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Habitat Suitability models: Approaches and models in Spanish rivers

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INTROD.

Species Distribution factors - scales
(the filter cascade)

- Populations of flora/fauna are limited in distribution, depending on ecological factors working in cascade (hierarchical organization) :

Dispersion Ability / Barriers / Physico-Chemical quality H_2O
(river network scale)

↓

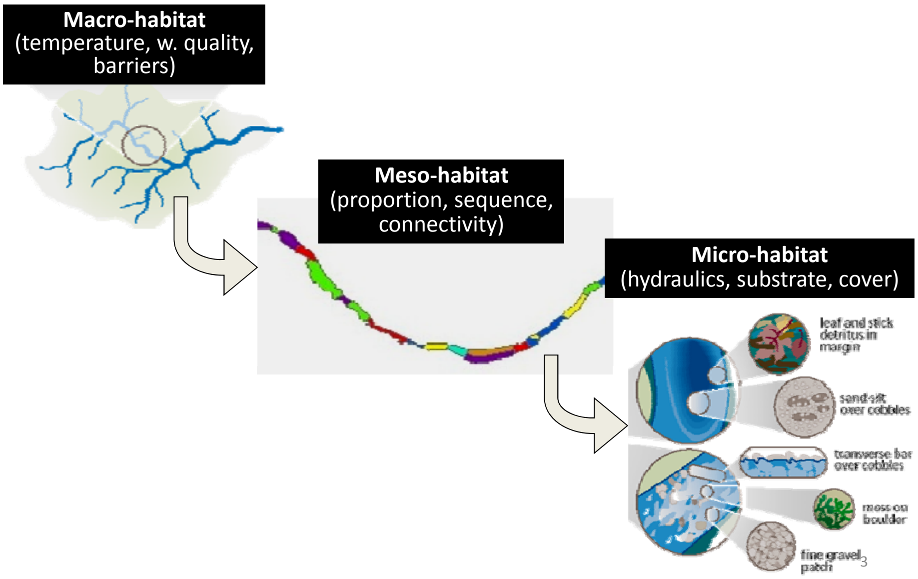
Intra-specific Relations & Availability of suitable physical Habitat
(segment-reach scale)

↓

Inter-specific Relations
(food-predation-competence,…)
(reach scale)

INTROD.

Hierarchy of Habitat factors



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HABITAT MODELLING

Instream Flow Incremental Methodology – IFIM

(includes Physical Habitat Simulation)

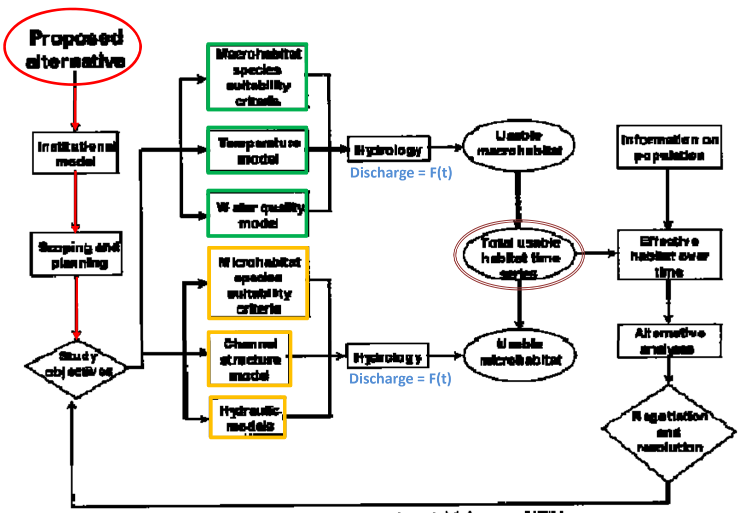


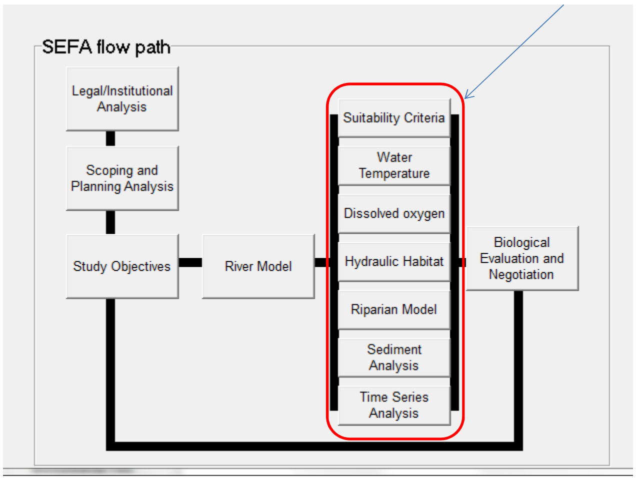
Fig. 1-1. Schematic diagram of the components and model linkages of IFIM.

IFIM is a process to help in decision making, a framework where you can use different types of models

HABITAT MODELLING

IFIM in software SEFA

Evaluation of habitat integrating habitat scales and time series



System for Environmental Flow Analysis

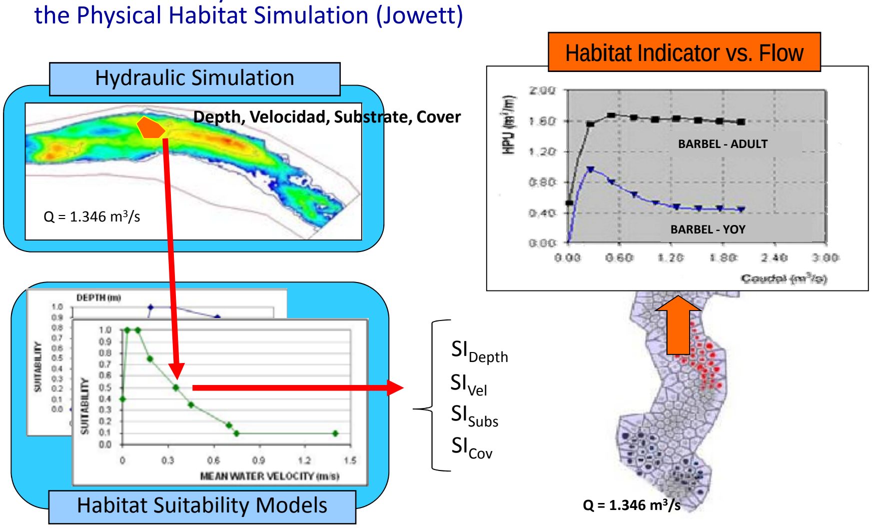
I.G. Jowett, R. Milhous, T.R. Payne

HABITAT MODELLING

Physical Habitat Simulation

Phases of Habitat simulation

- Frecuent procedure to support decisions about minimum flows (Spain, etc.)
- Habitat Suitability Models are the most influencial element in the results of the Physical Habitat Simulation (Jowett)



HABITAT MODELLING

Habitat Modelling & Habitat Suitability Models

- **Habitat Suitability Models -HSM- and species distribution models cover now a wide range of scales: microhabitat, mesohabitat, macrohabitat (river network, basin)**
- **Multivariate analyses allow the evaluation of importance and the integration of multiple variables at different scales.**
- **Species distribution models considering different scales outperform the single-scale models (Olden et al.2006), they integrate multiple ecological filters**
- **Machine Learning techniques allow the creation of predictive models with greater power for explaining and predicting ecological patterns; such models have the ability to model complex, nonlinear relationships in ecological data, without restrictive assumptions of parametric approaches (Elith et al.2006; Olden et al.2008)**
- **In this presentation there is a brief review of some of the models developed in Spain since 1997; these models were applied in studies of Environmental Flows in several river basins (Spain & Portugal) and to help environmental decisions.**

DEVELOPMENT HSM

Definition, Formats

- **Def.:** ***Mathematical functions which intend to describe how an organism select the habitats (usually at microhabitat or mesohabitat scale), or its probability of presence, or density in different habitats. These functions are usually normalized between 0 (unaceptable at mid-long term-?-) and 1 (maximum suitability).***

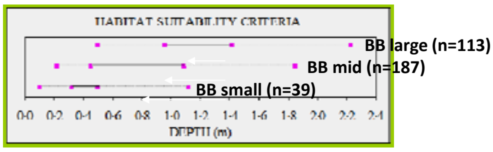
IN THE PHYSICAL HABITAT SIMULATION IN RIVERS, THE HSM (curves/models) ARE THE MOST CRITICAL FACTOR IN THE RESULTS, WHICH MAY GIVE MORE VARIABILITY TO THE FINAL RESULTS

- Formats, evolution (according to technical developments):
  - → Binary models (suitable vs. Unsuitable = presence vs. absence)
  - → Curves 1 variable (depth, velocity,…), Bivariate
  - → Statistical models - Multivariate

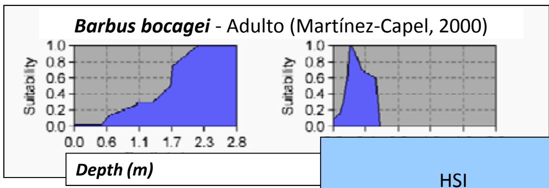
DEVELOPMENT HSM

Definition, Formats

Binary data: Ranges of habitat suitability (by percentiles)



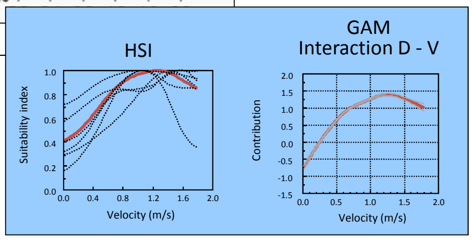
Univariate Curves of microhabitat suitability



Multivariate statistical models

E.g. Generalized Additive Models

(aquatic invertebrates, Jowett & Davey 2011)



DEVELOPMENT HSM

Categories of HSM

(classic classes in aquatic habitat simulation)

- Category I: Based on Expert knowledge, negotiation, etc. (roundtable discussions -BOGGSAT-, Delphi technique, etc.)
- Category II: “habitat use functions” describe the habitat variables in the points occupied by the target species (different scales).
- Category II½: when **habitat use functions** are developed with equal effort sampling (Johnson, 1980): different types of habitat sampled in equal proportion. The most robust for univariate curves, recommended by Instream Flow Group.
- Categoría III: “habitat preference functions/selection indices” describe the habitat with calculations of selection indices, e.g. forage ratio = use / availability. With potential problems about the statistical assumptions and in development.
- **Category IV: Multivariate statistical models** (may integrate absence, presence, abundance)

DEVELOPMENT HSM

Generic Assumptions we must assure

- The **organism select some habitat** types over others (description of habitat selection may need great effort for generalist species, or not possible)
- The **sampler is not disturbing** the habitat selection by the organism (disturbed animals are not recorded -> limitation in electrofishing)
- There is **no relevant alteration/limitation for the habitat** selection by other factors in the study area -at any scale- (degraded habitat, poor water quality, extreme flows, exotic predators, etc.). E.g., not good to work in sites where water quality or temperature is “extreme” within the species distribution area.
- **Habitat heterogeneity & connectivity** in the study area allow the organism to select a variety of habitat types (microhabitats, or mesohabitats, etc.)
- There is no relevant alteration by human in the area: the **quality of habitats** is good or excelent.
- Depending on model type: presence/absence, or density model, population density may be an important parameter to consider.

DEVELOPMENT HSM

Variables – Microhabitat Scale

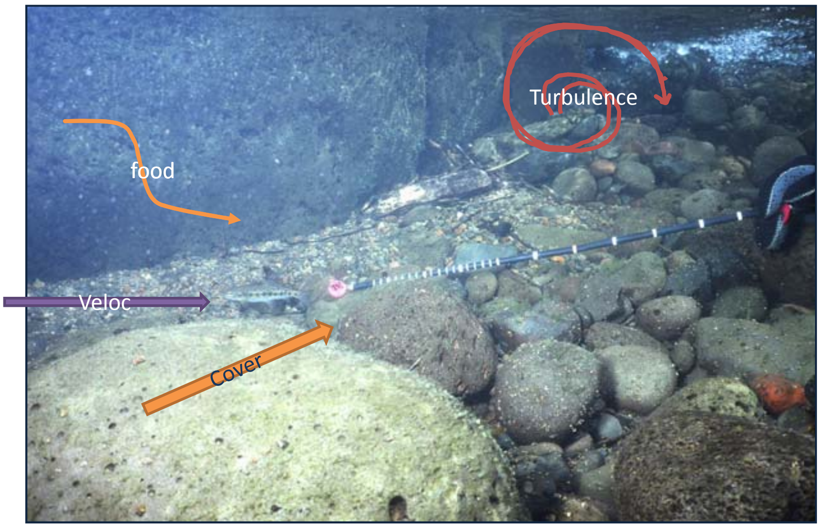


Photo Tom Payne & Mark Allen

DEVELOPMENT HSM

Variables of Habitat Selection

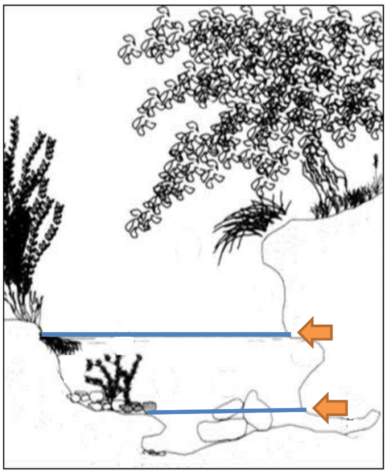
Microhabitat Scale

- **Questions:**
  - What variables at different scales have ecological meaning for the species?
  - Which ones can be simulated at the right scale?
  - Which ones are affordable with my budget, techniques and time frame?
- Which ones can be simulated - we need models working at ecologically relevant scale (usually hydraulic models, also water quality models, water temp, etc.). Generally:
  - Mean water column velocity (models 1D , 2D)
  - Depth
  - Types of Substrate and Cover (some variables can have constant distribution)
- Other variables used: Nose velocity, lateral velocity, shear velocity (ej. benthonic fish), FST number (invertebrates), Nº Froude, etc.
- Watch out!:
  - Atributes of sampling and modelling must match those in the HSM of the target species (substrate types, etc.).
  - Some software packs use each variable independently, there's no variables interaction, multivariate models not implemented.

DEVELOPMENT HSM

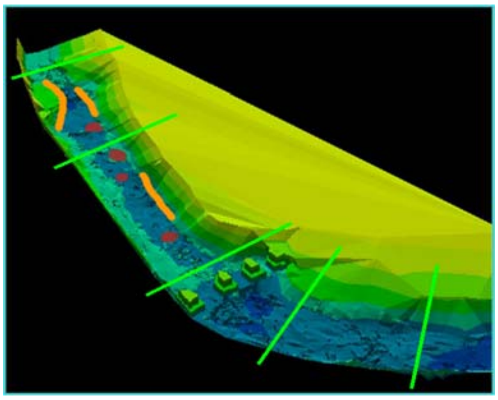
Variables of Habitat Selection

Variables of permanent distribution -not simulated-



Potential examples

- *Microhabitat*: substrate types (polygons in map), cover,...
- *Mesohabitat*: undercut banks %, number of boulders, ...



DEVELOPMENT HSM

Factors Afecting Habitat selection

Variables and Parameters in the study

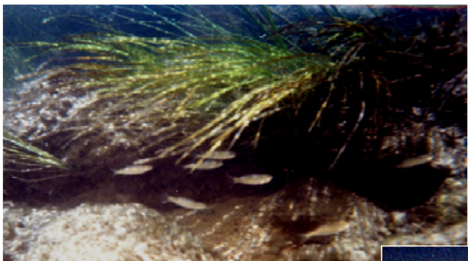
- **Remember: "Species Distribution factors-scales", the organism selects habitat based on different variables interacting at different scales (micro, meso, macro).**
- **Remember: if some factors are limiting habitat selection, this fact can bias the work or make it invalid.**
- **Important Stratification** for target species: By species, size class or life stage, activity (fish), spawning. A combination of data should be avoided if possible, becasue the mix of strata lead to difficult or wrong interpretation***, better never combine field data before analysis and interpretation.***
- **Important Stratification of habitat conditions (combine scales):** River types, order, season/temperature, stream flow. These are **parameters** to record.
- Other factors: diurnal/nocturnal, proportion of mesohabitats, population density, food abundance, competence and predation, abundance of exotics... **parameters**

If Possible, all the factors of habitat selection should be assessed; some will be variables to study, other are approximately uniform in a study reach, or in the study area. They are all important to stratify data and for comparison among rivers and other studies on the target species.

DEVELOPMENT HSM

Factors Afecting Habitat selection

cyprinids in clear waters: contrast of size classes



YOY protecting from stream current
Pseudochondrostoma polylepis < 10 cm
(Tagus River Basin)

Adult barbel in deep pools
Luciobarbus bocagei > 20 cm
(Tagus River Basin)

Sampling for HSM must be stratified by species, size classes or life stages, activity, time of the day or diurnal/nocturnal, season (or more)

DEVELOPMENT HSM

Sources of Information

- Development of site-specific models for target species or guilds. In the river under study or more general for regional application. This is first-best option, reliable.
- Consider Importance of Transferability:
  - Need to know characteristics (parameters) in the "source river": is it applicable to my study sites?
  - Empirical tests: with "less" data we can apply different types of transferability test or a statistical validation.
- Published or public information:
  - scientific journals, master & PhD thesis
  - possible future "curvoteca" (MARM Spain), estudios encargados por el Ministerio de Medio Ambiente.
  - NBS Library (USA), publications HSI (USGS), etc.

Approaches and Models in Spanish rivers
summary

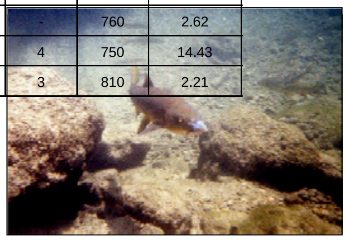
- Endemic cyprinids in Tagus River Basin (1997-2000): *Luciobarbus*, *Squalius*, *Pseudochondrostoma*. **Microhabitat Univariate curves; now under review for multivariate models.**
- Brown trout & endemic cyprinids in Júcar River Basin (2006-09): *Salmo*, *Luciobarbus*, *Squalius*, *Parachondrostoma*, Achondrostoma, *Salaria*. **Microhabitat Univariate curves; now under review for multivariate models.**
- *Parachondrostoma arrigonis* (endangered), study on factor degrading fish populations (2006-08). Included **Microhabitat Univariate curves; now in process for multivariate models at mesohabitat scale.**
- 2009-today, development of multivariate HSModels
- Review of habitat suitability curves in Spain (2011). For nationwide studies on Environmental Flows, curves for main species were developed in different basins. There was a small budget and short time to develop curves → some of them need new studies (more field data and processing); the methods to sample and to analyze data were diverse.

HSM - CYPRINIDS

Habitat Suitability Curves

Endemic cyprinids in Tagus River Basin: *Luciobarbus bocagei*

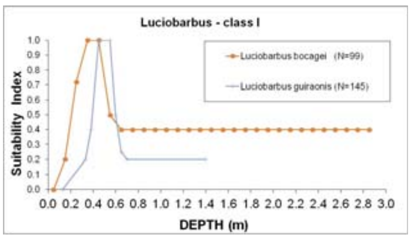
River	Location	Code	Coordinates		Order	Elevation	Mean annual
			X	Y	(Strahler)	(masl)	flow (m³/s)
Ambroz	Abadía	AM 99	246400	4461150	3	420	3.76
Guadiela	Alcantud	GU 99	557250	4484950	4	750	5.04
Jarama	Valdepeñas	JA 97	468250	4524850	4	735	5.03
	Valdepeñas	JA 98	468250	4524850	4	735	5.03
Lozoya	Pinilla del Valle	LO 98	430400	4529900	4	1090	1.41
	Pinilla del Valle	LO 99	430650	4529900	4	1095	1.41
Sorbe	Torrebeleña	SO 98	484800	4529900	-	760	2.62
Tajo	Cifuentes	TA 99	543800	4505950	4	750	14.43
Tajuña	Brihuega	TJ 99	513500	4513400	3	810	2.21

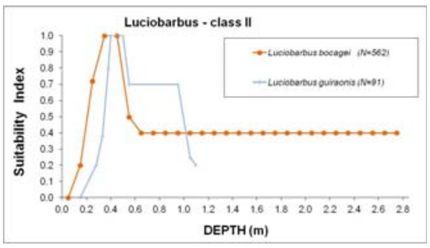


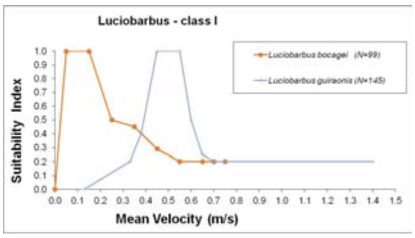
HSM - CYPRINIDS

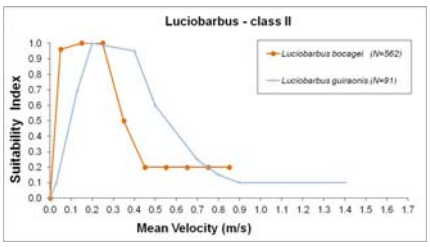
Habitat Suitability Curves

Endemic cyprinids: *Luc. bocagei* (Tagus) *vs. Luc. Guiraonis* (Júcar)





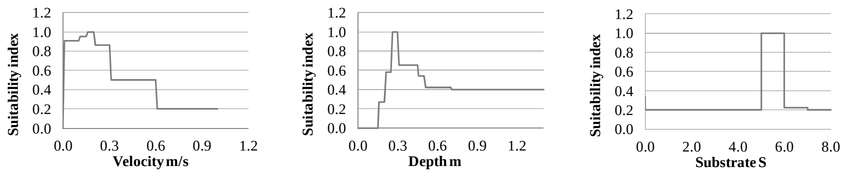


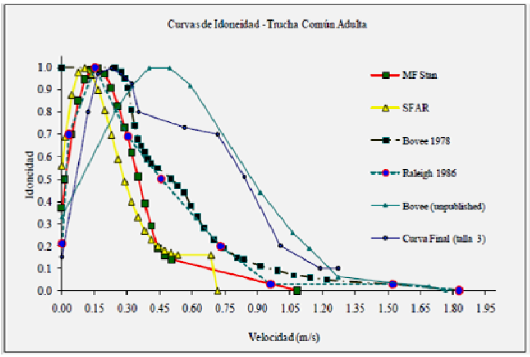


HSM - BROWN TROUT

Habitat Suitability Curves at Micro-scale

(medium size, length 10-20 cm)





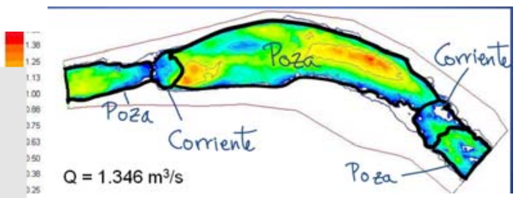
Range of conditions
in Spanish studies on B.T.

Variable	Range
Order (Strahler)	1-3
Mean annual flow (m^3/s)	0.25-0.65
Elevation (masl)	400-1200
Max depth (m)	1.78
Max velocity (m/s)	1.78

HSM - BROWN TROUT

Fuzzy Model at Meso-scale

Data-driven fuzzy habitat suitability models for brown trout in Spanish Mediterranean rivers, and comparison with Random Forest **(Comunidad Valenciana)**



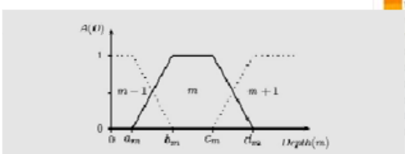


Fig. 2. The parameters a_m, b_m, c_m and d_m of the trapezoidal fuzzy set m of the variable 'Depth'.

Table 6
The fuzzy rule base of the optimal fuzzy model (model WCV). The number of habitats that covered each environmental condition is shown in the last column (L = Low, M = Moderate, H = High).

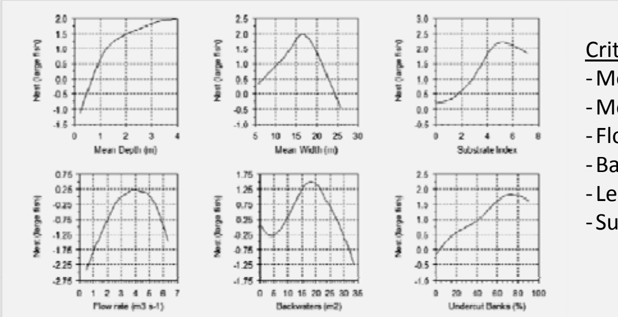
Width	Cover	Flow velocity	Habitat suitability	Rule coverage
L	L	L	H	0
L	L	H	L	5
H	L	L	H	2
H	L	H	L	9
L	M	L	H	17
L	M	H	H	17
H	M	L	L	21
H	M	H	L	9
L	H	L	H	8
L	H	H	H	2
H	H	L	L	3
H	H	H	L	0

Mouton et al. 2011
Environmental Modelling & Software

HSM - Parachondrostoma

HSM at Meso-Scale in the Cabriel River

Generalized Habitat Model (GAMs) of abundance for Júcar nase (*Parachondrostoma artigonis*), two models by fish size (small, large)



Response curves of Júcar nase abundance (large fish) obtained with the spline adjustment (df = 3) in the GAM

Critical Variables:
- Mean Depth
- Mean Width
- Flow rate
- Backwaters area
- Length of Undercut banks (%)
- Substrate index (1-8)

Habitat Simulation

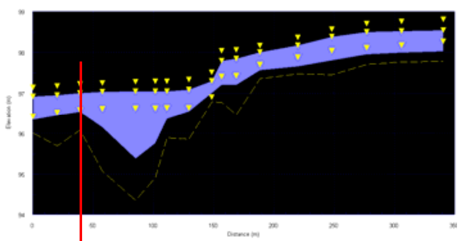
Costa et al. 2011, River Research & Applications

HSM – Meso-scale approach

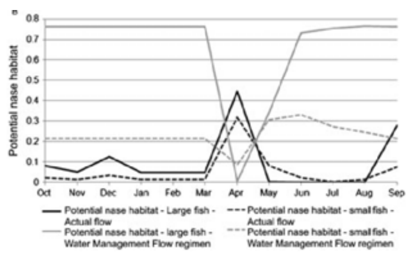
Meso-Scale Habitat Simulation & Evaluation of E-flow Regimes

Hydraulic-Based approach:

- For Hab.Simul. We did Not use any Classification
- Variables were calculated from 1D model (or approx. constant)
- Segmentation was permanent, (transects are "permanent")
- 3 calibration flows in the range of the flow regime
- Habitat Evaluation based on ecological knowledge (GAM)



Cross-Sections



Costa et al. 2011, River Research & Applications

HSM – Meso-scale approach

Meso-Scale Habitat Simulation & Evaluation of E-flow Regimes

Hydraulic-Based approach

PROS

- Objective, transparent, direct use of hydraulic variables
- Class. **A Priori** ("classic") Not necessary for meso-scale habitat simulation. Yet we need to do segmentation of river, coherent with ecological knowledge and physical heterogeneity
- We skip problems of parallel units and other of visual methods (wrong identification, consistency, etc.)
- Application with small budget

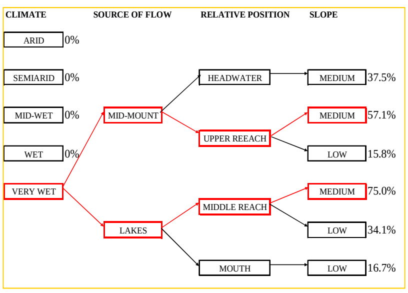
CONS

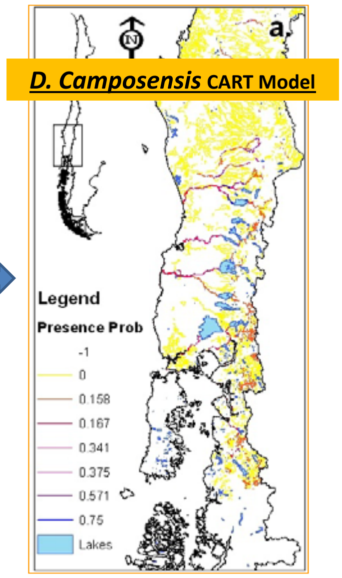
- Cross-sections (1D) are static, but length of meso-scale units changes with flow
- The hydraulic variables in 2 consecutive X-S do not always represent the habitat unit between (pools need more transects)
- Limited habitat representation in comparison with 2D (backwaters, side arms, transverse heterogeneity, etc.)

HSM – Basin Scale Approach

Development of HSM at basin-scale

POTENTIAL GEOGRAPHICAL DISTRIBUTION OF TWO ENDEMIC FRESHWATER FISHES (*P. GILLISSI* & *D. CAMPOSENSIS*) OF CHILE
Peredo-Parada et al.





Geographic distribution pattern:

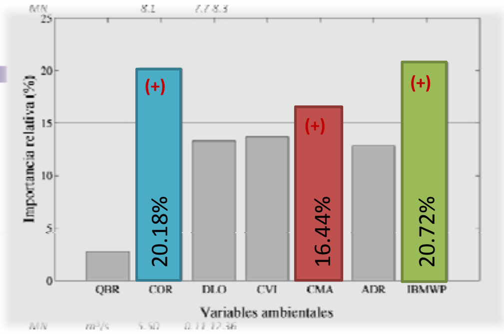
- River stretch with medium slope (0.02 y 0.04%) located in upper basin in mid-mountain river influenced
- River stretch with medium slope (0.02 y 0.04%) located in middle basin in lake river influenced

Peredo-Parada et al., 2009

HSM – Basin Scale – River Restoration

Predicting native fish richness in Mediterranean river basins using ANN to simulate river restoration measures

Variable	Method	Unit	Mean	Range
Physicochemical conditions of water				
Dissolved oxygen)	MN	mg/l	9.5	8-11
Biological Oxygen Demand	MN	mg/l	2.5	2.0-4.0
Total phosphorus	MN	mg/l	0.6	0.02-0.22
Nitrites	MN	mg/l	0.2	0.01-0.23
pH				
Suspended solids				
Conductivity				
Water temperature				
Hydromorfology				
Hydromorphological units:				
Pools (%)				
Glide (%)				
Riffle (%)				
Rapid (%)				
Run (%)				
Mean width of water surface				
Channel length without artificial barriers				
Altitude				
Drainage area				
Distance from headwater source				
Mean Annual flow rate				
Inter-annual mean flow (calculated for 5 years)				
Coefficient of variation of mean monthly flows (fish sampling year)	MN	-	0.5	0.28-0.94
Coefficient of variation of mean annual flows (calculated for 5 years)	MN	-	0.4	0.15-0.81
Biological indices of water quality and riparian quality				
IBerian Monitoring Working Party-IBMWP	BMN	-	131.6	64-260
Index of Riparian Habitat Quality	BMN	-	73.6	10-100



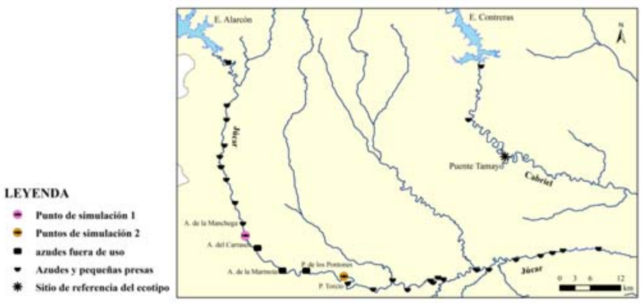
Olaya et al., 2011; Olaya-Marin, in review

HSM – Basin Scale – River Restoration

Predicting native fish richness in Mediterranean river basins using ANN to simulate river restoration measures

Simulation of the effects of mitigation measures (river restoration):

- Removal of 3 small weirs out of use: Carrasco, La Marmota y Los Pontones → Increase connectivity, mesohabitat proportion would change
- Increase percentage of riffle in 10, 20, 30, 40, 50% respect to observed values (field observations) in two river reaches oo the Júcar River below the large Alarcón Dam.

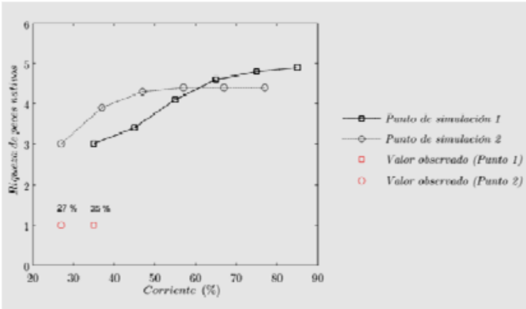


Olaya et al., 2011; Olaya-Marin, in review

HSM – Basin Scale – River Restoration

Predicting native fish richness in Mediterranean river basins using ANN to simulate river restoration measures

- Weir removal generates a segment of **37 km without obstacles**: the simulation indicated an increase fom **1 (observed) to 3** species in both reaches.
- The increase in percentage of riffles in relation to actual values could produce a progressive increase of *Native Fish Species Richness* until the maximum of this river ecotype, i.e. 4 or 5 species.



Proyect SCARCE: Plan CONSOLIDER, Ministerio de Ciencia e Innovación (ref.:CSD2009-00065).
http://www.idaea.csic.es/scarceconsolider

CONSOLIDER Ingenio 2010

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CIREF centro ibérico de restauración fluvial

Take-home Message:

1. Dedicate all necessary time to gather knowledge about what is really important for the target species or guilds
2. Find best possible study sites and techniques to comply with the assumptions
3. Make a good planning for a stratified random sampling based on sites exploration before you collect data, with equal effort, do not precipitate data collection.

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Thank you!!

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