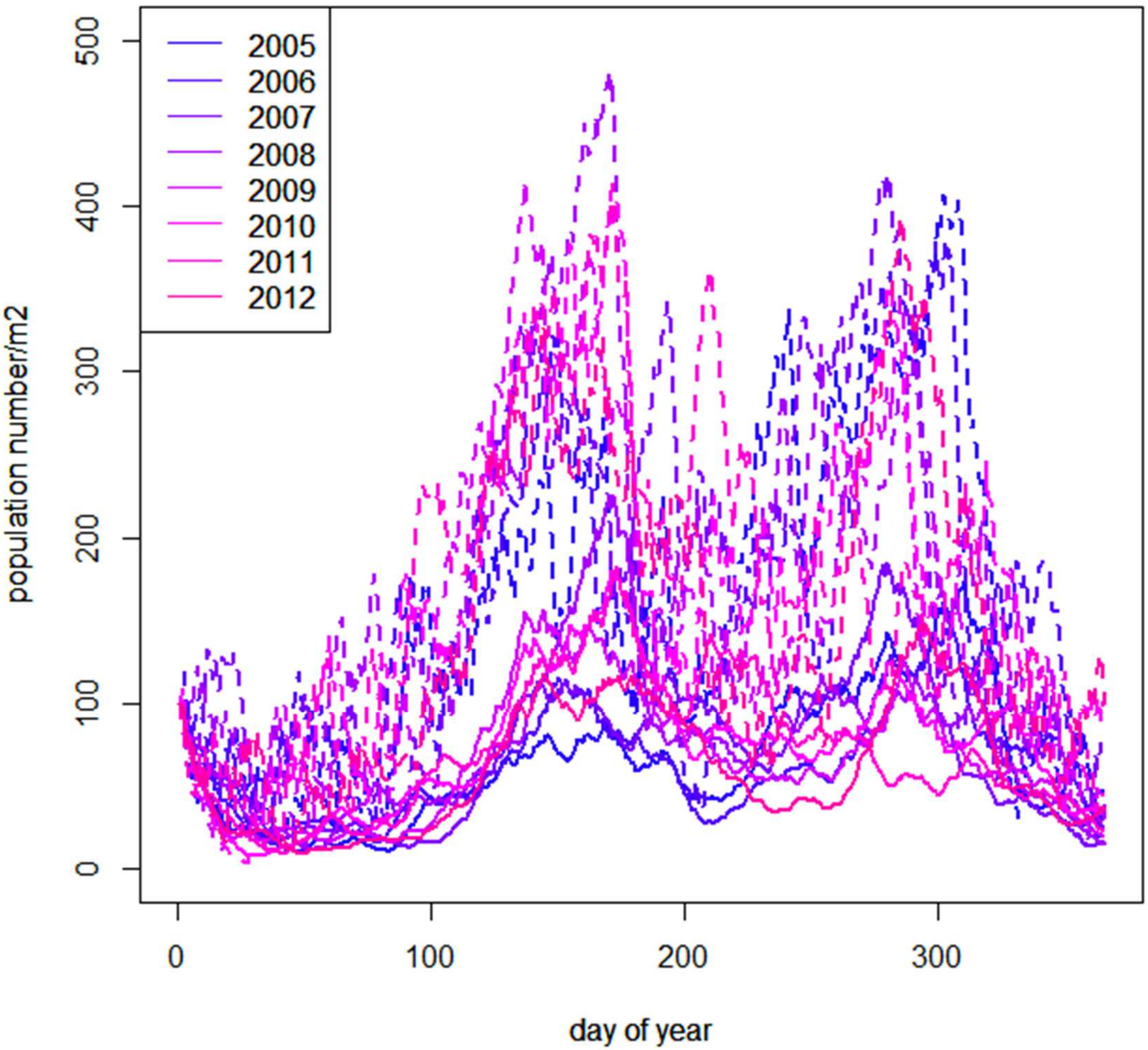
```
choi2004.model <- function(weather, J0, A0,duration){
# Calibrated (from Table 2)
aalpha=30.09;balpha=0;arho=0;brho=0.0299;lJ=0.1147;mJ=0;
lA=0.0902;mA=0.0254;pdeltaJ=1;palphadeltaA=0.1819
pdeltaA=palphadeltaA;palpha=palphadeltaA
prho = 1
# Initialize variables
# J : Juvenile
J=rep(NA,duration)
# A : Adult
A=rep(NA,duration)
 # Initialization of state variables
J[1]=J0
A[1]=A0
```

```
# Simulation loop
for (i in 1:(duration-1))  {
  Temp=weather$Temp[i]
  Rain=weather$Rain[i]
  alpha_j = omega(Temp, Rain, a=aalpha,b=balpha, p=palpha)
  rho_j = omega(Temp, Rain, a=arho,b=brho, p=prho)
  deltaJ_j = delta(Temp, Rain, l=lJ,m=mJ, p=pdeltaJ)
  deltaA_j = delta(Temp, Rain, l=lA,m=mA, p=pdeltaA)
 # Calculate rates of change of state variables
    dJ =  alpha_j -(deltaJ_j + rho_j)*J[i]
    dA =  rho_j*J[i] - deltaA_j*A[i]
# Uptade state variables
    A[i+1]= A[i] +dA
    J[i+1]= J[i] + dJ
  }
  # End simulation loop
results=data.frame(day=1:duration,
J=J[1:(duration)],A=A[1:(duration)])
return(results)}
```

Simulation type



Variabilité inter-annuelle



évaluation

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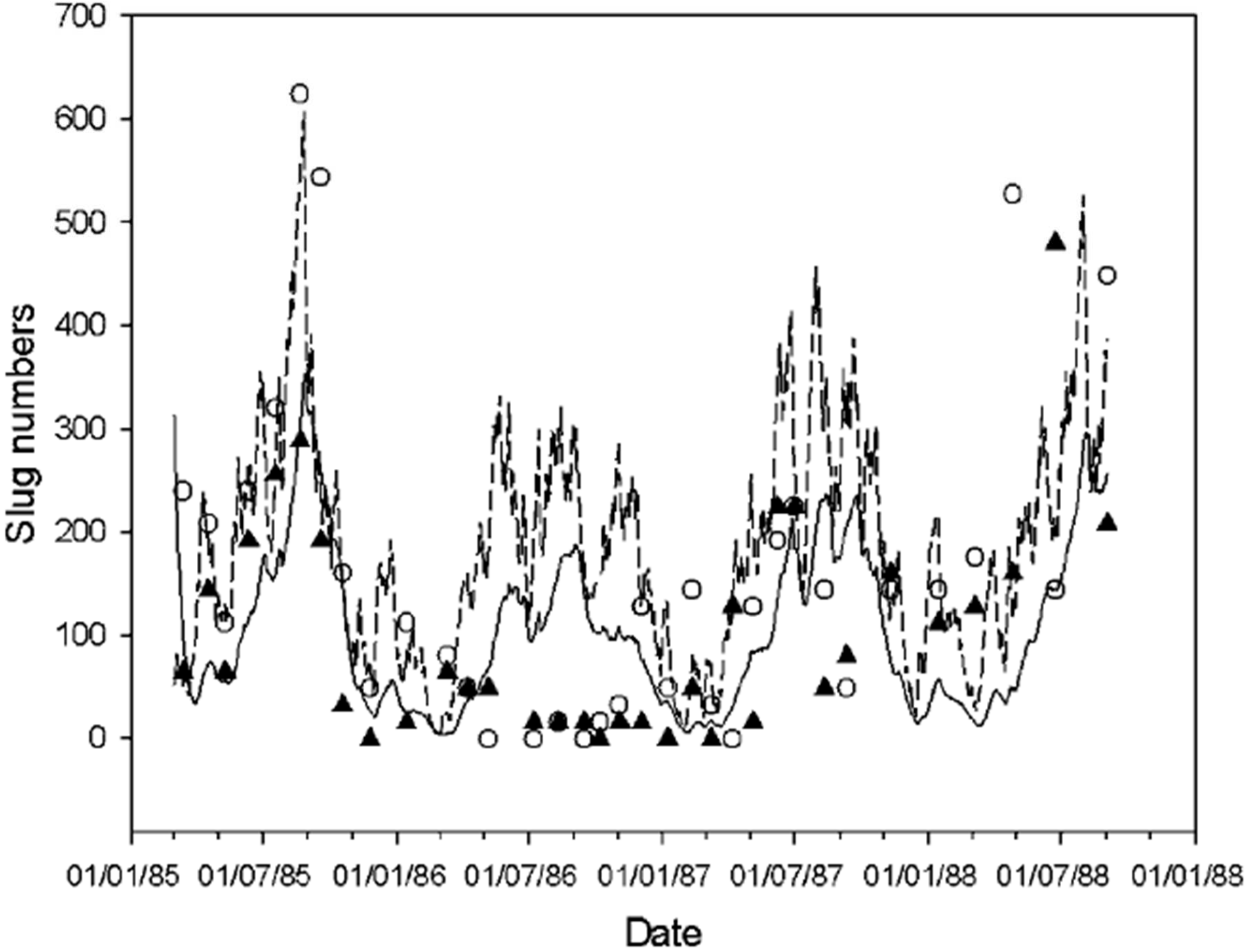

Dynamique des populations de limaces

- Représenter la dynamique de population au cours du temps (stade, croissance, reproduction, mortalité)
- modèle de **dynamique de populations relativement simple**
  - (Choi et al., 2004) : relativement simple. Deux classes Juvéniles, Adultes. Prise en compte température et pluviométrie.
- modèles **individus centrés**
  - (Shirley et al., 2001). Modèle de stade et de croissance.
  - (Choi et al., 2006). simulation du déplacement fonction état de la culture et répartition spatiale à l'échelle de la parcelle.
- **Evaluation de ces modèles**
  - OK pour les grands traits de la dynamique des populations
  - MAUVAISE prise en compte des conditions météorologiques (variabilité interannuelle) ou les effets sites (type de sol).