Modeling population growth of Pyrenean Chamois (Rupicapra Pyrenaica) by using P-systems

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Population dynamics

- Complexity of the processes involved.
- Modeling with classical methods. Limitations.
- Relevance of computational models.

Previous studies of the group in the population dynamics modeling

- **Modeling Ecosystems Using P Systems: The Bearded Vulture, a Case Study .** Cardona et al. *LNCS.* Vol 5391,2009,137-156.
- **P System Based Model of an Ecosystem of the Scavenger Birds.** Cardona et al*. LNCS,* Vol 5957 (2010),182-195.
- **A computational modeling for real ecosystems based on P systems.** Cardona et al. *Natural Computing,* 2010. On line version.

↓

P-systems are able to model both a large number of species together with their interactions

Previous work

- Problems associated with population dynamics:
  - large number of individuals and species.
  - basic processes in the like cicles of species inhabiting ecosystem: feeding, growth, reproduction and death.
  - processes are periodicaly repeated.
  - the evolution often depends on the environment: climate, soil, ...
  - human activities modify natural dynamics.
- Each problem:
  - has its own specific features.
  - requires a precise modeling.
  - requires its own simulator.

Common + especific features

↓

Need to define a new variant of P-systems

- Cooperation.
- Randomness.
- Possibility of communication between environments.
- Membrane polarization

A P system based modeling framework

A *skeleton of an extended P system* with active membranes of degree q ≥ 1,

$$(\Gamma, \mu, R)$$

⇓

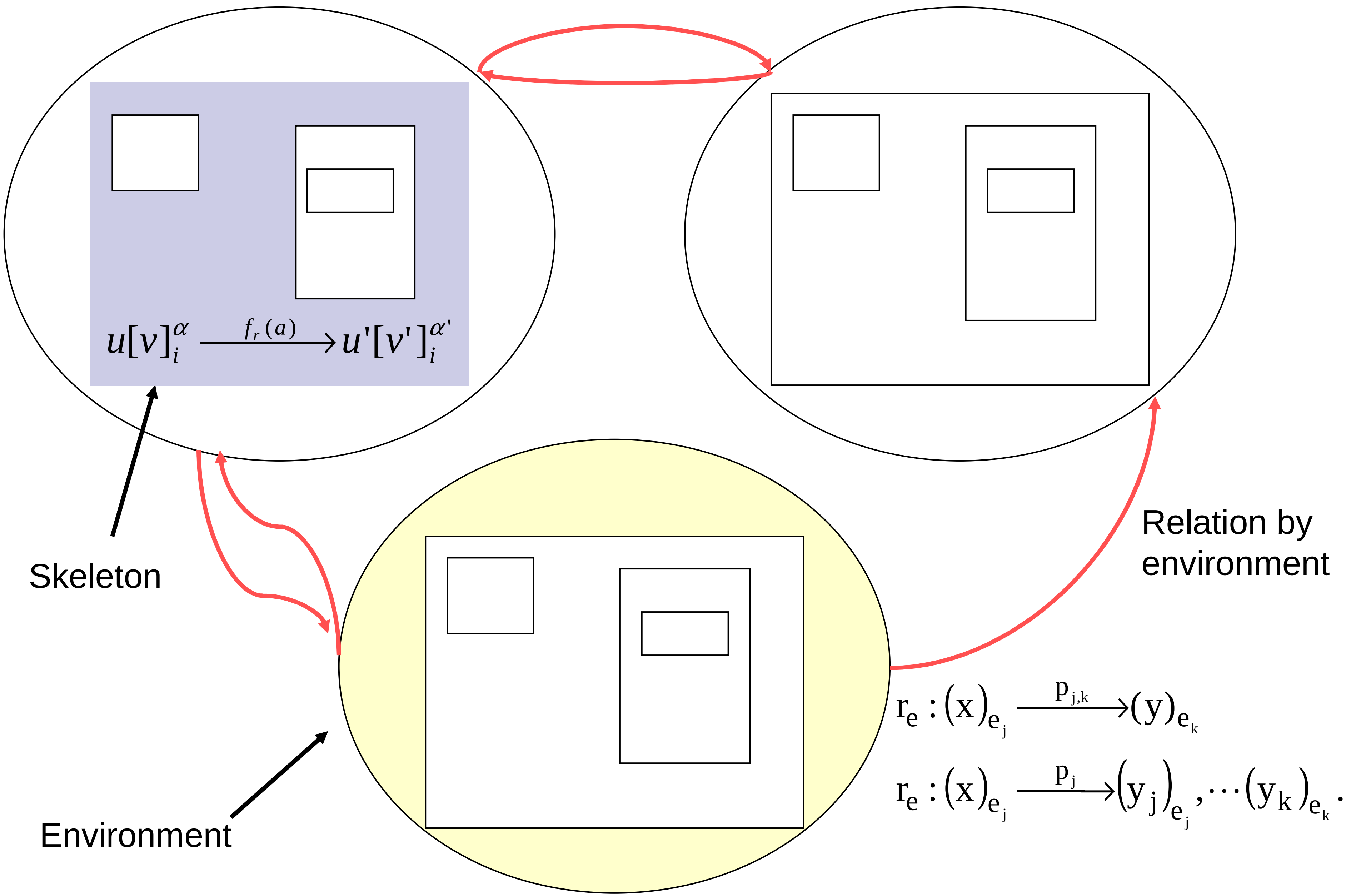
A probabilistic functional extended P system with active membranes of degree q ≥ 1 taking *T* time units,

$$\Pi = (\Gamma, \mu, R, T, \{f_r : r \in R\}, M_0, \ldots, M_{q-1})$$

⇓

A *multienvironment probabilistic functional extended P system* with active membranes of degree (m,q) taking *T* time units,

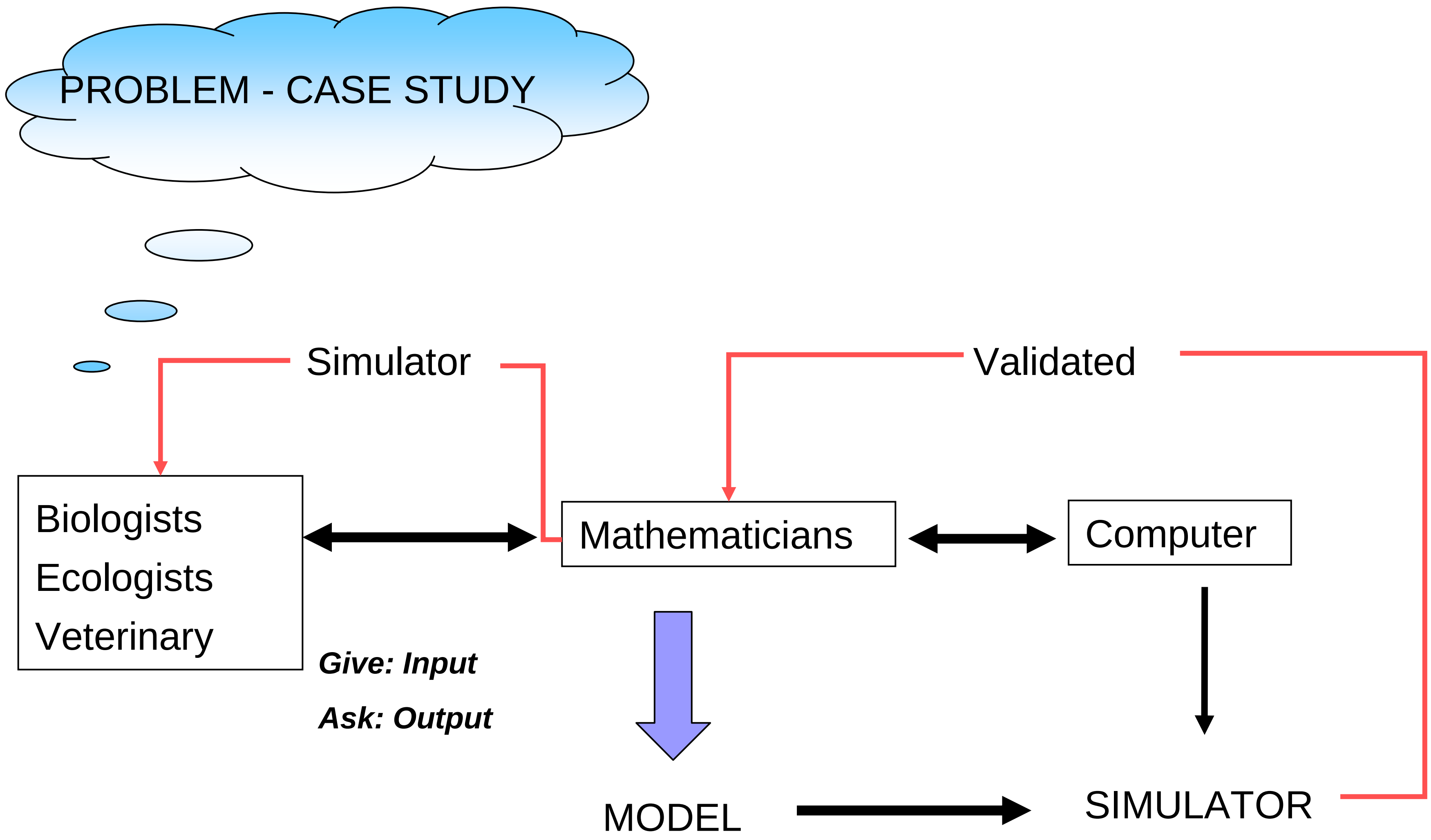
$$(\Sigma, G, R_E, \Gamma, \mu, R, T, \{f_{rj} : r \in R_\Pi, 1 \le j \le m\}, M_{ij} : 0 \le i \le q-1, 1 \le j \le m)$$



$u[v]_i^{\alpha} \xrightarrow{f_r(a)} u'[v']_i^{\alpha'}$
Skeleton
Environment
Relation by environment
$r_e : (x)_{e_j} \xrightarrow{p_{j,k}} (y)_{e_k}$
$r_e : (x)_{e_j} \xrightarrow{p_j} (y_j)_{e_j}, \cdots (y_k)_{e_k}.$

Relevant features of P systems for modeling ecosystem

- The rules of the real observed processes are introduced.
- Ability to work in parallel as the processes in nature do.
- Its modularity allows modifications (easily).
- Easy computational implementation.


PROBLEM - CASE STUDY
Simulator
Validated
Biologists
Ecologists
Veterinary
Mathematicians
Computer
Give: Input
Ask: Output
MODEL
SIMULATOR

Objective:

To obtain a model in order to study the dynamic of Pyrenean Chamois

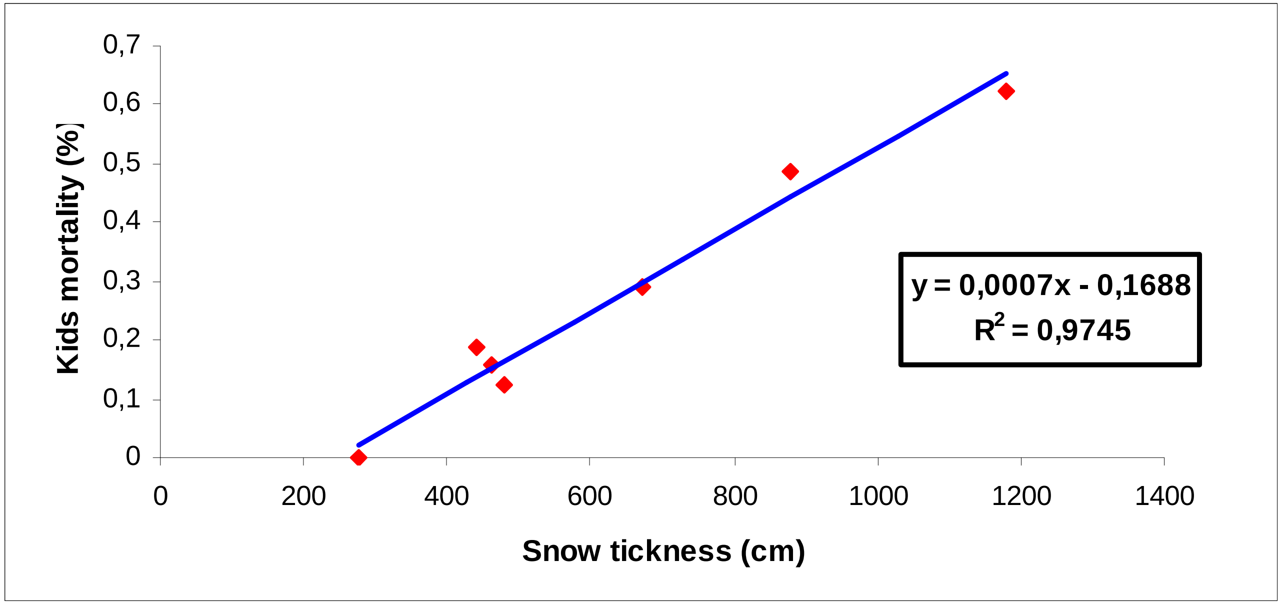
Catalan Pyrenees

Pyrenean Chamois

Pestivirus

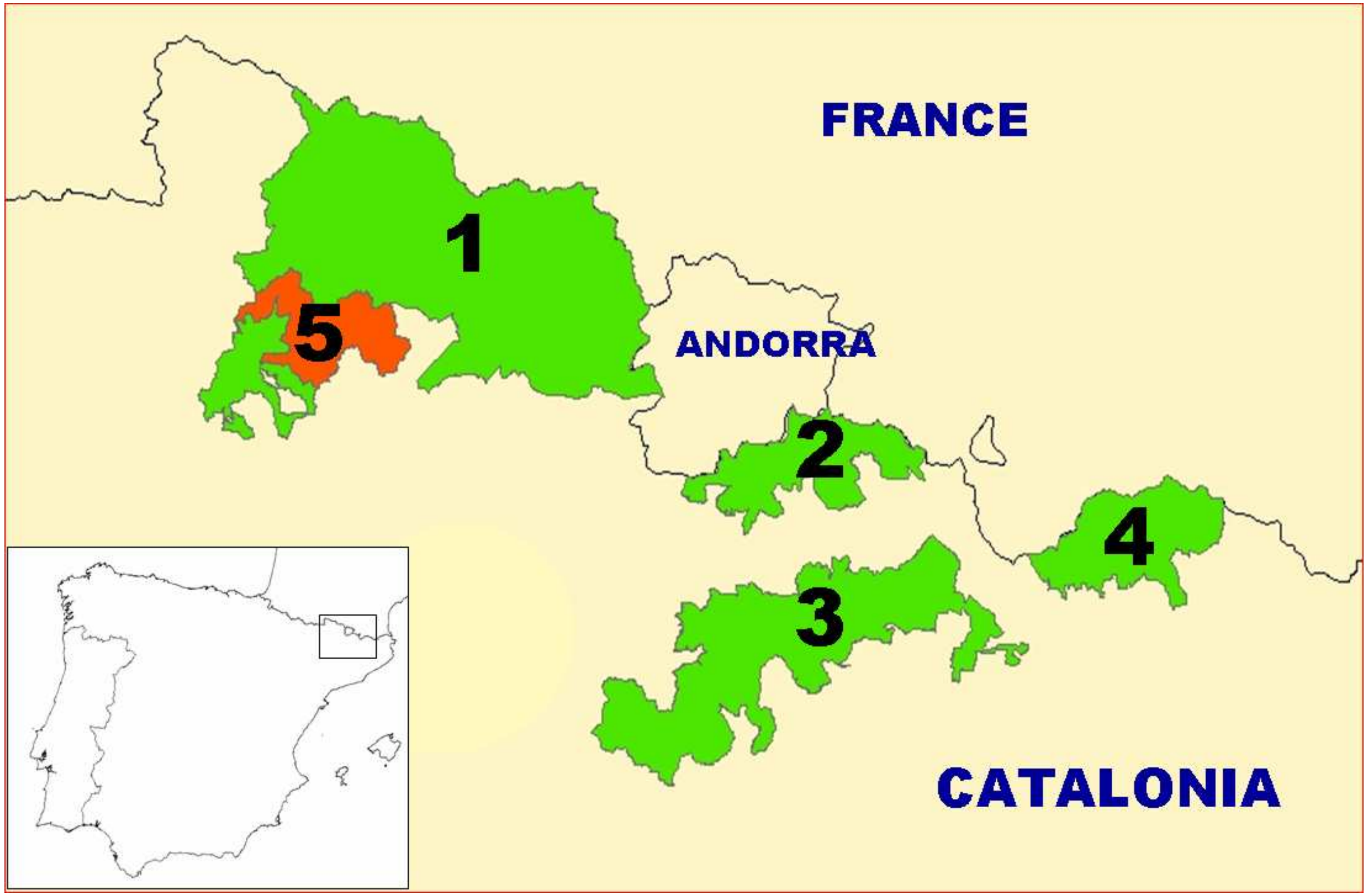
- Disease caused by a virus belonging to the genus Pestivirus.
- It causes weakness, reduced movement, ...
- Greater population impact. Mass mortality in some populations (up to 90%).

Snow thickness effect



Patrons de reproduction des femelles d'isard (Rupicapra pyrenaica pyrenaica) dans une population non chassée et conséquences demographiques. Jean-Paul Crampe, Anne Loison, Jean Michel Gaillard, Étienne Florence, Patrick Caens et Joël Appolinaire. *CNRC Canada (2006)*

Area where the species live

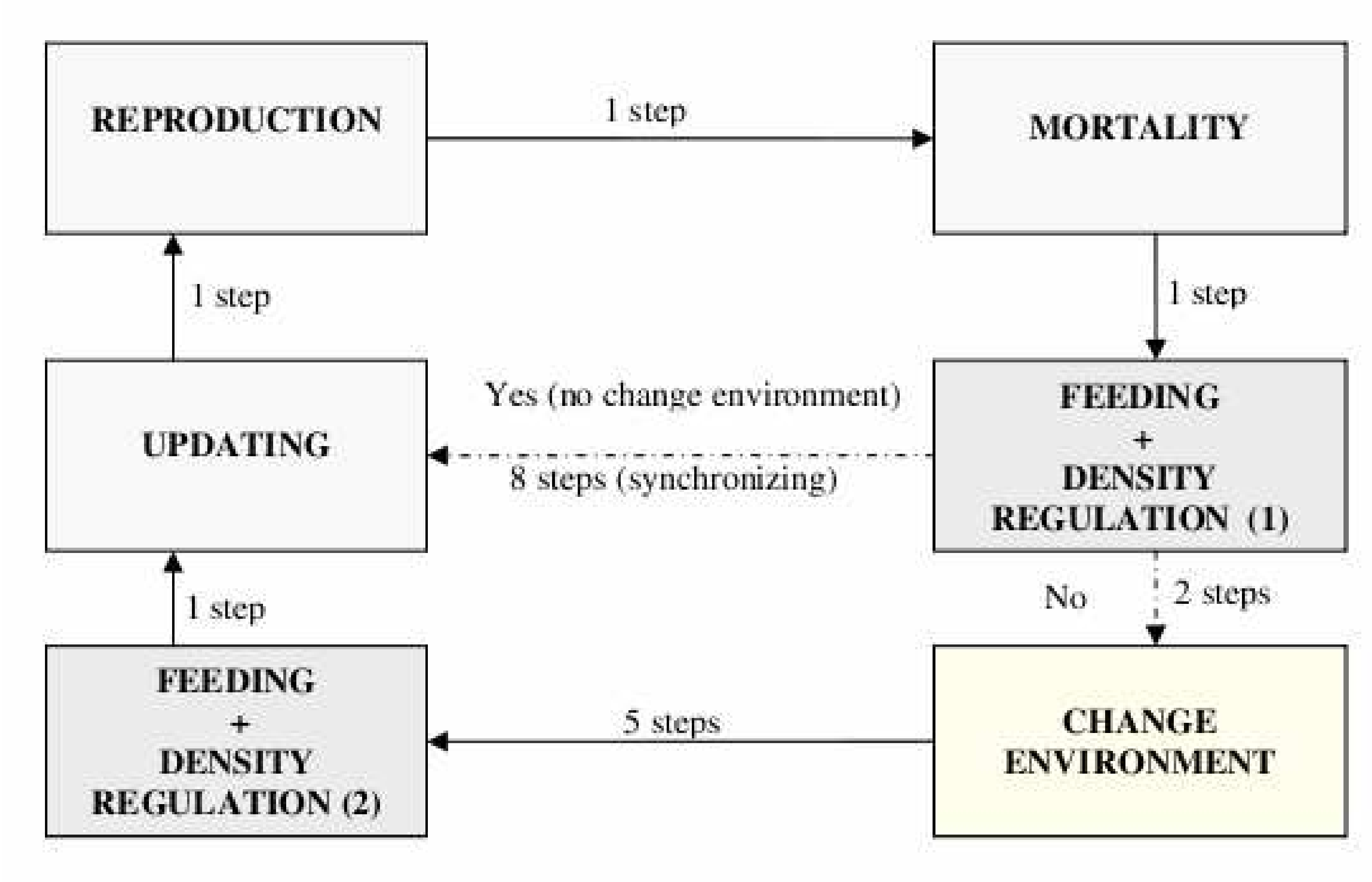


Modeling process

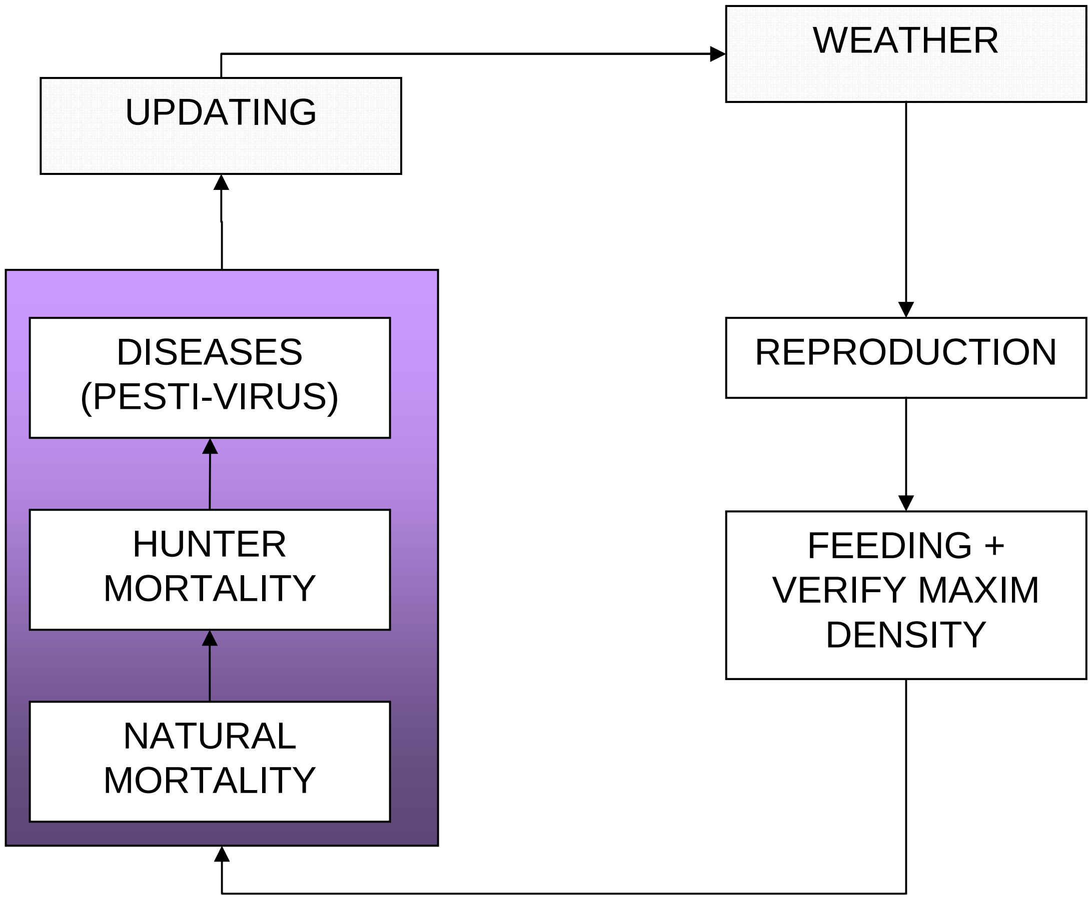
- Weather: Snow thickness.
- Reproduction
- Feeding
- Demographic density
- Mortality:
  - Natural.
  - Hunting
  - Disease: Pestivirus

P System Based Model of an Ecosystem of the Scavenger Birds.

Cardona et al. *LNCS*. Vol IV (2010)



Model proposed



Model Propose

A multienvironment probabilistic functional extended P system with active membranes of degree (q,m)=(4,11)

$$\left(\Gamma, \Sigma, G, R_4, \Pi, \{f_{rj} : r \in R_\Pi, 1 \leq j \leq 4\}, M_{ij}, 0 \leq i \leq 10, 1 \leq j \leq 4\right)$$

Membrane structure $\mu = \left[[\ ]_1^0 \ldots [\ ]_{10}^0 \right]_0^0$

Initial alphabet $M_0 = \{X_{j,1}, F_0, R_0, c, d\}$ $M_i = \{\varnothing\}, 1 \leq i \leq 10$

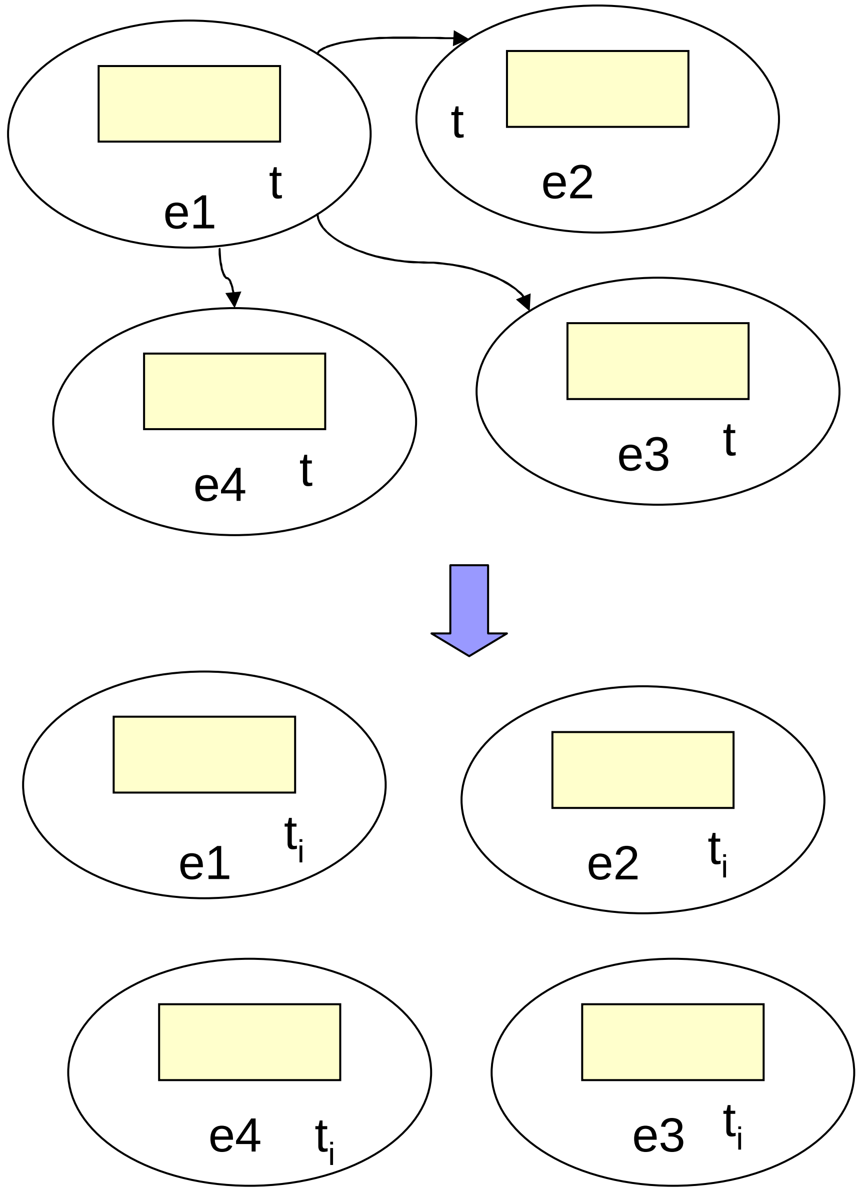
Initial alphabet in the environment $e_i = \{t\}, 1 \leq i \leq 4$

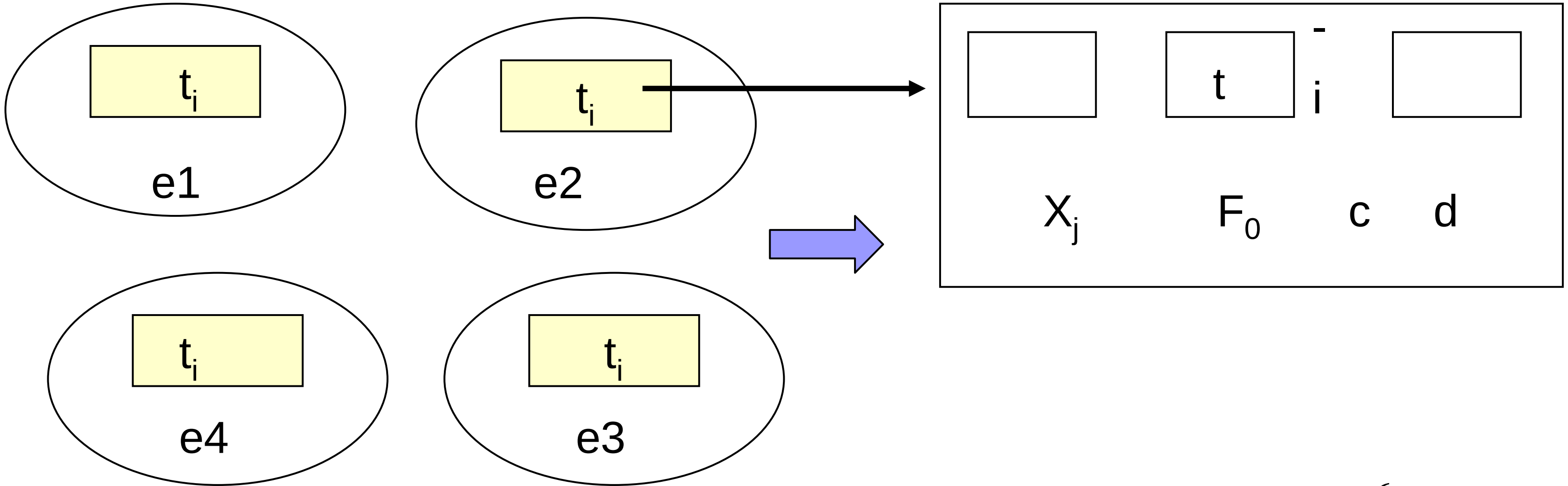
Weather rules

$$re_1 \equiv (t)_{e_1} \xrightarrow{1/10} (t_i)_{e_1}(t_i)_{e_2}\ldots(t_i)_{e_4}, 1 \le i \le 10.$$

$$re_2 \equiv (t)_{e_k} \longrightarrow (\#)_{e_k}, 1 < k \le 4.$$

$$r_1 \equiv t_i[\ ]_0^0 \longrightarrow [t_i]_0^0, 1 \le i \le 10.$$





$$r_2 \equiv t_i[\ ]_i^0 \longrightarrow [t]_i^-, 1 \le i \le 10.$$

$$r_3 \equiv X_{j,y}[\ ]_k^- \longrightarrow [X_{j,y}], \begin{cases} 1 \le j \le g_{i,6}, \\ 1 \le y \le T, \\ 1 \le k \le 10. \end{cases}$$

$$r_4 \equiv \left(F_0[\ ]_k^- \longrightarrow \left[G_4^{\alpha_4}(v), \ldots, G_{10}^{\alpha_{10}}(v) \right]_k^0 \right)_{e_v},$$

$$1 \le k \le 10, 1 \le v \le 4.$$

Diseases rules

When the appear disease in an area, the object h is created. This object will always be present in the first configuration of all loops

$$r_7 \equiv d[\ ]_k^- \rightarrow [d]_k^0,\ 1 \leq k \leq 10.$$

$$r_8 \equiv [d\ h \rightarrow d_1]_k^0,\ 1 \leq k \leq 10.$$

$$r_9 \equiv \left([d_1 \xrightarrow{ms_\nu} S]_k^0\right)_{e_\nu},\ \begin{cases} 1 \leq k \leq 10, \\ 1 \leq \nu \leq 4. \end{cases}$$

$$r_{10} \equiv \left([d_1 \xrightarrow{1-ms_\nu} N]_k^0\right)_{e_\nu},\ \begin{cases} 1 \leq k \leq 10, \\ 1 \leq \nu \leq 4. \end{cases}$$

The presence of the object S indicates that the disease is manifested

$$r_{33} \equiv [R_5 S]_k^0 \rightarrow [R_6\ h]_k^-,\ 1 \leq k \leq 10.$$

$$r_{34} \equiv [R_5 N \rightarrow R_6\ h]_k^0,\ 1 \leq k \leq 10.$$

$$r_{35} \equiv [R_5 d_0 \rightarrow R_6\ h]_k^0,\ 1 \leq k \leq 10.$$

$$r_{36} \equiv [R_5 d \rightarrow R_6]_k^0,\ 1 \leq k \leq 10.$$

$$r_{39} \equiv ([W_{j,y}]_k^- \xrightarrow{md_\nu} [\#]_k^+)_{e_\nu},\ \begin{cases} 0 \leq j < g_3, \\ 1 \leq y \leq T, \\ 1 \leq k \leq 10, \\ 1 \leq \nu \leq 4. \end{cases}$$

$$r_{40} \equiv ([W_{j,y}]_k^- \xrightarrow{1-md_\nu} [W_{j,y}]_k^+)_{e_\nu},\ \begin{cases} 0 \leq j < g_3, \\ 1 \leq y \leq T, \\ 1 \leq k \leq 10, \\ 1 \leq \nu \leq 4. \end{cases}$$

A software tool for simulation. Users

Two types of users:

the designer and the end-user (the ecologist)

The designer:

- Debugs the model
- Validates the model

The end-user:

- Runs virtual experiments

A software tool for simulation
Simulation core

- The model is written in a P-Lingua File
- P-Lingua is a programming language that allows defining P systems in an easy-way.
- The simulation of the P system is given by a Java library (pLinguaCore)
- The values of the initial parameters have set by a GUI (Graphics User Interface)

A software tool for simulation The problem of the Graphics. User Interface

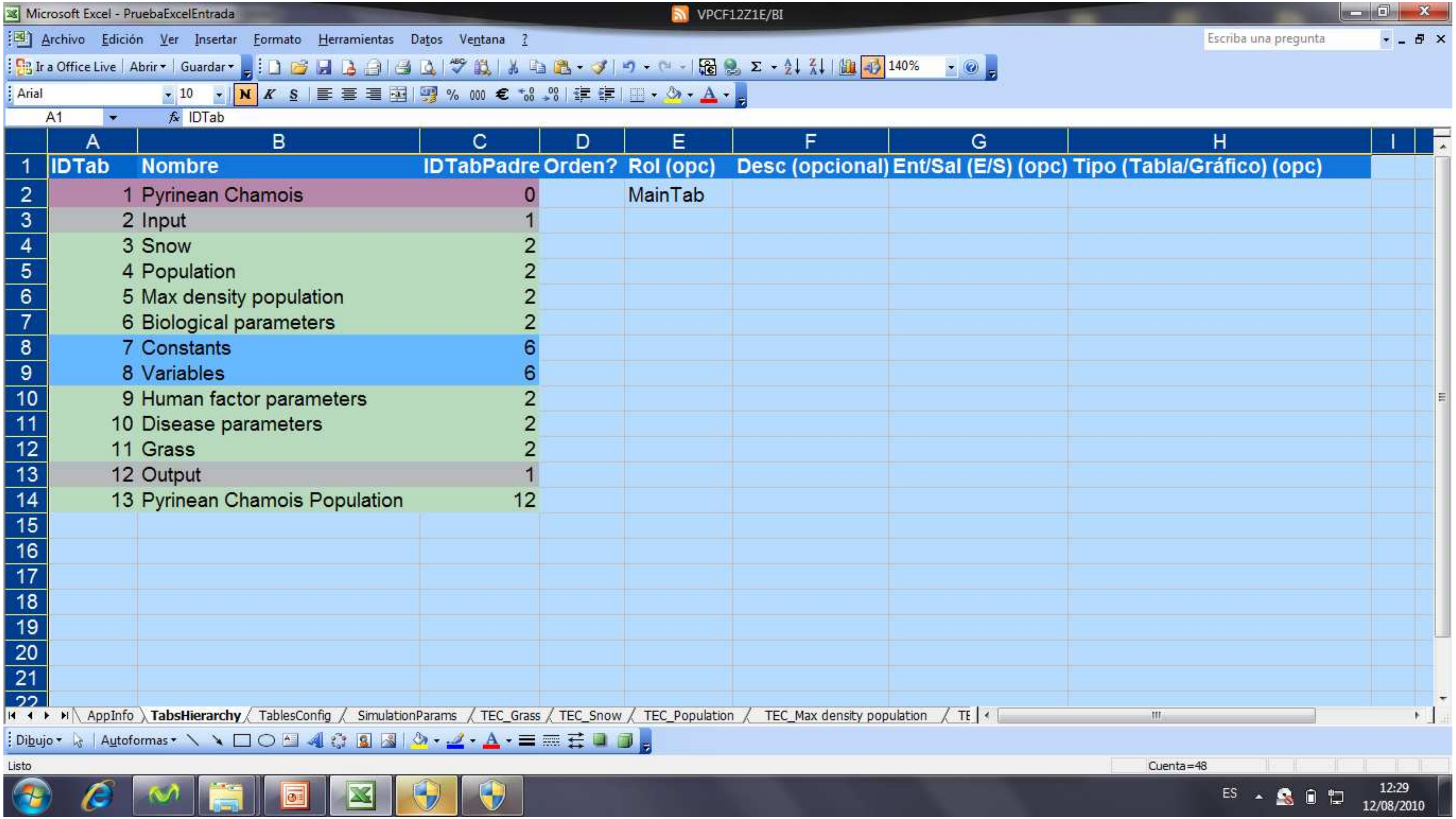
- Each case of study needs a specific GUI
- Previous works:
  - The same simulation core: P-Lingua + pLinguaCore
  - A specific GUI for each case of study (bearded vulture, zebra mussel...)
- The problem: It is necessary to design and develop (by Java programming) many different GUIs

A software tool for simulation. MeCoSim, a framework for simulation

- MeCoSim (Membrane Computing Simulator) solves the previous problem
- The same simulation core: P-Lingua + pLinguaCore
- It is not necessary to program different GUIs
- The designer user can design the GUIs by editing a datasheet (i.e. MS Excel, OpenOffice Calc)

A software tool for simulation. MeCosim, some features

- The datasheet allows to configure:
  - Input GUI tables
  - Output GUI tables
  - Definition of the initial parameters
  - Number of computational steps per simulated year
- MeCoSim is currently under development
- GNU GPL license



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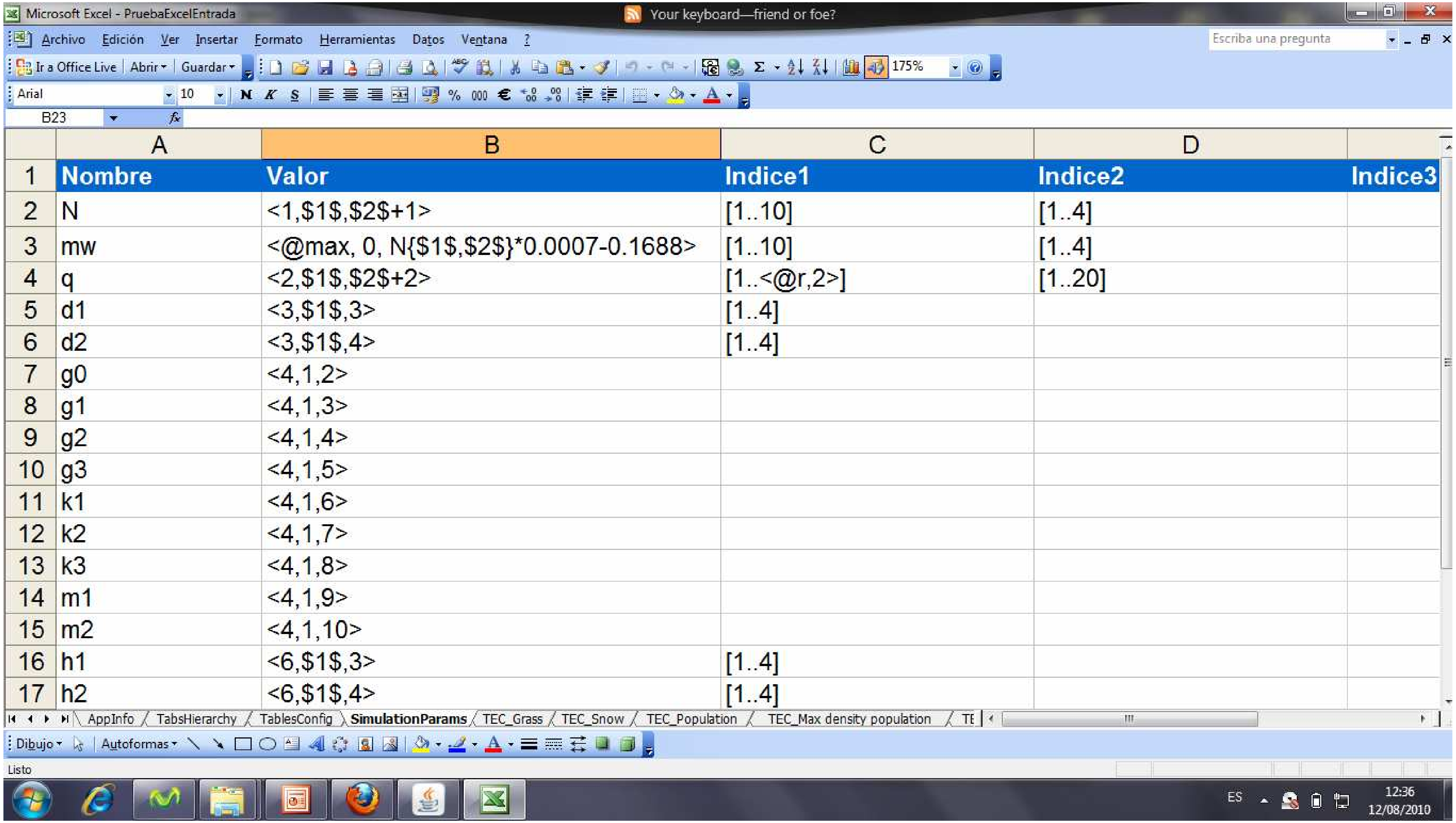
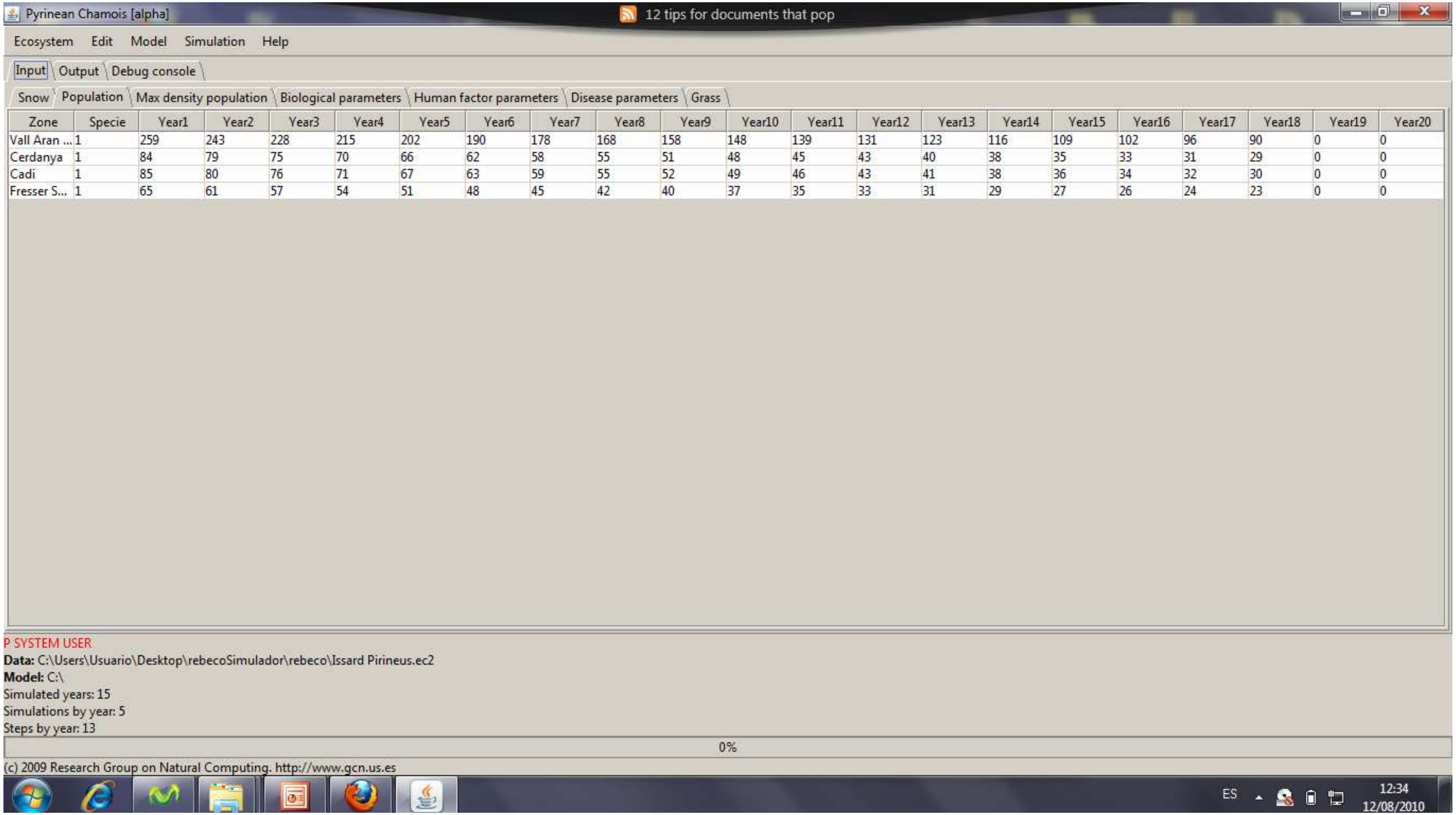
2	1	Pyrinean Chamois	0		MainTab			
3	2	Input	1					
4	3	Snow	2					
5	4	Population	2					
6	5	Max density population	2					
7	6	Biological parameters	2					
8	7	Constants	6					
9	8	Variables	6					
10	9	Human factor parameters	2					
11	10	Disease parameters	2					
12	11	Grass	2					
13	12	Output	1					
14	13	Pyrinean Chamois Population	12					



Nombre	Valor	Indice1	Indice2	Indice3
N	<1,1,2+1>	[1..10]	[1..4]	
mw	<@max, 0, N{1,2}*0.0007-0.1688>	[1..10]	[1..4]	
q	<2,1,2+2>	[1..<@r,2>]	[1..20]	
d1	<3,1,3>	[1..4]		
d2	<3,1,4>	[1..4]		
g0	<4,1,2>			
g1	<4,1,3>			
g2	<4,1,4>			
g3	<4,1,5>			
k1	<4,1,6>			
k2	<4,1,7>			
k3	<4,1,8>			
m1	<4,1,9>			
m2	<4,1,10>			
h1	<6,1,3>	[1..4]		
h2	<6,1,4>	[1..4]		

Simulator


Pyrinean Chamois [alpha]
12 tips for documents that pop
Ecosystem Edit Model Simulation Help
Input Output Debug console
Snow Population Max density population Biological parameters Human factor parameters Disease parameters Grass
Zone	Specie	Year1	Year2	Year3	Year4	Year5	Year6	Year7	Year8	Year9	Year10	Year11	Year12	Year13	Year14	Year15	Year16	Year17	Year18	Year19	Year20
Vall Aran ...	1	259	243	228	215	202	190	178	168	158	148	139	131	123	116	109	102	96	90	0	0
Cerdanya	1	84	79	75	70	66	62	58	55	51	48	45	43	40	38	35	33	31	29	0	0
Cadi	1	85	80	76	71	67	63	59	55	52	49	46	43	41	38	36	34	32	30	0	0
Fresser S...	1	65	61	57	54	51	48	45	42	40	37	35	33	31	29	27	26	24	23	0	0
P SYSTEM USER
Data: C:\Users\Usuario\Desktop\rebecoSimulador\rebeco\Issard Pirineus.ec2
Model: C:\
Simulated years: 15
Simulations by year: 5
Steps by year: 13
0%
(c) 2009 Research Group on Natural Computing. http://www.gcn.us.es
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12:34
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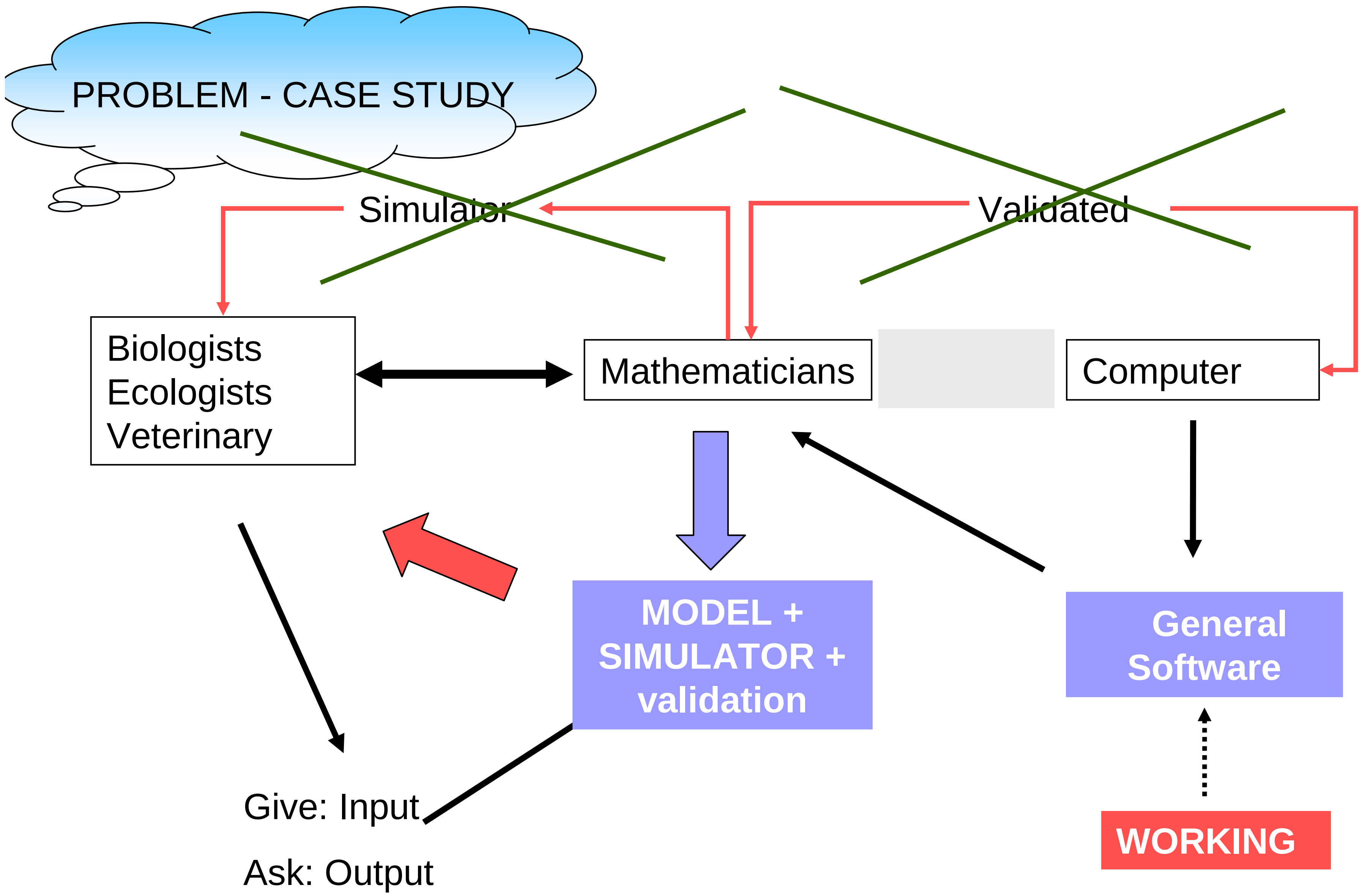
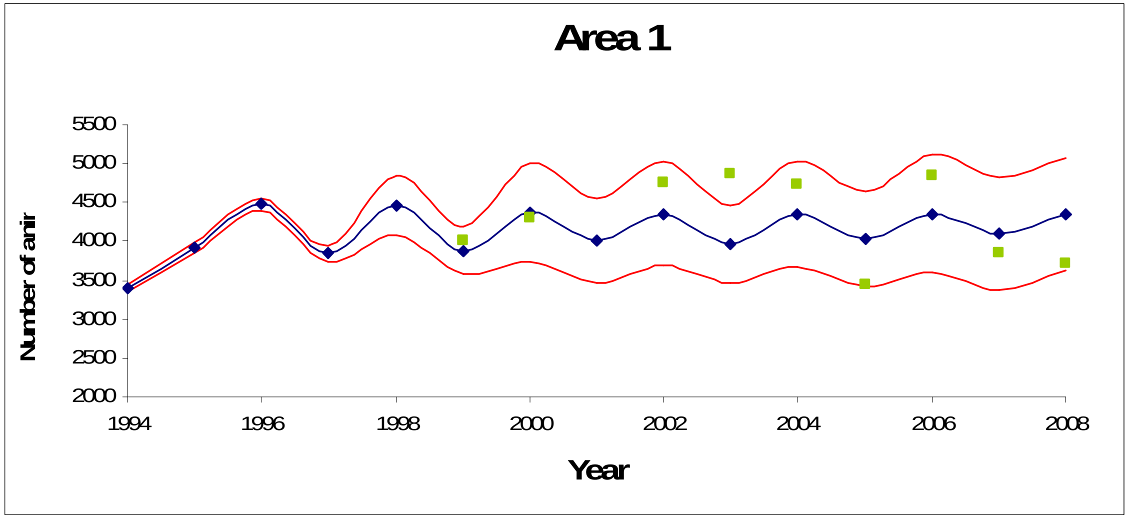
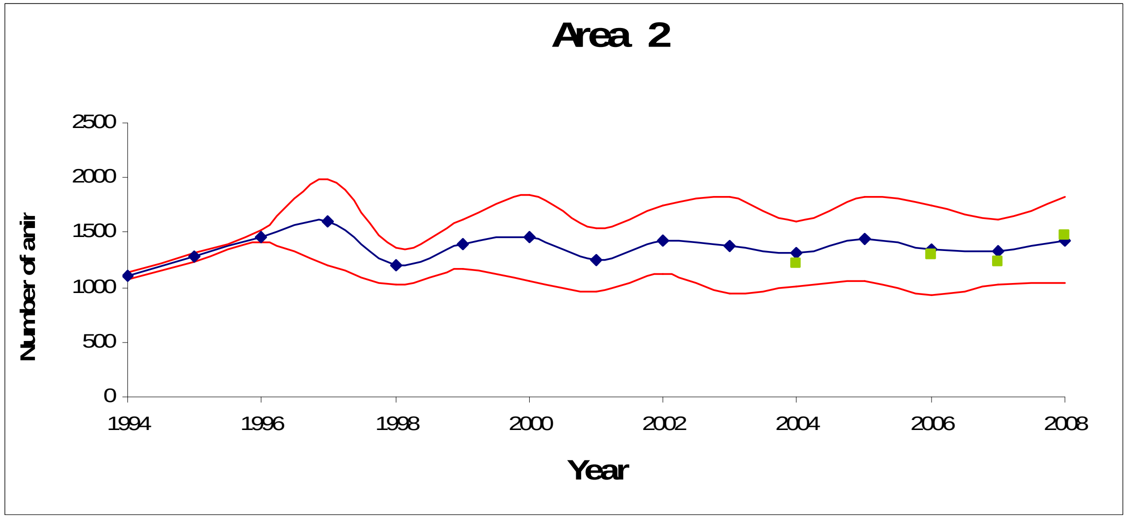


PROBLEM - CASE STUDY
Simulator
Validated
Biologists
Ecologists
Veterinary
Mathematicians
Computer
MODEL + SIMULATOR + validation
General Software
Give: Input
Ask: Output
WORKING

Results

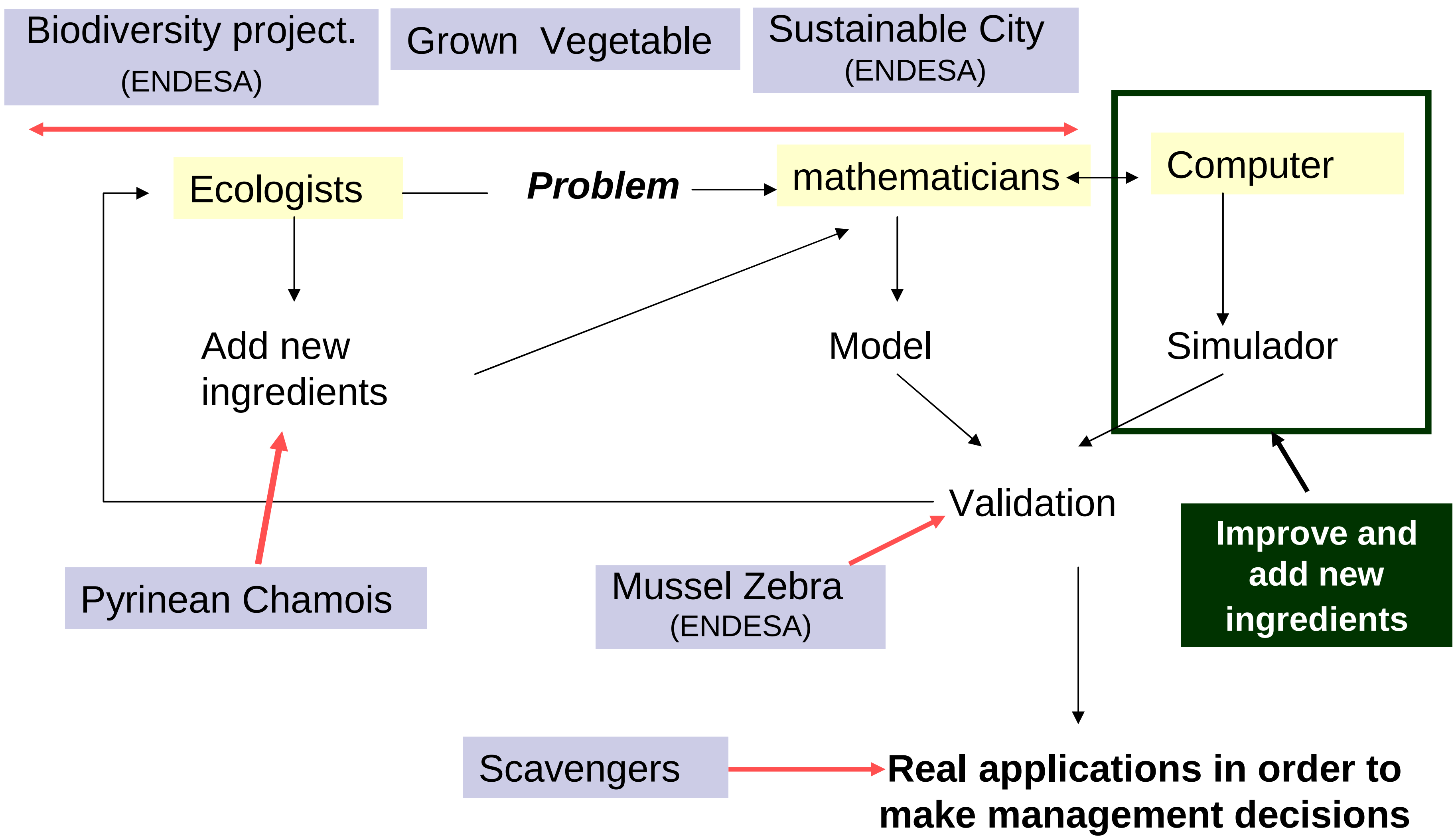


Area 1
5500
5000
4500
4000
3500
3000
2500
2000
Number of anir
1994
1996
1998
2000
2002
2004
2006
2008
Year



Area 2
2500
2000
1500
1000
500
0
Number of anir
1994
1996
1998
2000
2002
2004
2006
2008
Year

Current situation



Thank you for your attention!