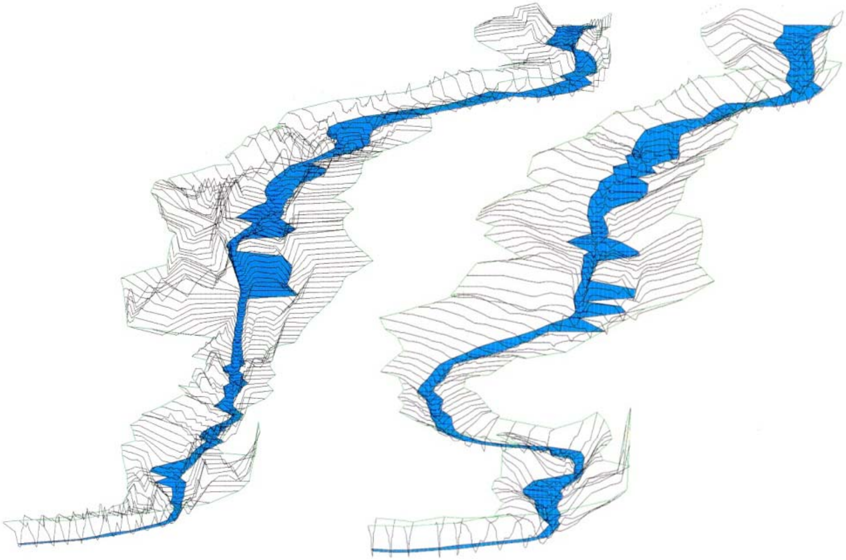
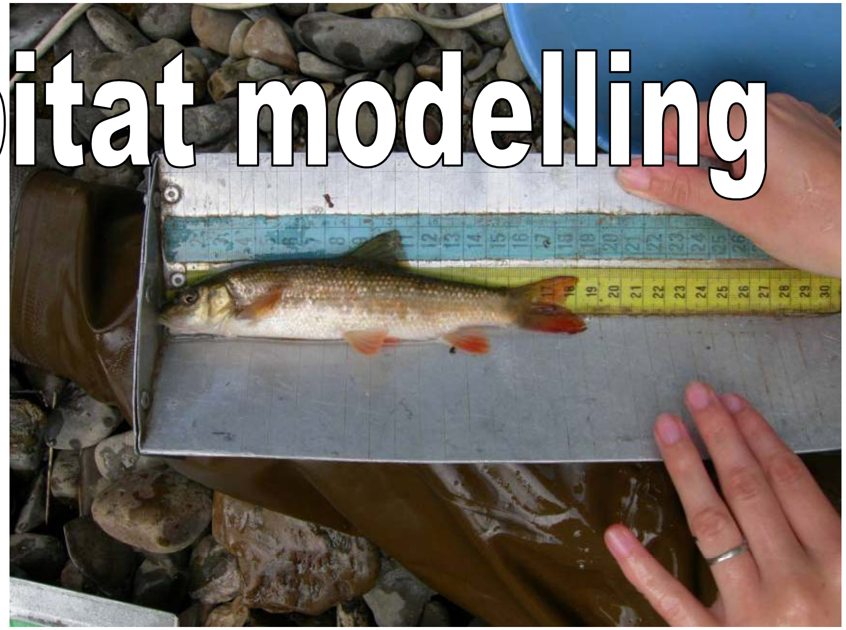
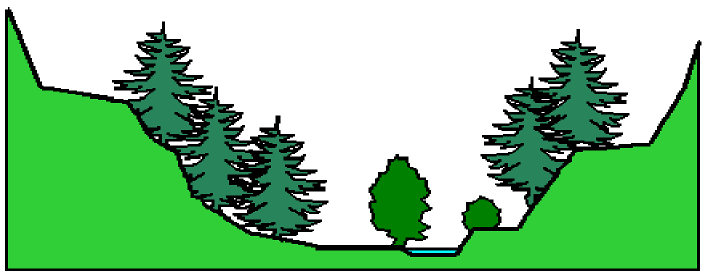


4-. Aquatic habitat modelling



Carlos Alonso y Miguel Marchamalo. Universidad Politécnica de Madrid.

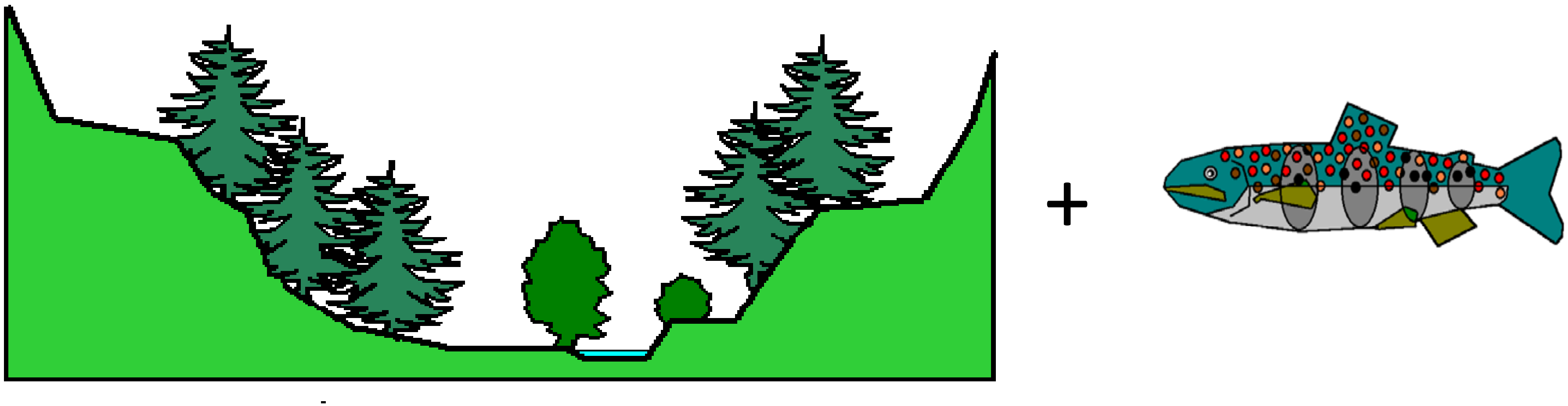
- What is a model?
  - A model is an abstraction of reality. This abstraction represents a **complex reality** in the **simplest way** that is adequate for the **purpose** of the modelling.
  - A good model has to be:
    - **Realistic** (agreement between model outputs and real-world observations).
    - **Parsimonious** (the one with the greatest explanation or predictive power and the least parameters or process complexity).



A model has to be usefull, not perfect

- Types of models
  - Conceptual type:
    - **Empirical:** based on observation (high predictive power and low explanatory depth)
    - **Conceptual:** based on preconceived notions (slightly greater explanatory depth)
    - **Physically based:** derived deductively from established physical principles (expl. depth)
  - Level of process detail and understanding:
    - **Analytical** (white box): all elements and processes are known
    - **Syhthetic** (black box): only the input and output are known
  - Mathematical type:
    - **Deterministic:** a single set of inputs always produces one (and the same) output
    - **Stochastic:** a single set of inputs can produce very different outputs according to a random process
  - Spatial type:
    - **Lumped:** simulate a satially heterogeneous environment as a single -lumped- value
    - **Semi-distributed:** may have multiple lumps representing clearly identifiable units
    - **Distributed:** break space into discrete units
    - GIS
    - 2D
    - 3D
  - Temporal type:
    - **Static:** exclude time
    - **Dynamic:** include time explicitly

Aquatic Habitat Modelling = Physical habitat modelling + Biological modelling



Physical Habitat Modelling (I)

- Aquatic habitat modelling includes the modelization of the following parameters:
  - Habitat availability in terms of: refuge, feeding areas, nesting/spawning areas
  - Quantification of habitat: area, volume,...
  - Habitat suitability for a given species depending on its preferences on flow velocity, depth, substrate.
- The input parameters for the modelization are:
  - Channel geometry (topography)
  - Hydraulic conditions (flow, initial depth,…)
  - Channel substrate.

Physical Habitat Modelling (II)

- These studies depend on the **quality and continuity of the input topographic data**. Conventional fish habitat studies are limited by the feasibility of field survey in time and budget

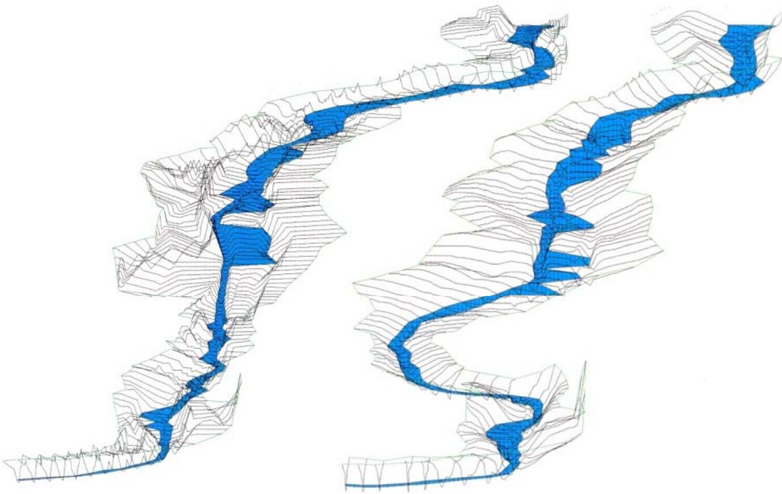
- This limitation results in **differences between the level of river management and the level of models**; river management mostly operates at catchment or river sector level, while modeling uses the much smaller site level (Borsanyi et al., 2004)

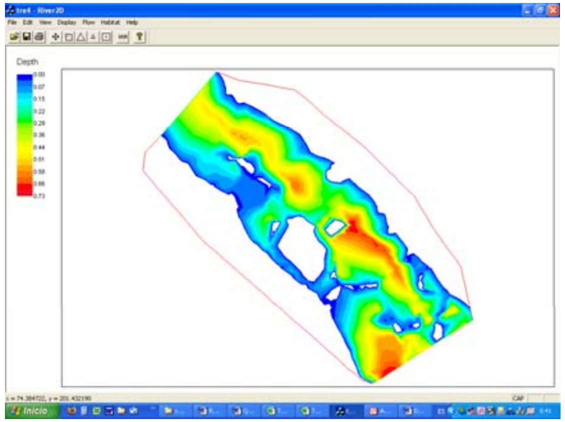
- In order to facilitate **upscaling processes** from modeling to management units, intermediary methods between the micro- and the macroscale level were developed (Habitat Mapping (Maddock & Bird, 1996; Maddock, 1999); MesoHABSIM (Parasiewicz, 2001).

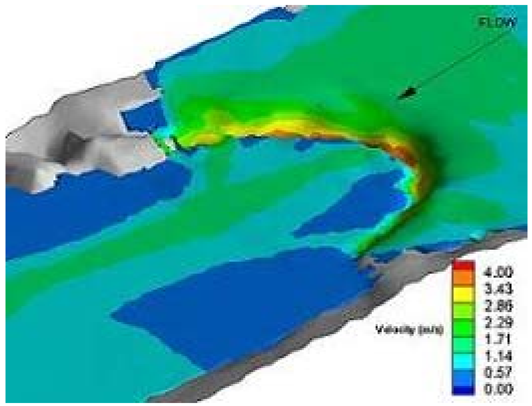
Physical Habitat Modelling. Dimensions (I)

- **1-D Modelling**. Uses cross-section topographic input data for wich flow velocity and depth are modeled. Results are extrapolated to the channel between cross sections. One-dimensional, 1D, numerical simulations model downstream changes in hydraulics while neglecting vertical and lateral variation. Software: HEC-RAS,...
- **2-D Modelling**. Two-dimensional, 2D, models incorporate lateral differences in velocity and water surface elevation, but not vertical variation. Computes habitat using DTM grids (TIN or raster DTM). An average value of depth and velocity (modulus and direction) is calculated for the water column above each pixel. Software: RIVER 2D, GUAD 2D,...
- **3-D Modelling**: Three-dimensional, 3D, modeling simulates the motion of water in all directions and most accurately captures flow patterns.Velocity direction and modulus are calculated for each water cell in the modelled flow.
- Flow simulation and habitat analyses have been assessed based on conventional topography (cross sections) and 1D hydraulic models.
- Remote sensing, increasing calculation capabilities and higher field work costs have changed the actual scenario of environmental flows analysis.
- There is a **need of methodologies employing remote-sensed data coupled to 2D or 3D hydraulic models to allow efficient analysis of long river segments**.

Physical Habitat Modelling. Dimensions (II)

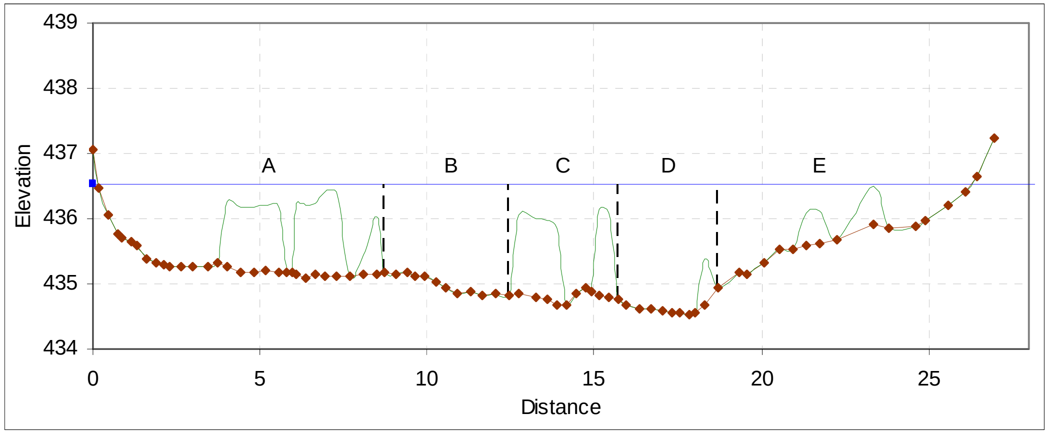






Physical Habitat Modelling. Topographic survey

Total Station



GPS

Infrared pulse (Topographic LiDAR) is reflected in the water surface

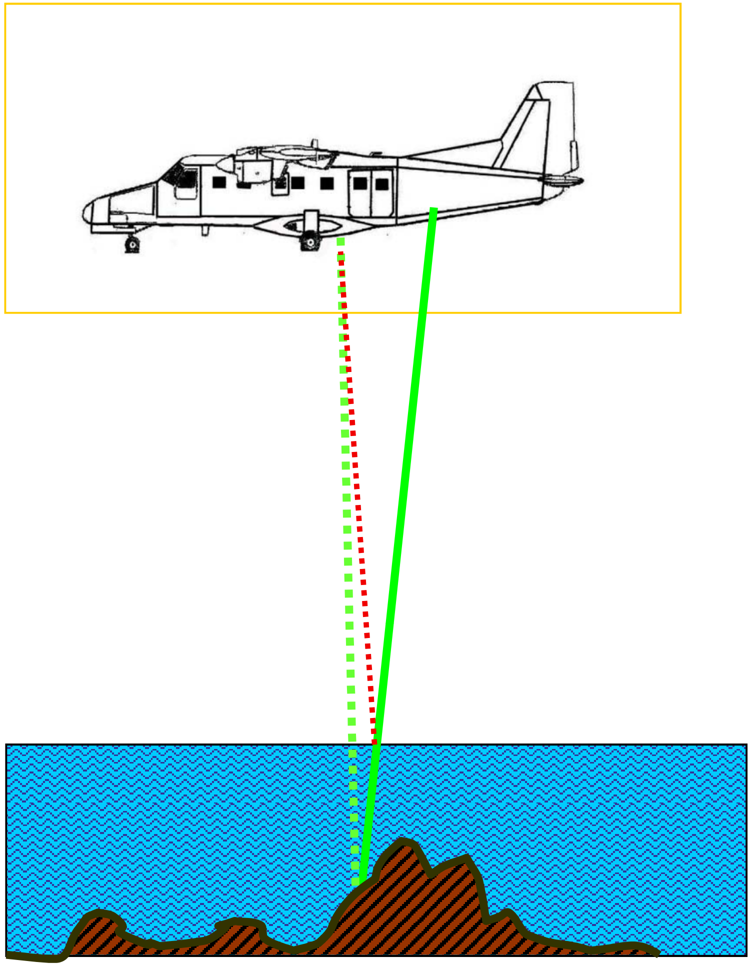
Green-LiDAR (Bathymetric LiDAR) pulse reaches the bottom substrate (> 50 m)

Depth is calculated by means of differences in time for each pulse:

$p = \Delta t \cdot c / 2$

Optech

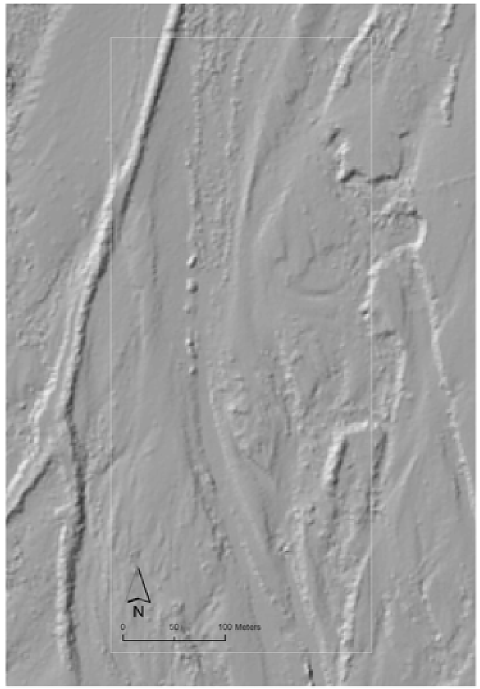
Quoted by ICC, 2005



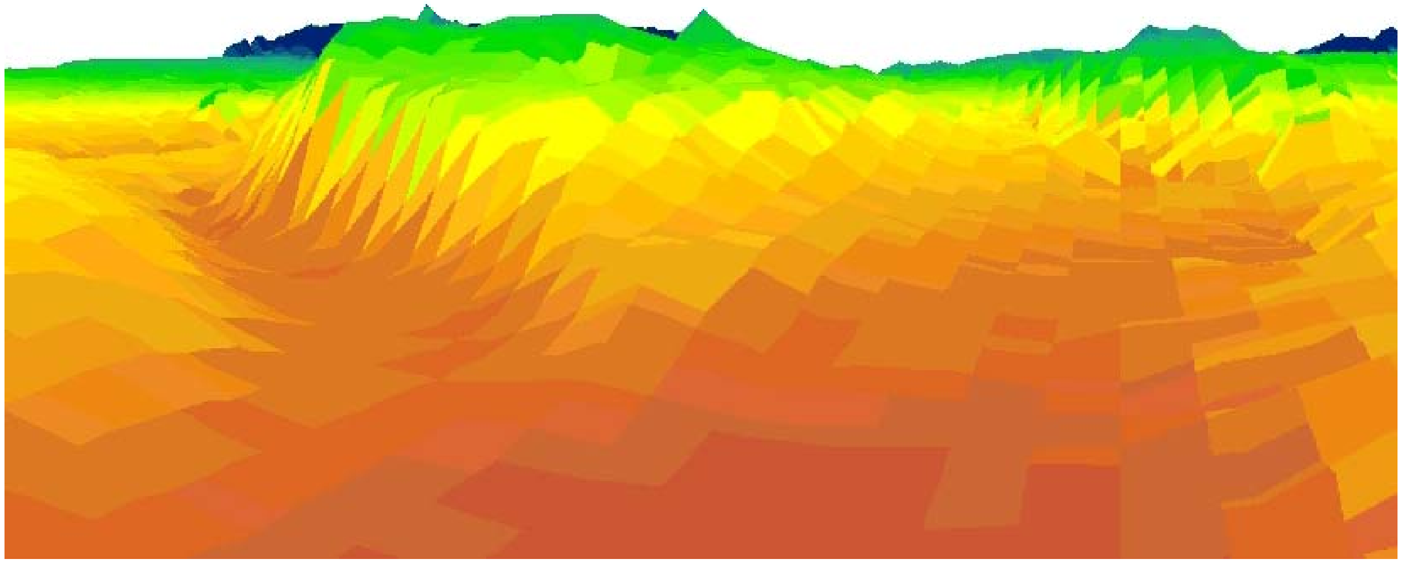
Shoals/Hawk-Eye II

- Postprocessing work involves the application of filters and error controllers to get two final products:
- Digital Surface Model (dsm); 2 m pixel grid based on the analysis of the first and last LIDAR pulses (LEFT)
- Digital Terrain Model (dtm); 2 m grid obtained using the last LIDAR pulse. (RIGHT)

PRECISION
Horizontal:
RMSE < 0.50 m
Vertical:
RMSE 0.15 m

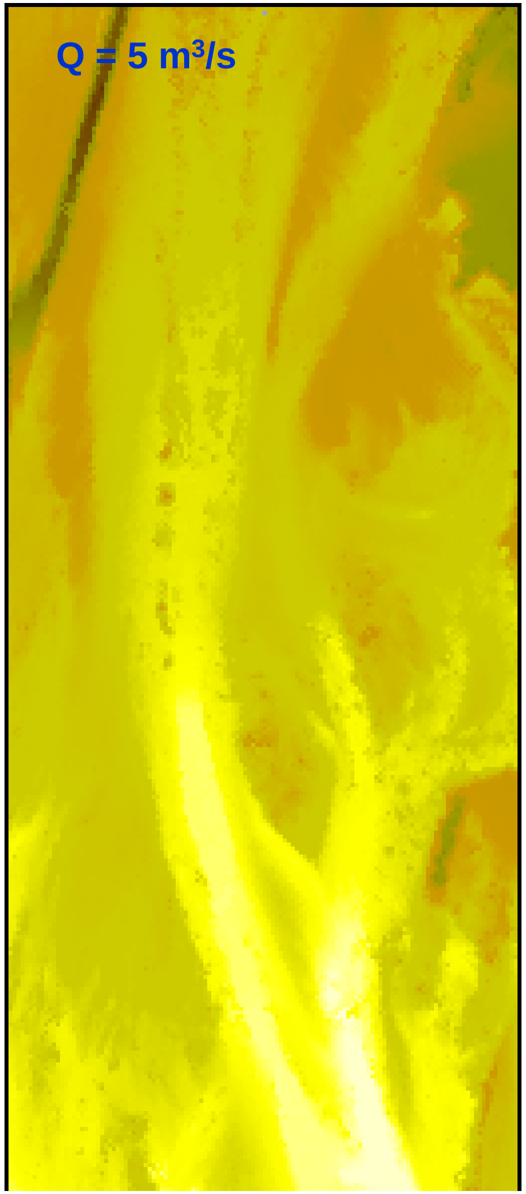


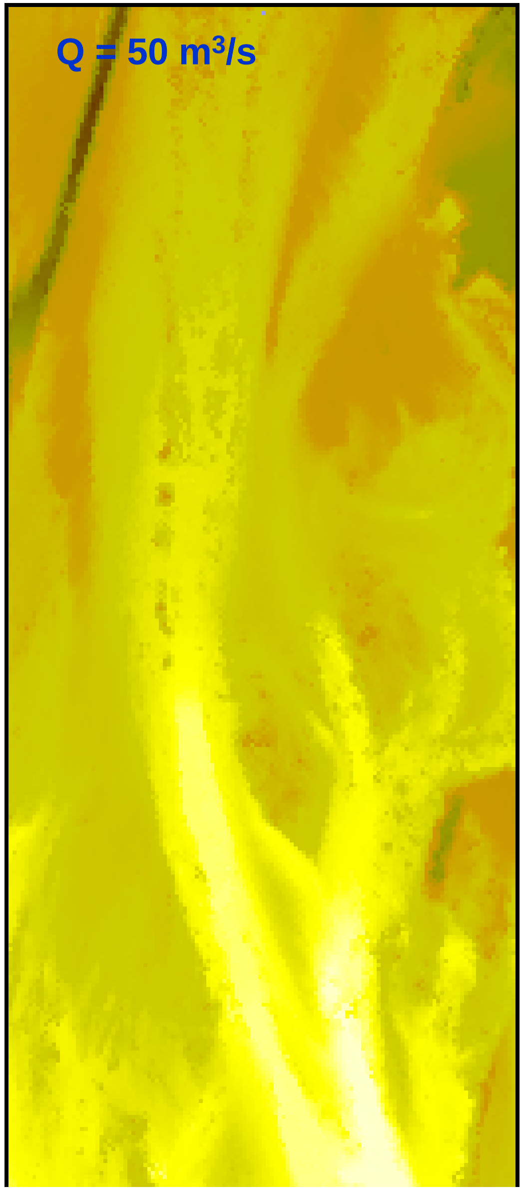

Airborne Hydrography, 2007



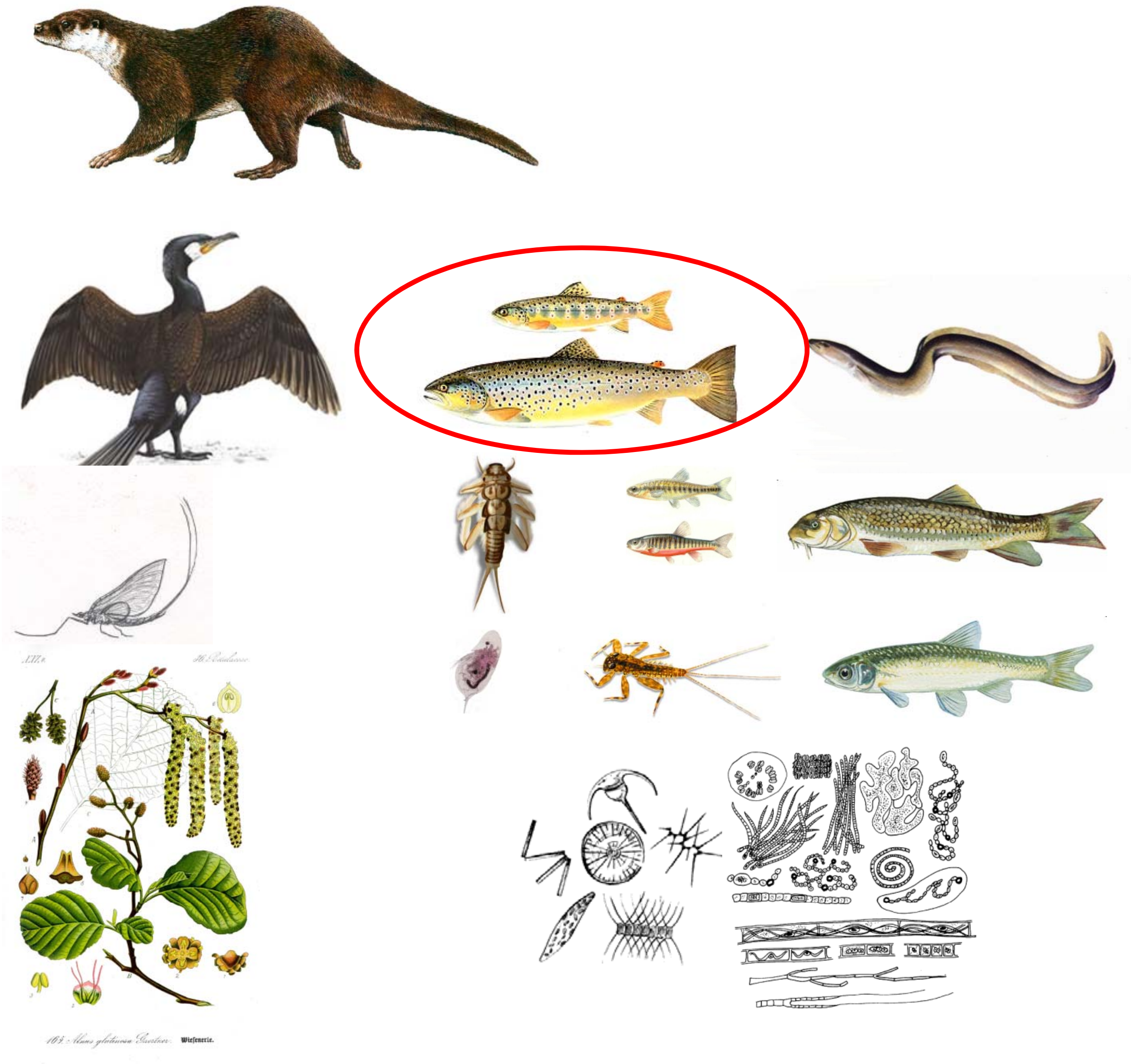
Vertical 5x

Physical Habitat Modelling. Hydraulic simulation (2D)





Biological Modelling. Rationale (II)



Secondary consumers, predators

Primary consumers, phytophags

Primary producers

What determines where a species lives and what determines its abundance?

POPULATION GROWTH RATE (PGR)

What is population growth rate?

PGR measures the per capita rate of growth of a population. It tells us whether population sixe is increasing, stable or decreasing, and indicates how fast it is changing.

$$\lambda_t = \frac{N_{t+1}}{N_t}$$

$$r_t = \log_e \lambda_t = \log_e \left(\frac{N_{t+1}}{N_t} \right)$$

Biological Modelling. r function

Pgr is influenced by **endogeous (x_i)** and **exogenous (z_i)** variables; and its variation can be represented by a function of those variables (*r function*):

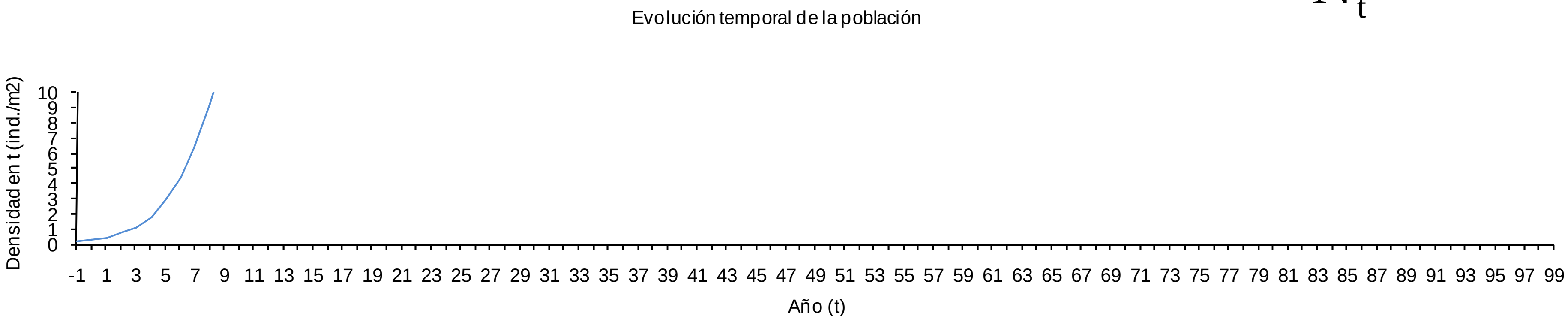
$$r_t = f\,(x_{1,t}, x_{2,t}, \ldots, x_{k,t}, z_{1,t}, z_{2,t}, \ldots, z_{j,t}, \varepsilon)$$

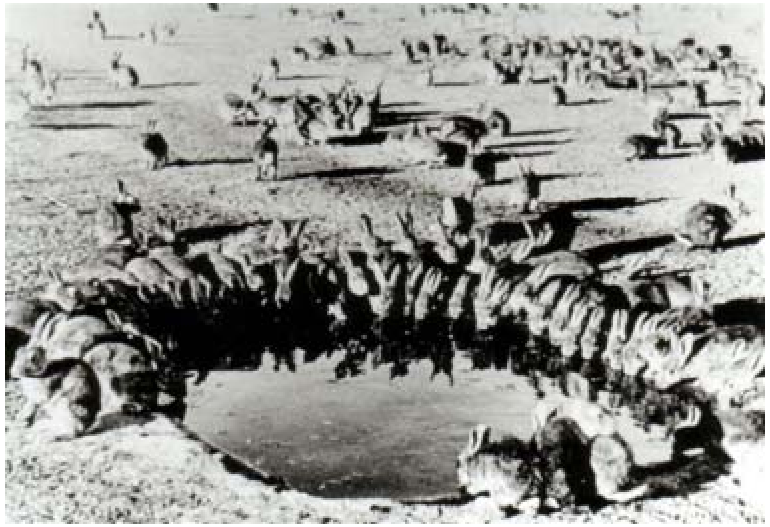
Model selection: Principles of Population Dynamics

How does the population work?

First principle - Geometric growth: All populations grow in a constant logarithmic rate, unless factors impede it.

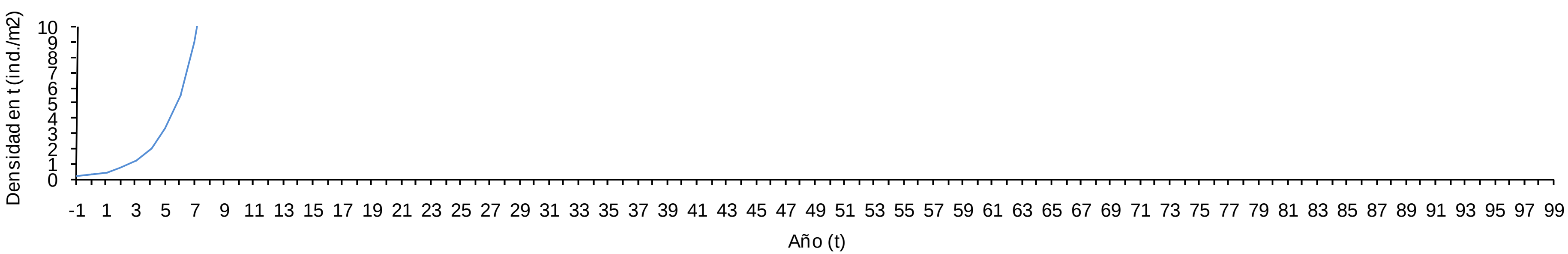
$$r_t = \log_e \frac{N_{t+1}}{N_t} > 0$$

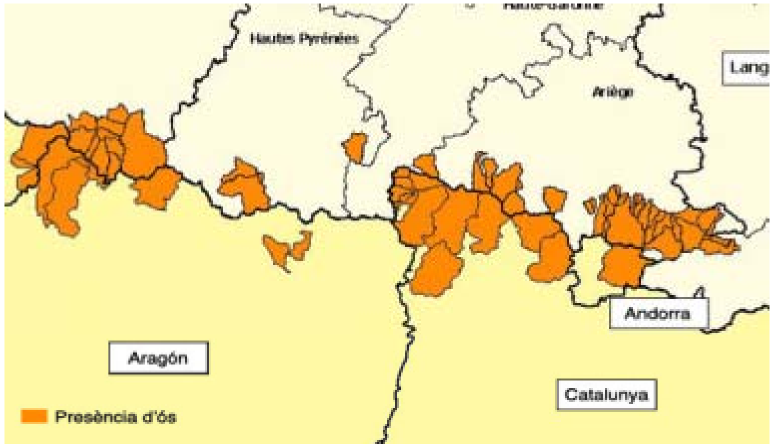




Second principle – Cooperation: there is a positive correlation between density *Nt* and population growth rate. (Positive feedback)

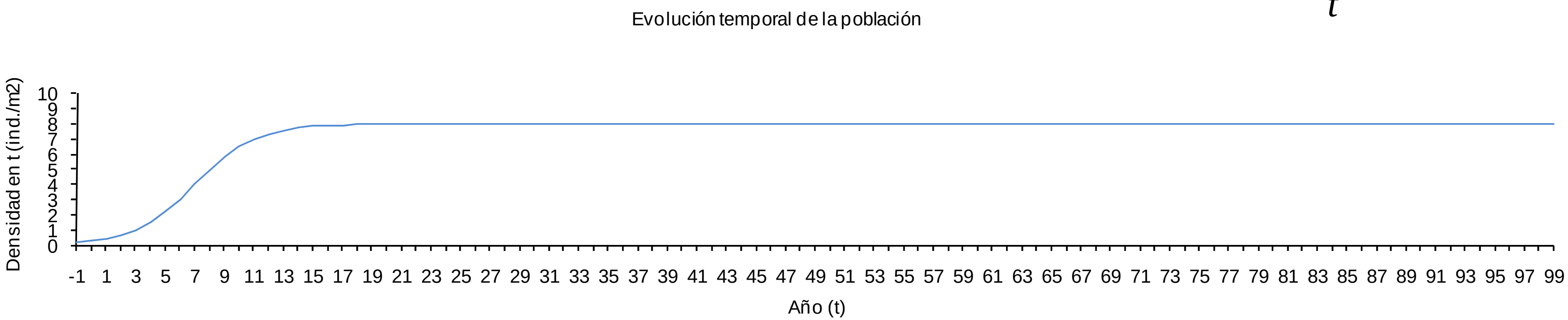
$$r_t = a \cdot N_t$$

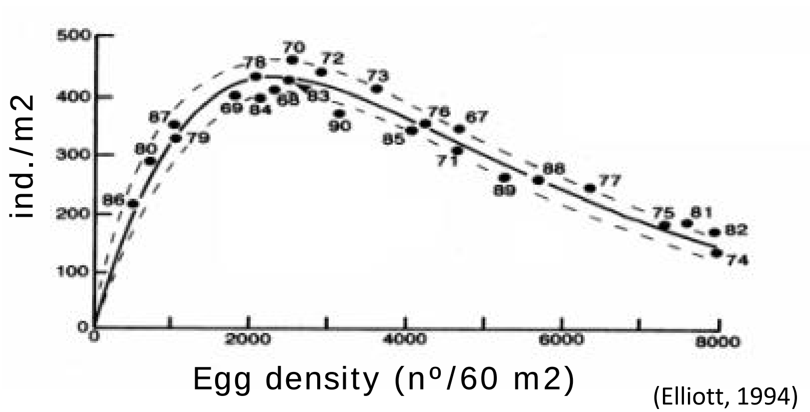




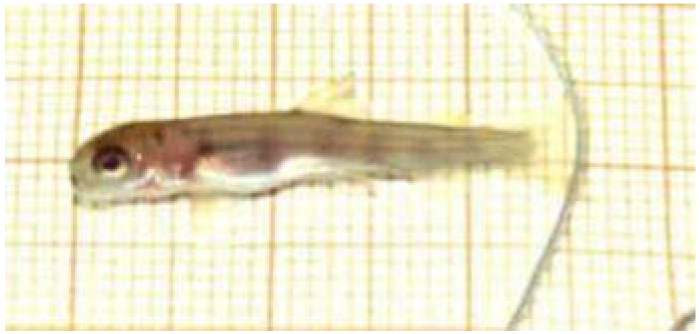
Third principle – Competition: there is a negative correlation between density Nt and population growth rate. (Negative feedback)

$$r_t = \frac{b}{N_t}$$

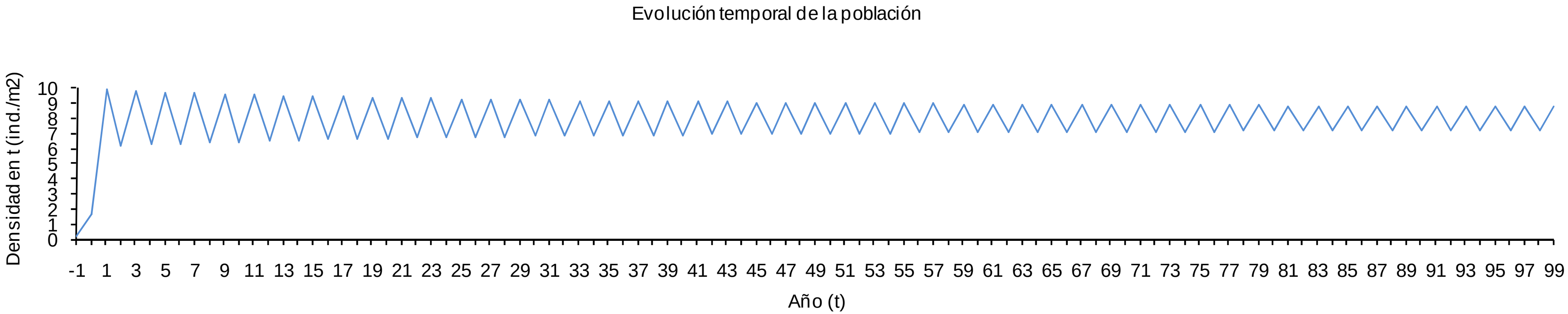


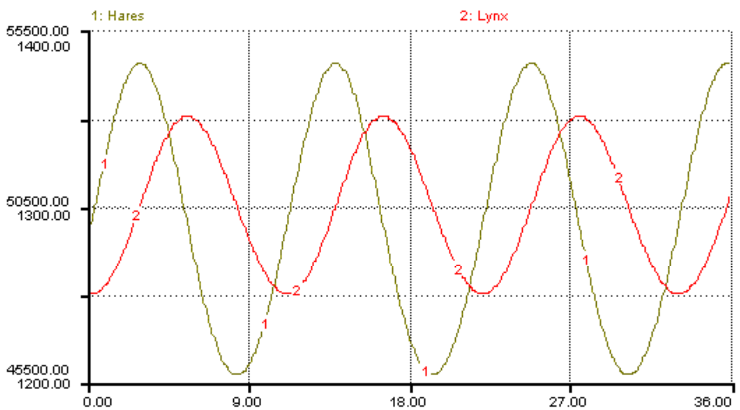


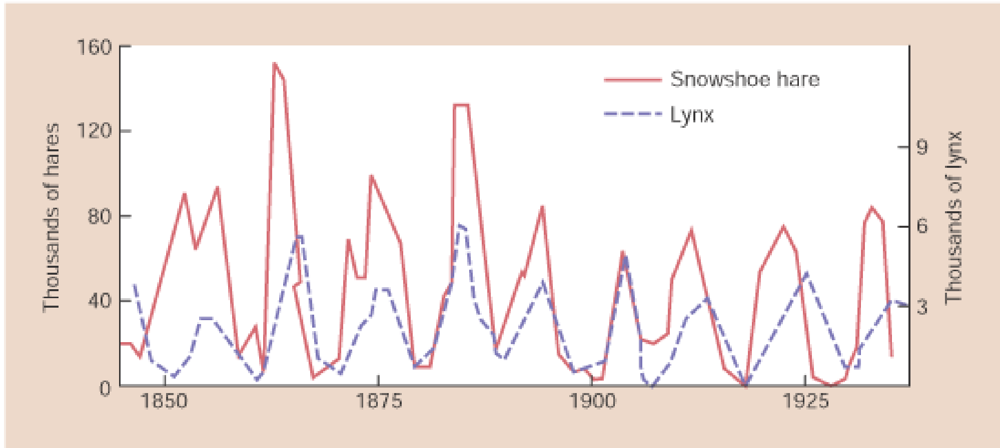
(Elliott, 1994)



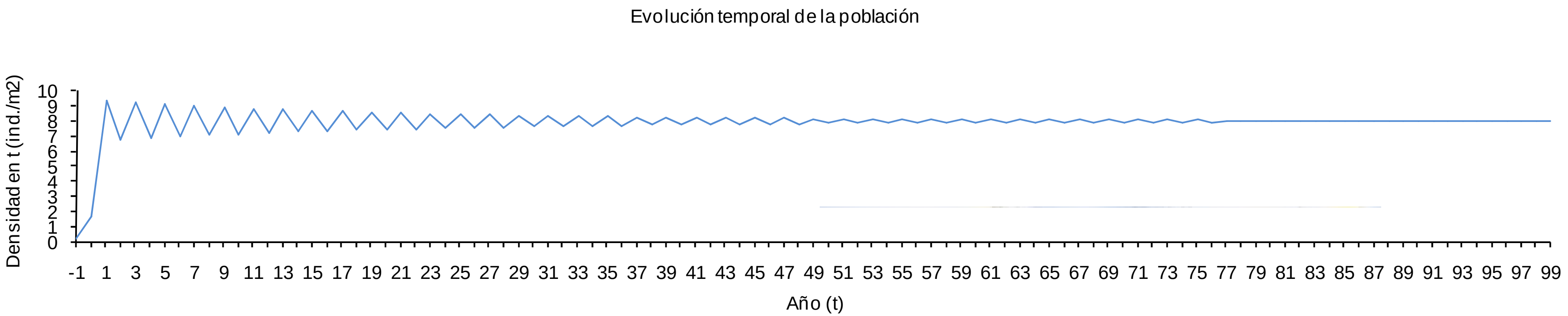
4th principle– Interaction among species: Trophic relations amnogs species can lead to lags in the negative feedback.

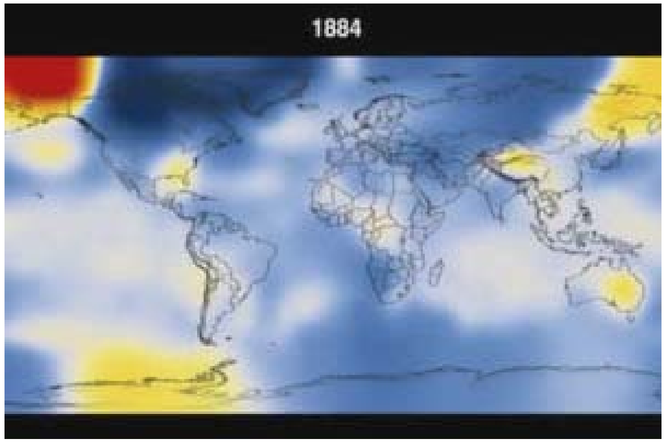


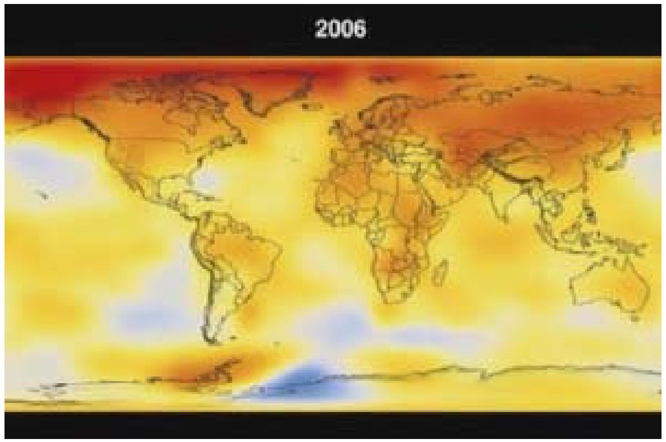


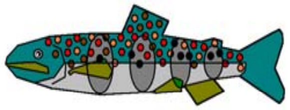


5th principle – Limiting factors: temporal variation of exogenous drivers produce changes in their relationship with the population growth rate.

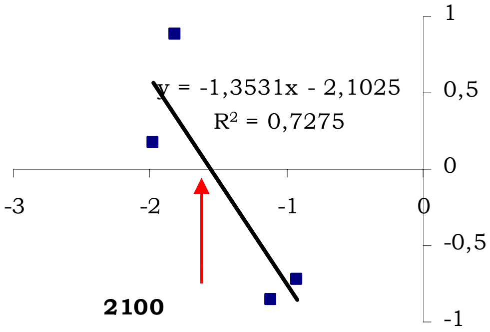




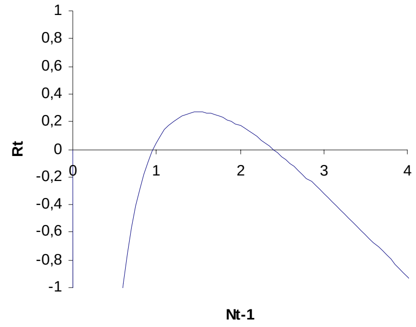


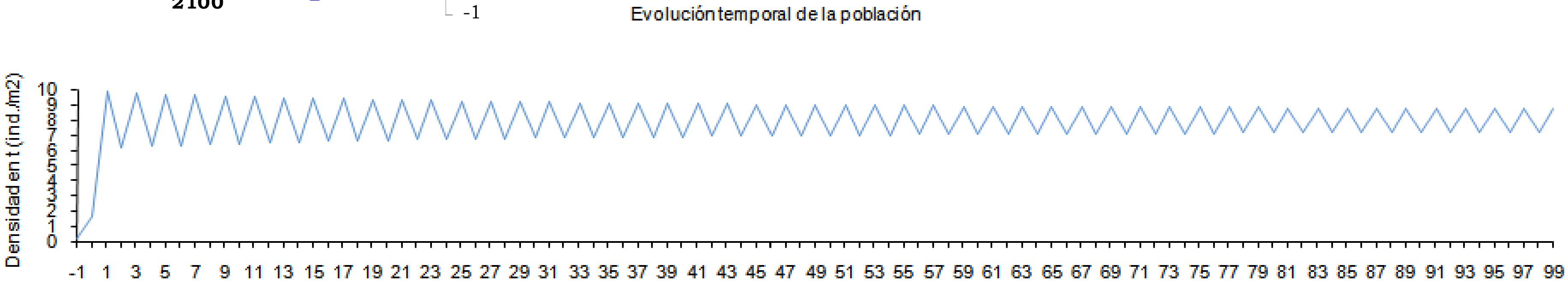


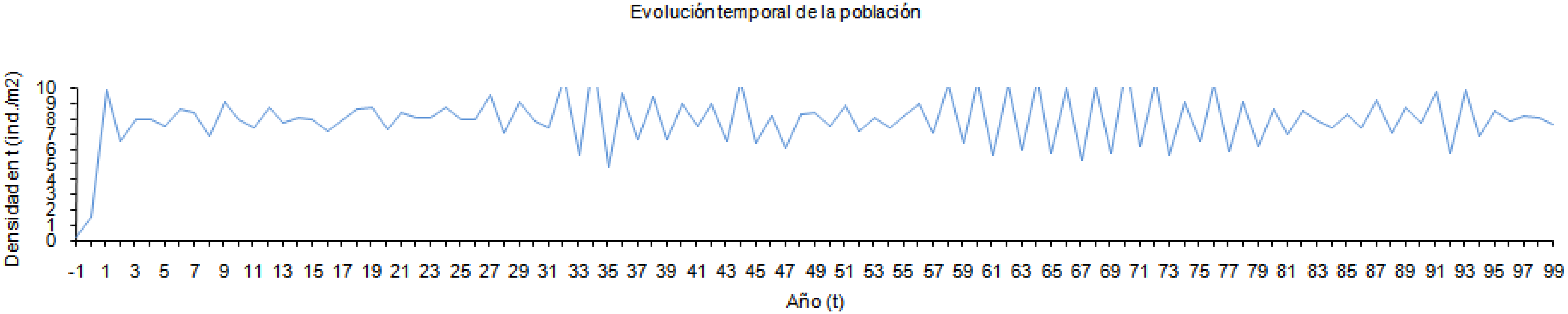
Biological Modelling. Population Dynamics Model



$$\lambda = A.\left(1 - \frac{U}{B_t^{>1+}}\right).\left(1 - \frac{N_t}{K}\right)^{\theta}$$



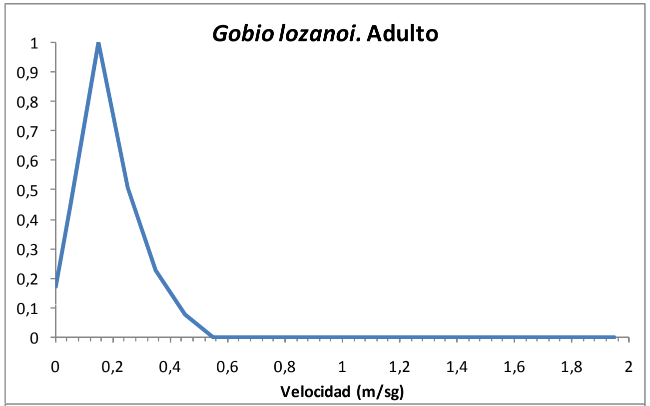


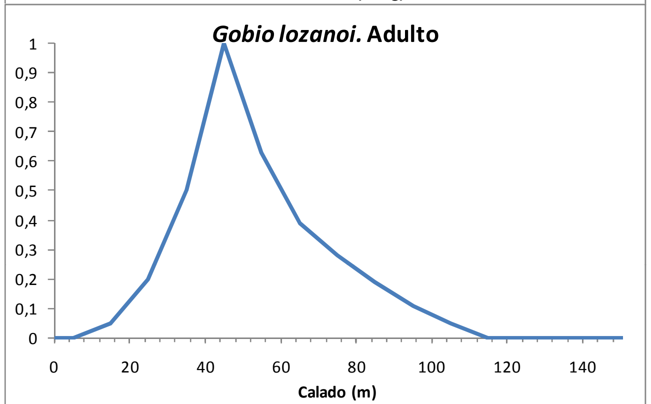


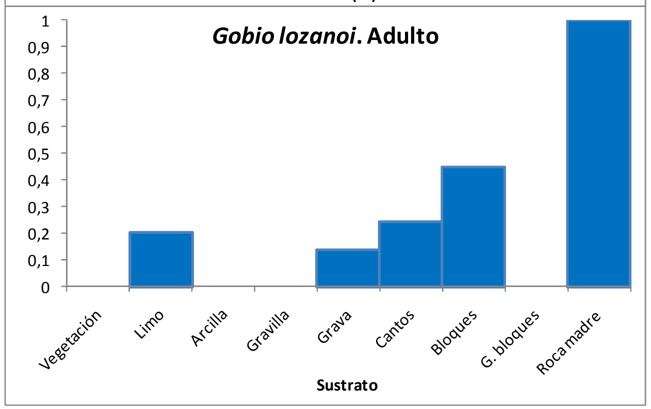
Biological Modelling. Habitat Requirements

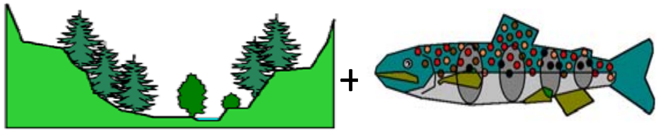
Habitat suitability curves:

Preference = Used / Available

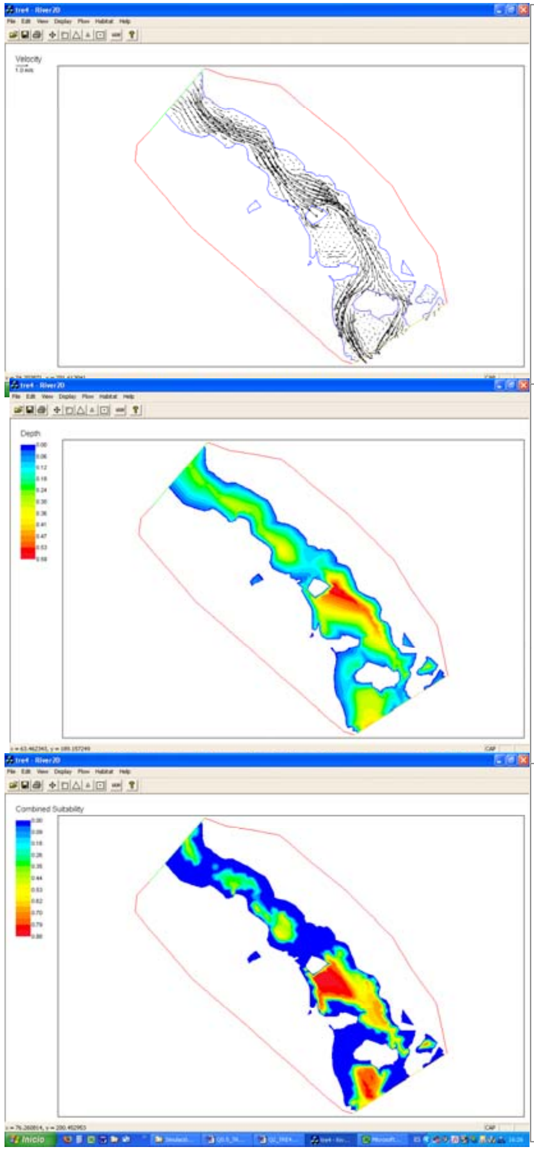


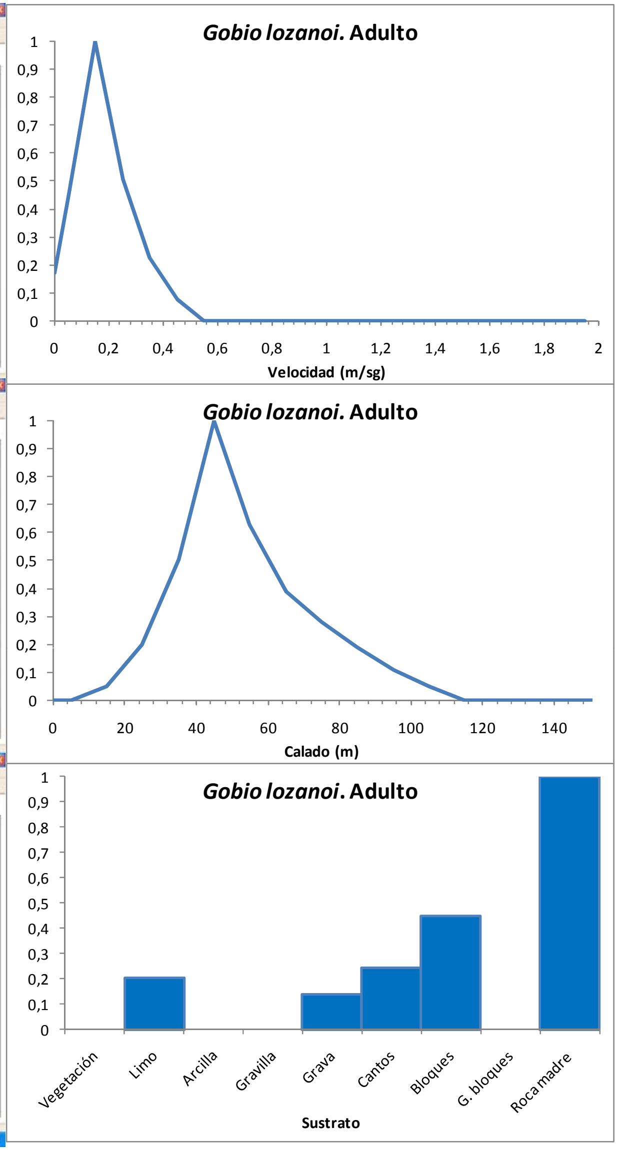


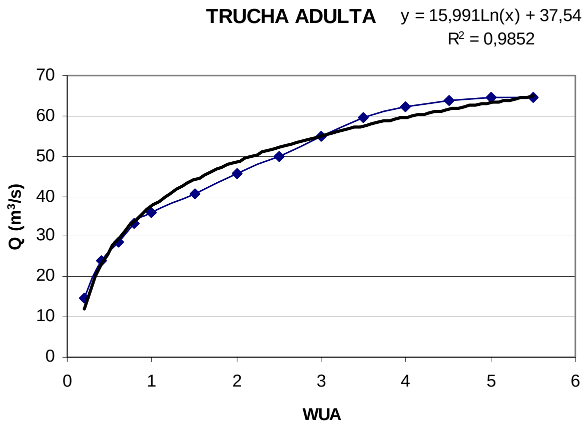


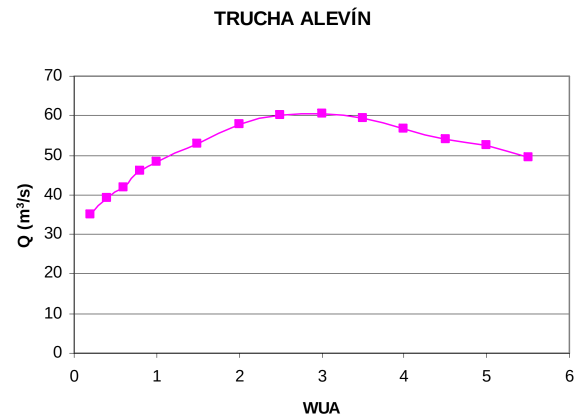


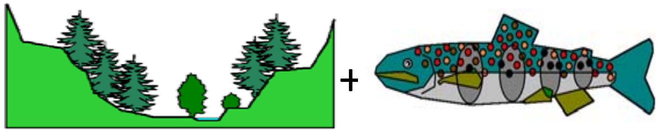
Physical-Biological Synthesis: Habitat availability



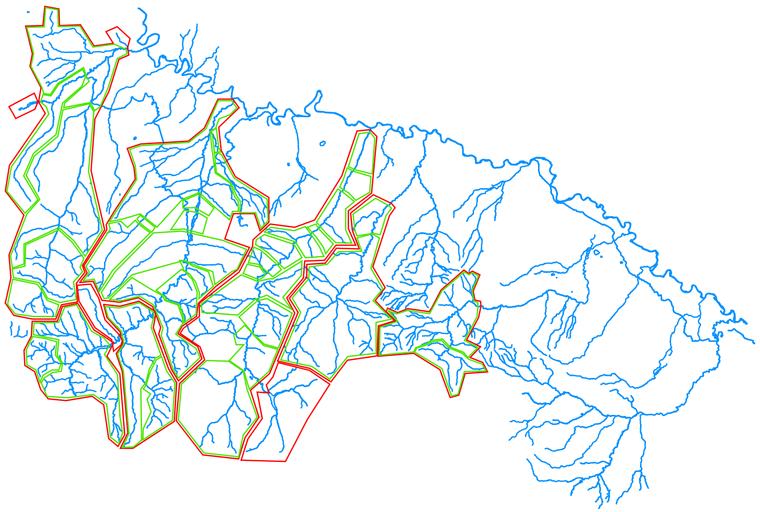


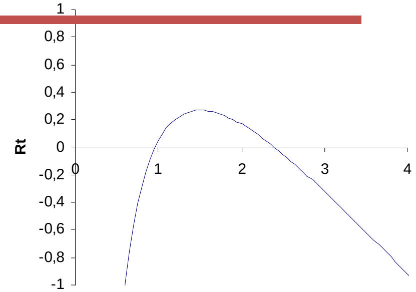


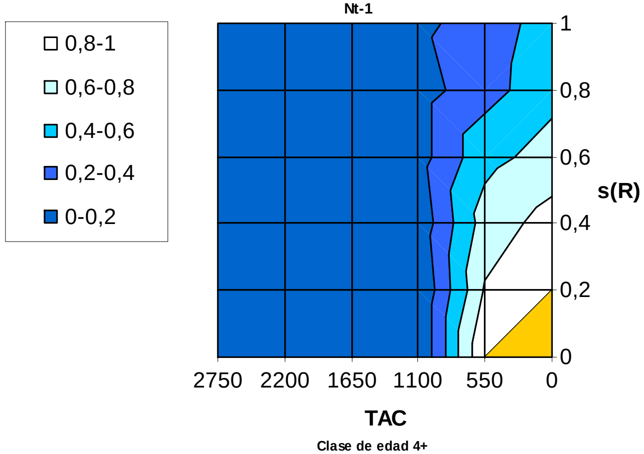


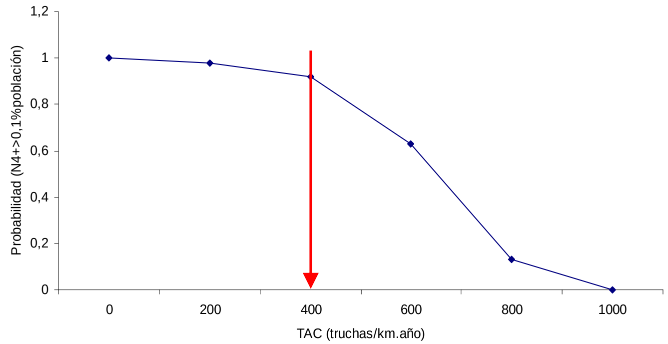


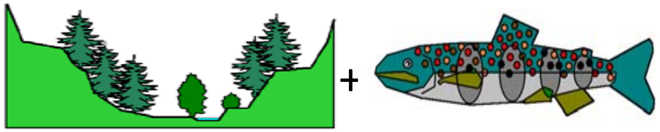
Physical-Biological Synthesis: Management



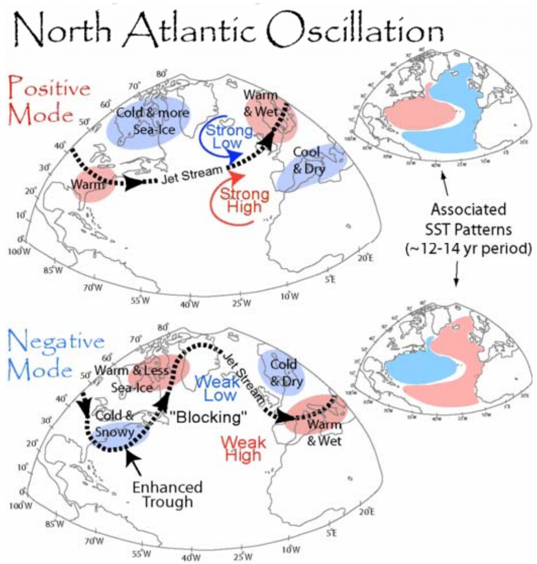


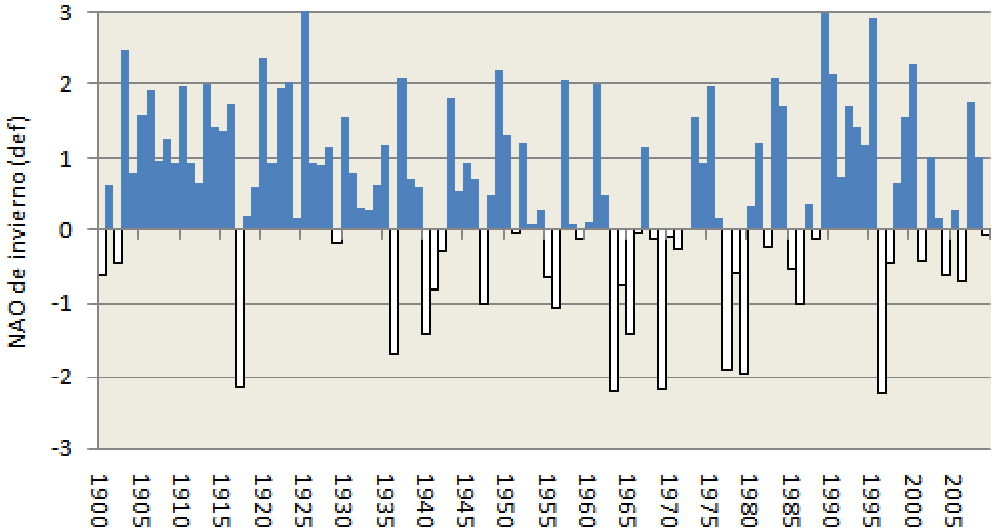


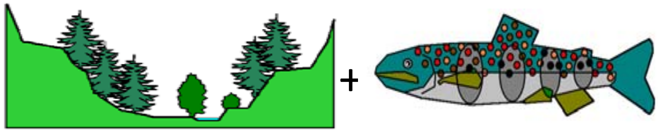




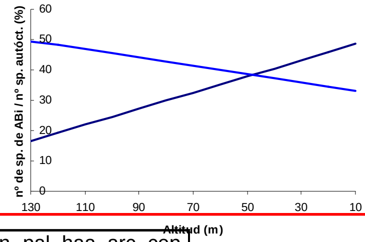
Physical-Biological Synthesis: Prediction

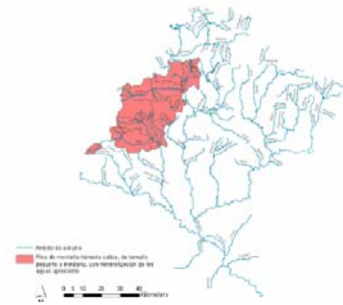






Physical-Biological Synthesis: Reference conditions





Altitud (m)	alo	mar	lab	fle	ang	sal	gym	bar	pho	tru	cot	pla	gra	mie	gob	cal	flu	tin	pal	haa	arc	cep
1100										2												
(...)										2												
650										2												
640					1			0,5	0,8	3				0,6								
630					1			0,5	0,8	3				0,6							1	
620					1			0,5	1,8	4				0,6							1	
610					1			0,5	1,8	4			0,5	0,6							1	
600					1			0,5	1,8	4			0,5	0,6							1	
590					1			2,5	2,8	4			0,5	0,6						1	2	
580					1			2,5	2,8	4			0,5	0,6						1	2	
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460					2			2,5	2,8	4			2,7	2,8		1				1		
450					2			2,5	2,8	4			2,7	2,8		1				1		
440					2			2,5	2,8	4			2,7	2,8						1		
430					2			2,5	2,8	4			2,7	2,8						1		
420					3			2,5	2,8	4			3,7	3,8						1		
410					3			2,5	2,8	4			3,7	3,8						1		
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