Modelling hydrological, morphological and water physico-chemistry characteristics to entire river networks: Explaining spatial variability on stream biological communities

1st INHABIT International Workshop on Rivers

THE IMPORTANCE OF HABITAT FEATURES AND LOCAL HYDRO-MORPHOLOGY FOR THE DEFINITION OF ECOLOGICAL STATUS IN MEDITERRANEAN RIVERS'

Universitat de Barcelona, Aula 35, Barcelona (Spain), October 17th 2012

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Water Framework vs Habitats Directive

Management plans based on environmental assessment: the "good ecological status" (WFD) and the "favorable conservation status" (HD).

DIRECTIVA 2000/60/CE DEL PARLAMENTO EUROPEO Y DEL CONSEJO

de 23 de octubre de 2000

por la que se establece un marco comunitario de actuación en el ámbito de la política de aguas

DIRECTIVA 92/43/CEE DEL CONSEJO

de 21 de mayo de 1992

relativa a la conservación de los hábitats naturales y de la fauna y flora silvestres

(DO L 206 de 22.7.1992, p. 7)

Good Ecological Status	**Objective**	Good Conservation Status
Biological: Macrophytes, Diatoms, Invertebrates, Fishes Water P&Q Characteristics Hidromorphological	**Indicators**	¿Ecosystem? ¿Habitat structure? ¿Population dynamics?
Water Bodies within Typologies	**Assesment Units**	¿@ which scale? ¿SAC?

The linkage between WFD and HD in Cantabrian rivers…

Conservation Status Assessment

Assessment of Habitats / Species

Basic Indicators

- **Endemicity**
- **Fragility**
- **Relictism**
- **Priority**

Specific Indicators

- **Rareness**
- **Vulnerability**

Ecosystem Assessment

Ecological Integrity

Invertebrates
Fishes
Riparian Vegetation

Physical Integrity

Conectivity
Habitat Heterogeneity
Hidrological Condition

Environmental Objectives

Conservation and/or Restoration Measures – Management Plan

The definition of river "units" to apply management practices should incorporate recent theoretical development (RES) on river ecology and management (ELOHA), which give importance to hydro-geomorphic features

One of the major challenges in river ecology and management nowadays is identifying river reaches where hydrological and geomorphological characteristics are equivalent and maintained by similar river processes.

Definition of "Functional Processes Zones"

RIVER RESEARCH AND APPLICATIONS
River Res. Applic. **22**: 123–147 (2006)
Published online in Wiley InterScience
(www.interscience.wiley.com). DOI: 10.1002/rra.901

THE RIVERINE ECOSYSTEM SYNTHESIS: BIOCOMPLEXITY IN RIVER NETWORKS ACROSS SPACE AND TIME

JAMES H. THORP[a]*, MARTIN C. THOMS[b] and MICHAEL D. DELONG[c]
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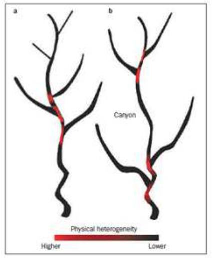
Articles

The Network Dynamics Hypothesis: How Channel Networks Structure Riverine Habitats

LEE BENDA, N. LEROY POFF, DANIEL MILLER, THOMAS DUNNE, GORDON REEVES, GEORGE PESS, AND MICHAEL POLLOCK

May 2004 / Vol. 54 No. 5 • **BioScience 413**



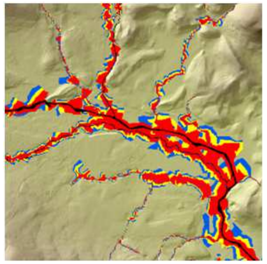
Definition of "River types" based on:

Hydrology, geomorphic features and… Water quality (p.e. temperature regimens)?

Freshwater Biology
Freshwater Biology (2010) 55, 147–170 doi:10.1111/j.1365-2427.2009.02204.x

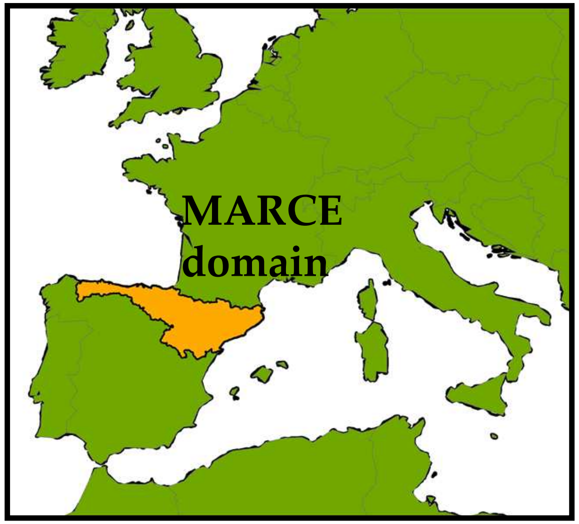
The ecological limits of hydrologic alteration (ELOHA): a new framework for developing regional environmental flow standards

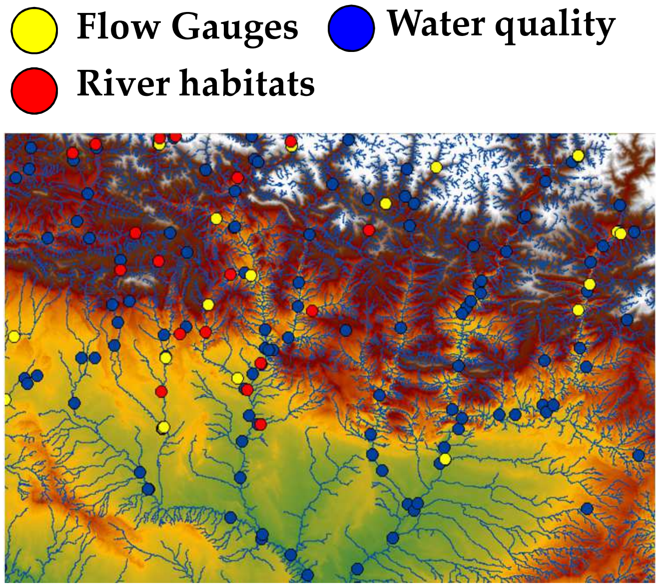
N. LEROY POFF*, BRIAN D. RICHTER†, ANGELA H. ARTHINGTON‡, STUART E. BUNN‡, ROBERT J. NAIMAN§, ELOISE KENDY¶, MIKE ACREMAN**, COLIN APSE††, BRIAN P. BLEDSOE‡‡, MARY C. FREEMAN§§, JAMES HENRIKSEN¶¶, ROBERT B. JACOBSON***, JONATHAN G. KENNEN†††, DAVID M. MERRITT‡‡‡, JAY H. O'KEEFFE§§§, JULIAN D. OLDEN¶¶¶, KEVIN ROGERS****, REBECCA E. THARME†††† AND ANDREW WARNER‡‡‡‡



Moreover, when linking hydromorphological characteristics to biological communities two aspects should be considered. First, the role of river network characteristics in controlling riverine habitat characteristics (NDH: Benda et al., 2004) and, second, river habitats are more than the channel hydraulic sequences and they integrate active and fossil channels, secondary channels, floodplain lakes and ponds, confluence ambients, wetlands, terraces and riparian vegetation (Fluvial landscapes: riverscapes, Fausch et al., 2002, Nakamura, 2006, Poole et al. 2006).

MARCE project - Development of a Spatial Framework for Integrated Catchment Management





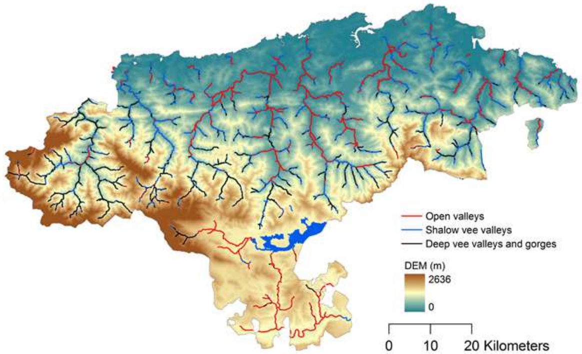
Quantifying the relationships between hydrology, geomorphology, water quality and fluvial biota is a major challenge. On of the main problems is the lack of properly designed databases…(among others!)

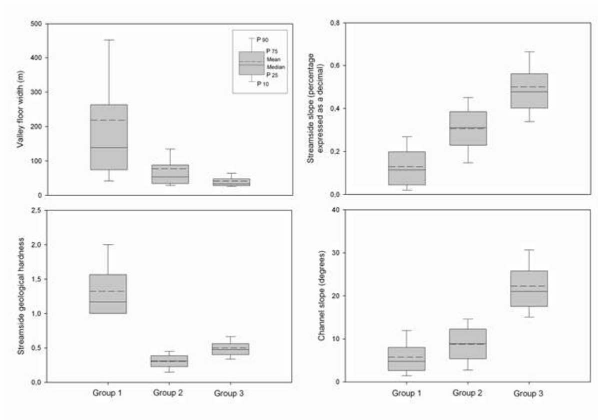
MARCE main Objectives:

- **Key biophysical relationships that account for the greatest variability in river ecosystems**
- **Ecological consequences of human impacts on river ecosystems**

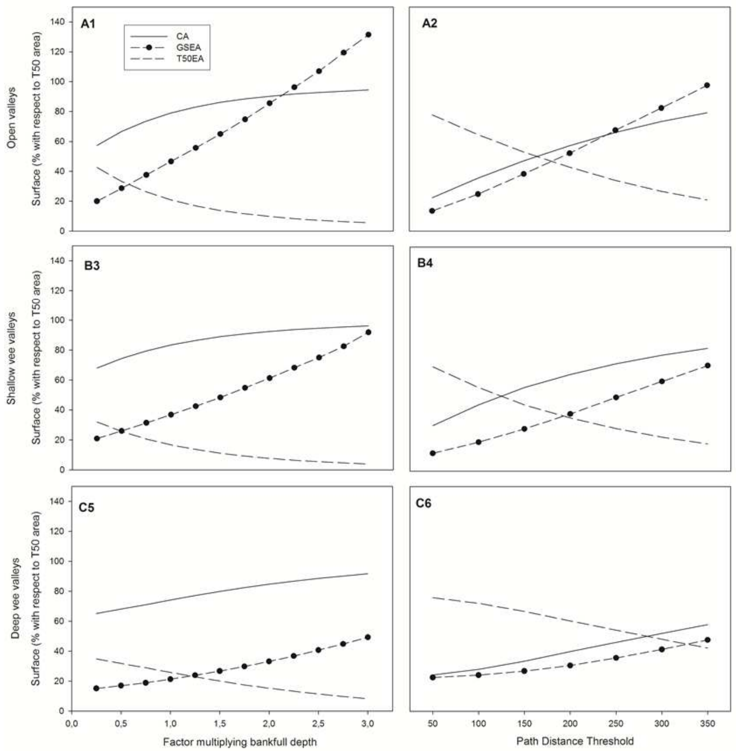
How did we identified river units and river zones (riverscapes…) for Nature 2000 network habitat modelling?

We used a derivation of the NetMap software provided by the Earth System Institute, CA, USA (Lee Benda and Daniel Miller) to extract river networks, river reaches and relevant geomorphological characteristics from Digital Elevation Models (DEMs; Fernández *et al.*, in Press)

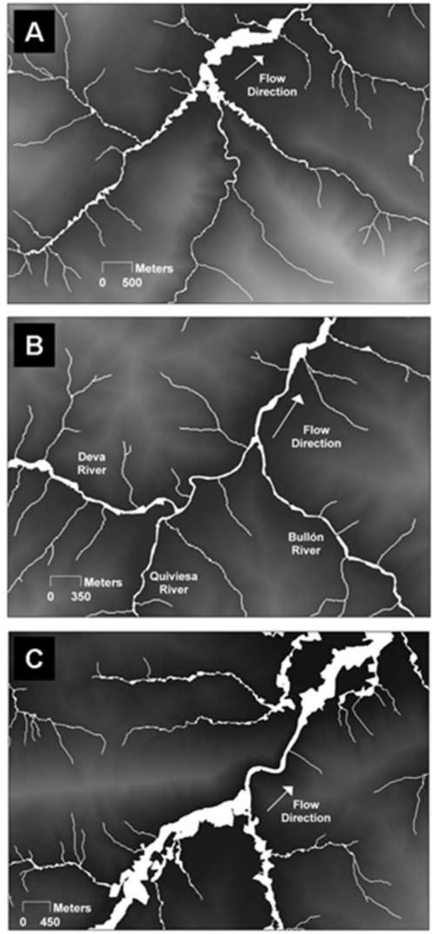




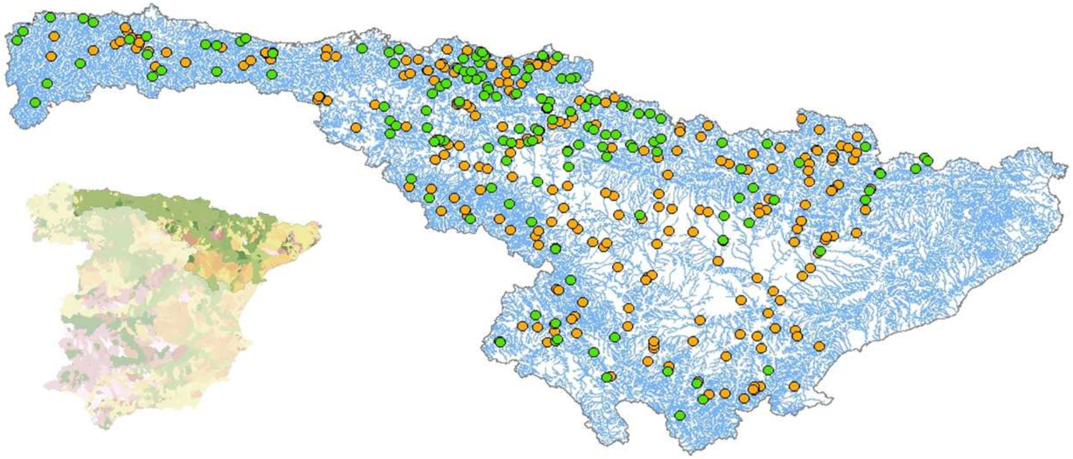
Floodprone area at 1.25-BFD over the digital elevation model: at a river confluence deriving in wider floodprone areas (A), at a river confluence not deriving in wider floodprone areas (B) and at an unconstrained-constrained-unconstrained valley transition (C)



Number of Bankfull Depths and Path Distances to match the 50 year flood



Hydrological Data

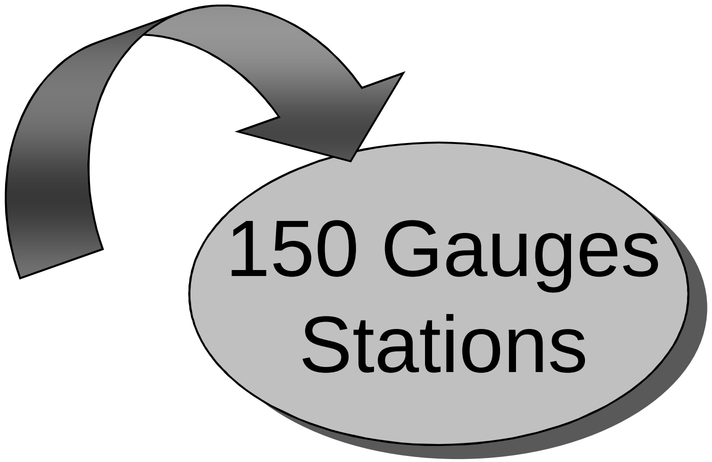


- Series of daily mean flow (Gauges station)
- UNMODIFIED flow records
- Criteria to select unmodified gauges

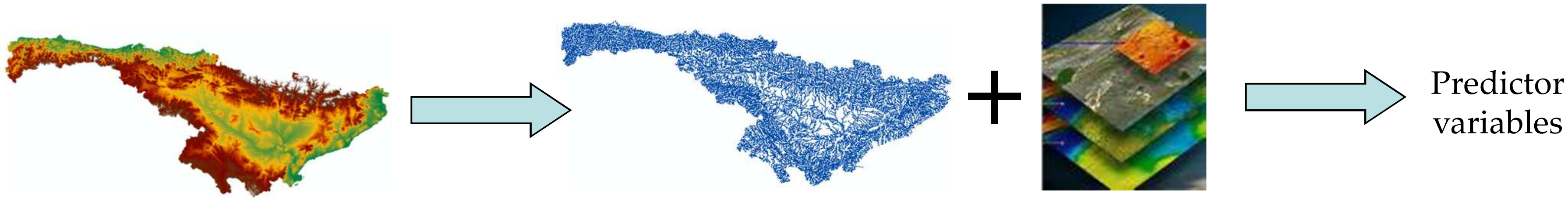
  Visual examination of hydrographs

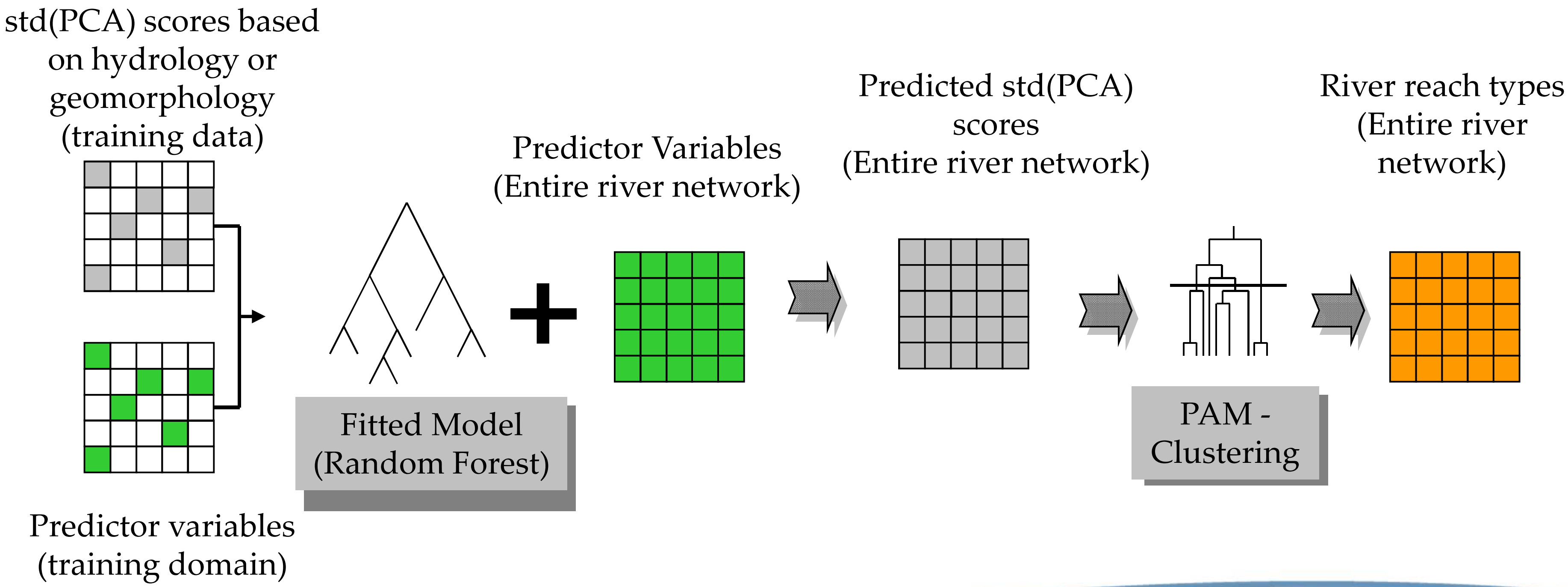
  Elimination of yeras with gaps > 30 days

  Retention of 7 years for the period 1976-2006



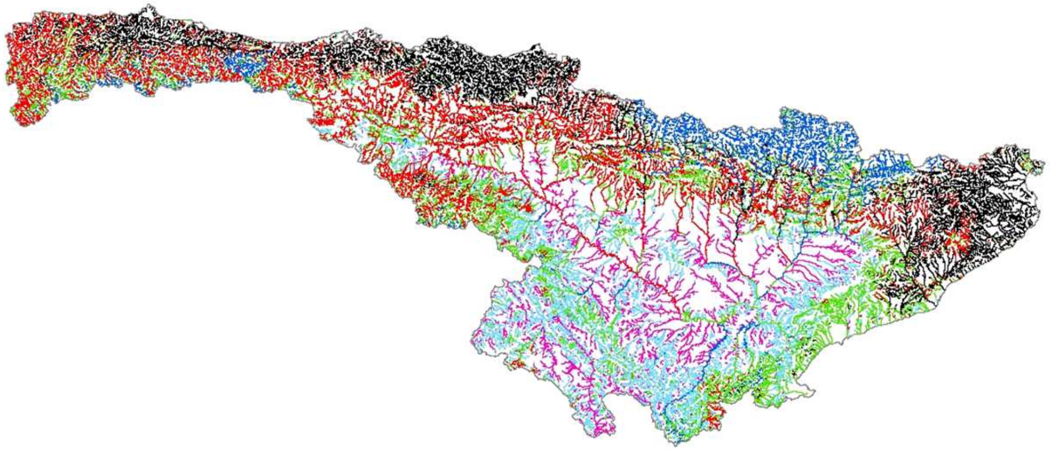
River Network Hydrological Classification



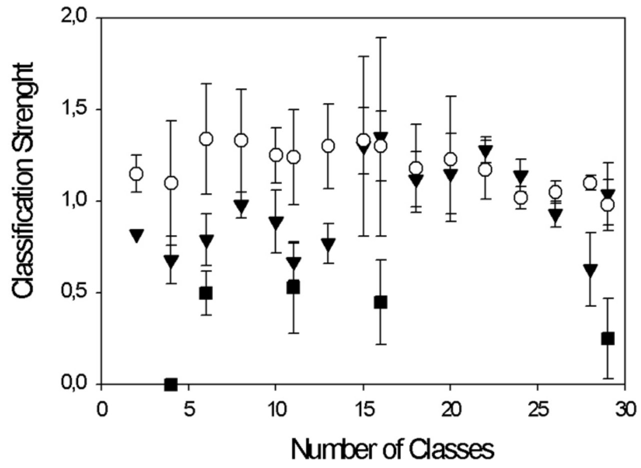


River Network Hydrological Classification

Predict-Then-Classify: Level 6

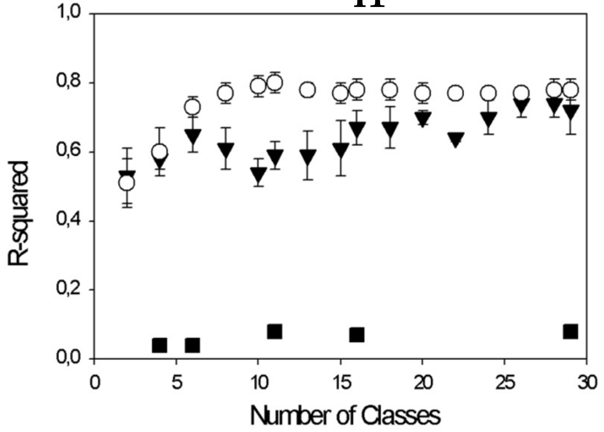


Classification Strength (CS)

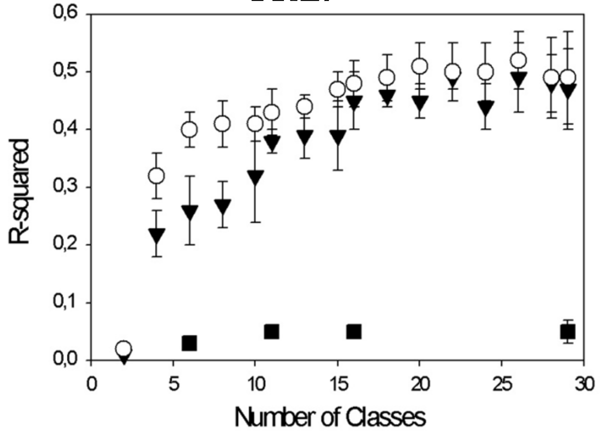


Coefficient of determination (R^2)

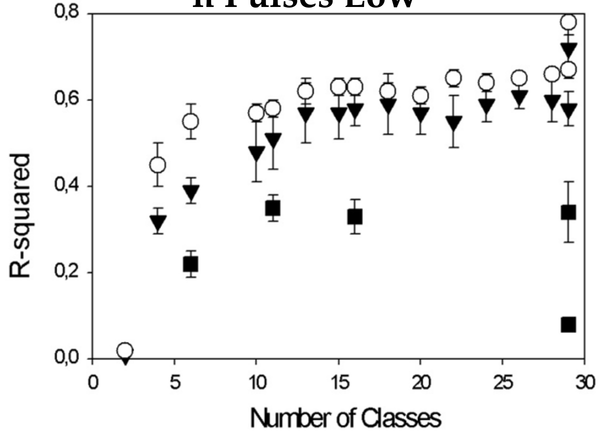
I1



FRE7



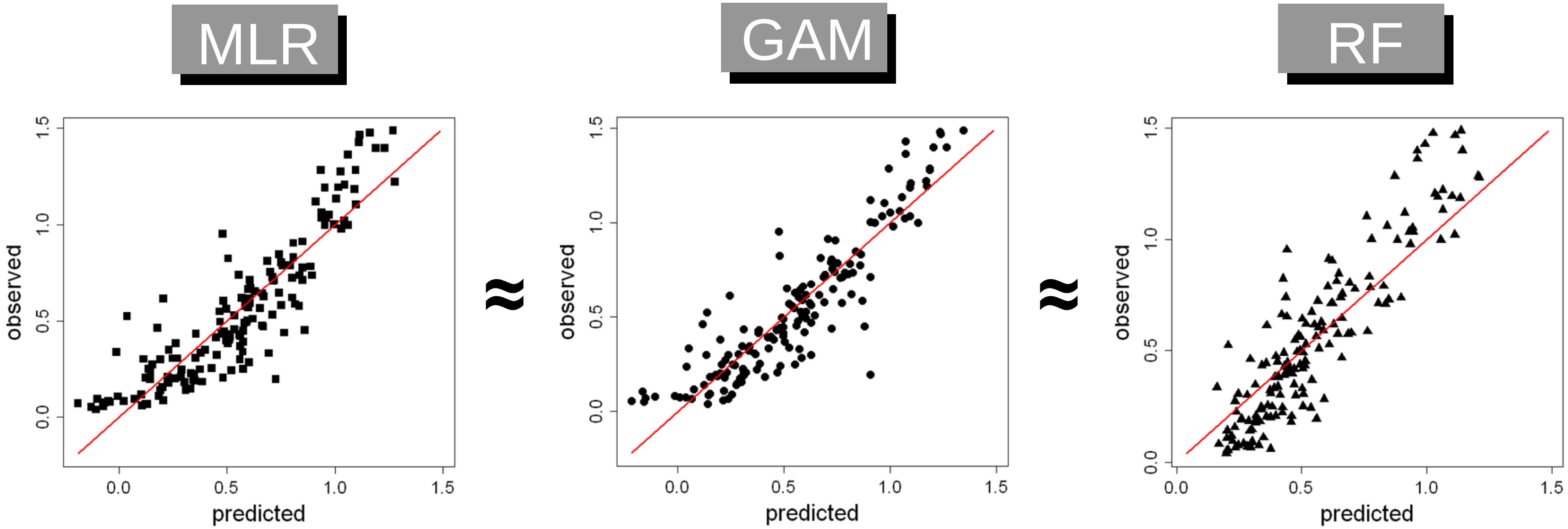
n Pulses Low



○ Predict First ▼ Classify First ■ Official

MAGNITUDE OF AVERAGE FLOWS:

AnnFlo meanApr



Adjusted $r^2 = 0,80$

Area

Precipitation

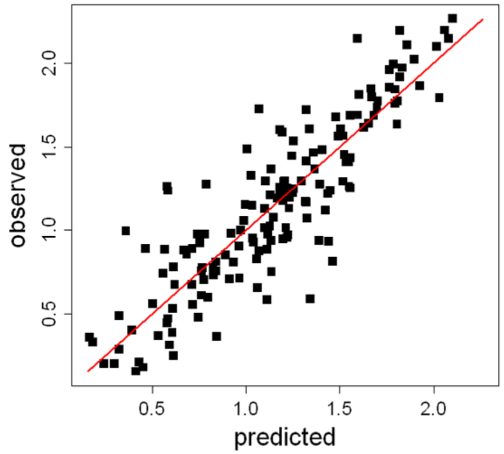
Land uses (agr)

Predicting hydrological characteristics to entire river networks.

MAGNITUDE & DURATION OF HIGH FLOWS:

7MAF 30MAF Xper5

MLR



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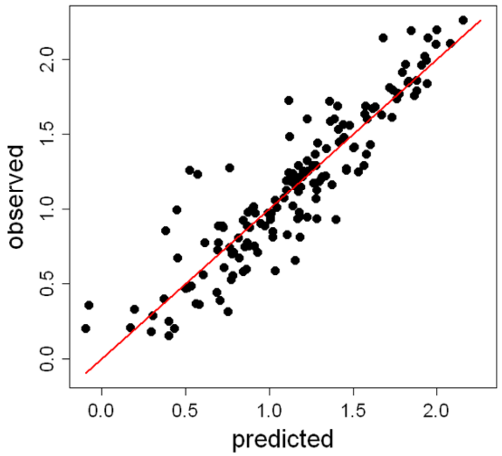
GAM



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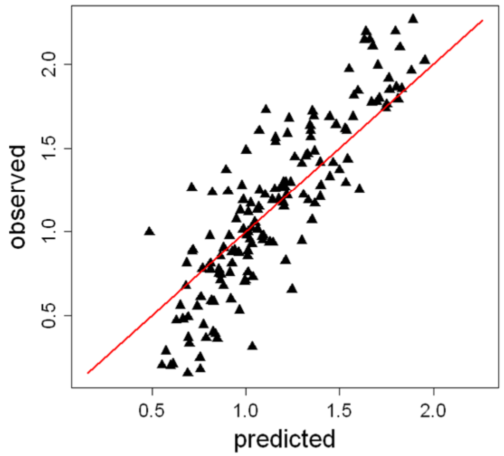
RF



Adjusted r^2 (GAM) = 0,85

Adjusted r^2 (MLR & RF) = 0,75-0,80

Area

Precipitation

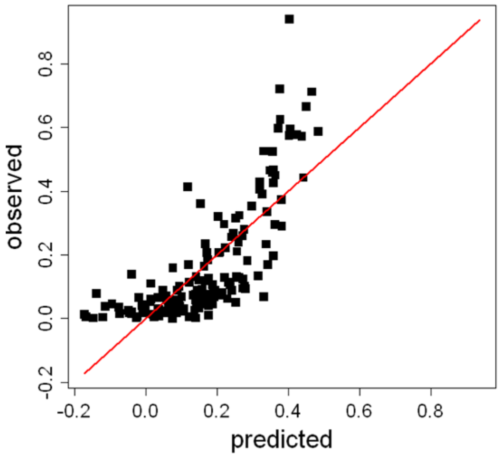
Land uses (agr & blf)

Predicting hydrological characteristics to entire river networks.

MAGNITUDE & DURATION OF LOW FLOWS:

meanSep 7MALF 30MALF

MLR



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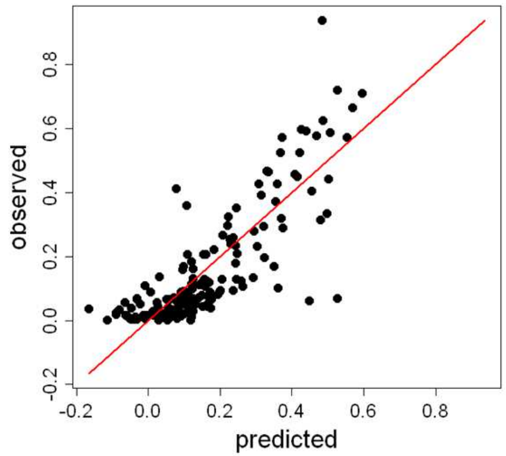
GAM



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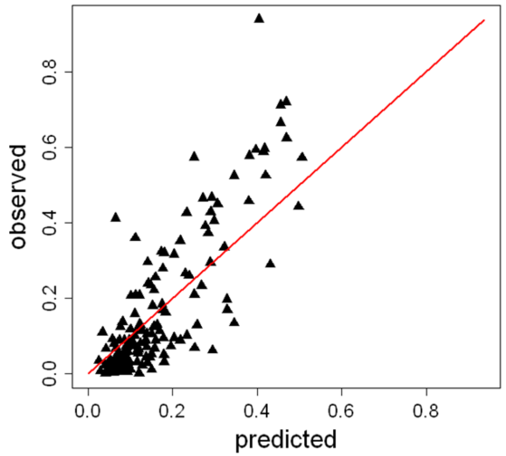
RF



Adjusted r^2 (RF) = 0,70

Adjusted r^2 (GAM)= 0,65

Adjusted r^2 (MLR)= 0,60

Area

Precipitation

Gradient

Precip. Range

Predicting flow duration curves to entire river networks.

Journal of Hydrology 434–435 (2012) 78–94

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Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

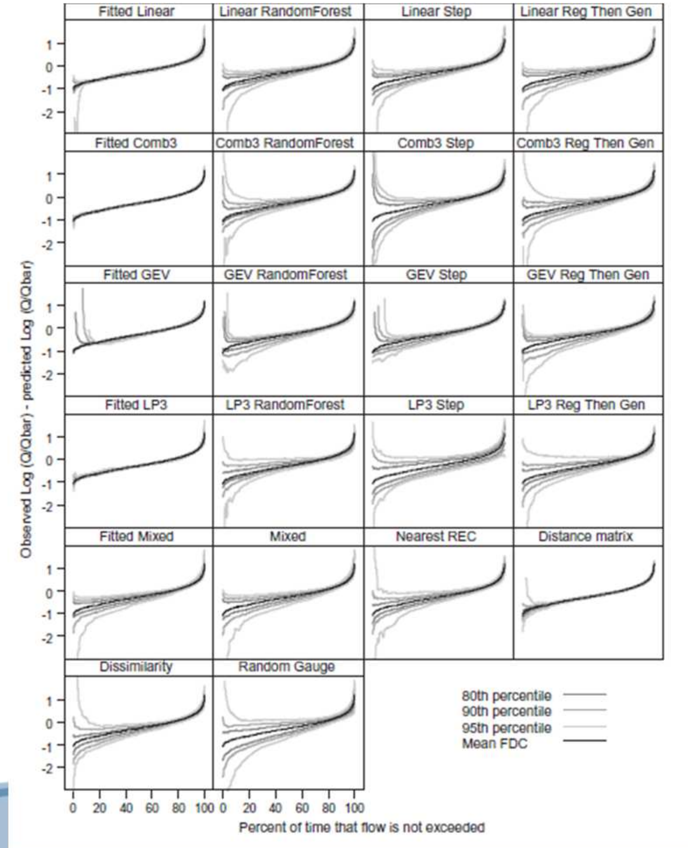
Comparing methods for estimating flow duration curves at ungauged sites

D.J. Booker *, T.H. Snelder

National Institute of Water and Atmospheric Research, PO Box 8602, Riccarton, Christchurch, New Zealand

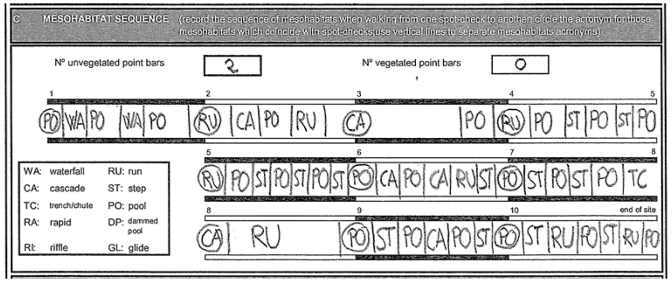
At the moment we are working on the modelling of FDC for the MARCE domain in collaboration with Ton Snelder and Doug Booker (NIWA, New Zealand).

This will be really useful to understand how river networks could be split in order to discriminate different hydrological functioning river reaches with relevance for biological communities



River reach hydraulic classification

We recorded channel unit sequences for 500m river reaches


C MESOHABITAT SEQUENCE (record the sequence of mesohabitats when walking from one spot-check to another; circle the acronym for those mesohabitats which coincide with spot-checks;use vertical lines to separate mesohabitats acronyms)

Nº unvegetated point bars: 2

Nº vegetated point bars: 0

1–5: PO | WA | PO | WA | PO | RU | CA | PO | RU | CA | PO | RU | PO | ST | PO | ST | PO

5–8: RU | PO | ST | PO | ST | PO | ST | PO | CA | PO | CA | RU | ST | PO | ST | PO | ST | PO | TC

8–end of site: CA | RU | PO | ST | PO | CA | PO | ST | PO | ST | RU | PO | ST | RU | PO

WA: waterfall	RU: run
CA: cascade	ST: step
TC: trench/chute	PO: pool
RA: rapid	DP: dammed pool
RI: riffle	GL: glide

Response variables

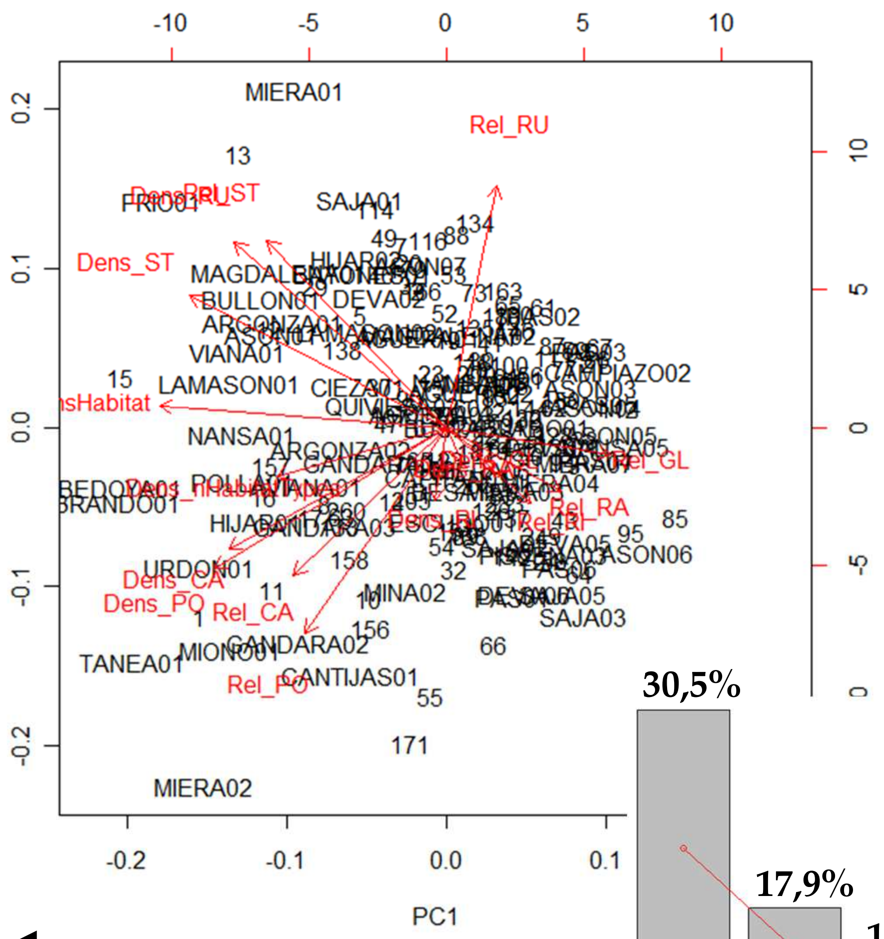
River channel structure and composition was determined by calculating:

- Number of channel units / surveyed length (1 variable)
- Channel unit number of types / surveyed length (1 variable)
- Number of each type of channel unit / surveyed length (7 variables)
- Relative proportion of each channel unit (7 variables)

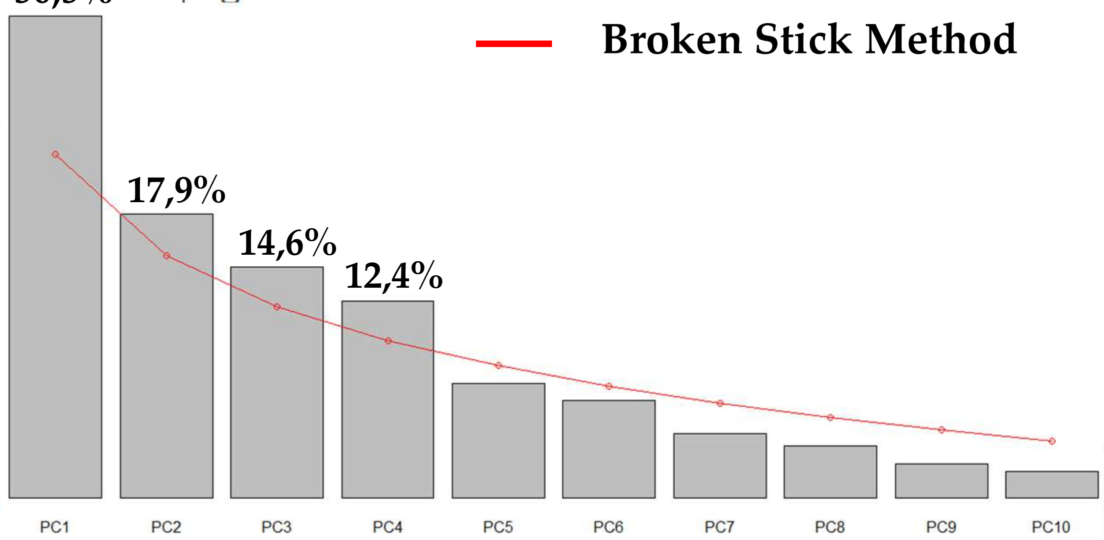
River reach hydraulic classification

ST & RU

PO & CA



Channel unit density (ST, PO, CA and RU)



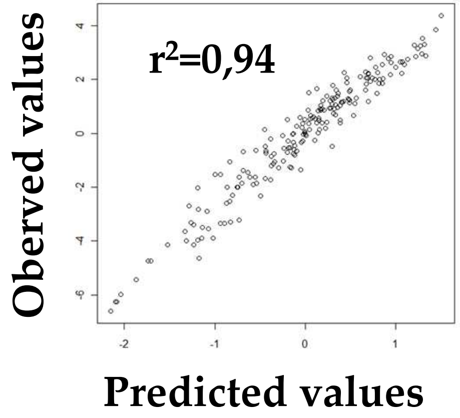
The first 4 PC explained 75% of the variability on river channel structure and composition.

PC3 was correlated with RA (-) and with RI & GL (+).

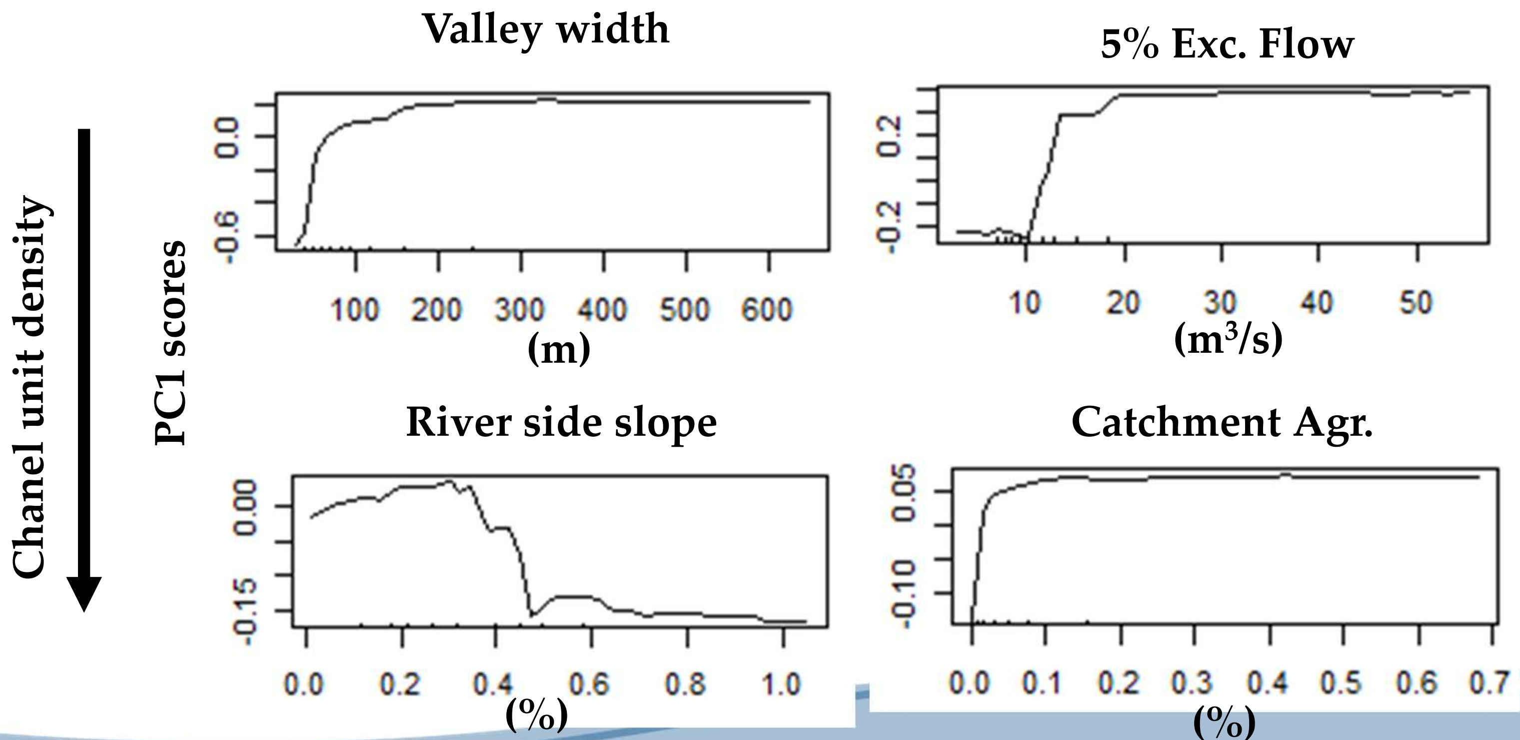
PC4 was correlated with GL (-) and with RI (+).

Broken Stick Method

Random Forest fitted models for PC1

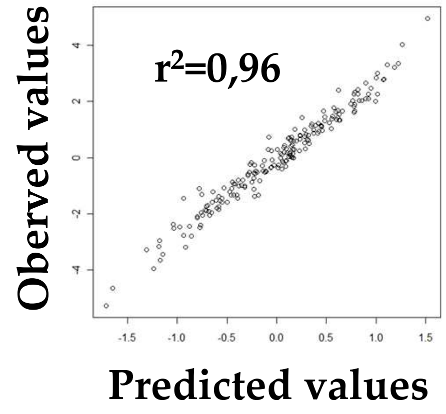


Best predictors for PC1

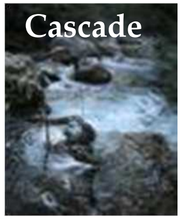


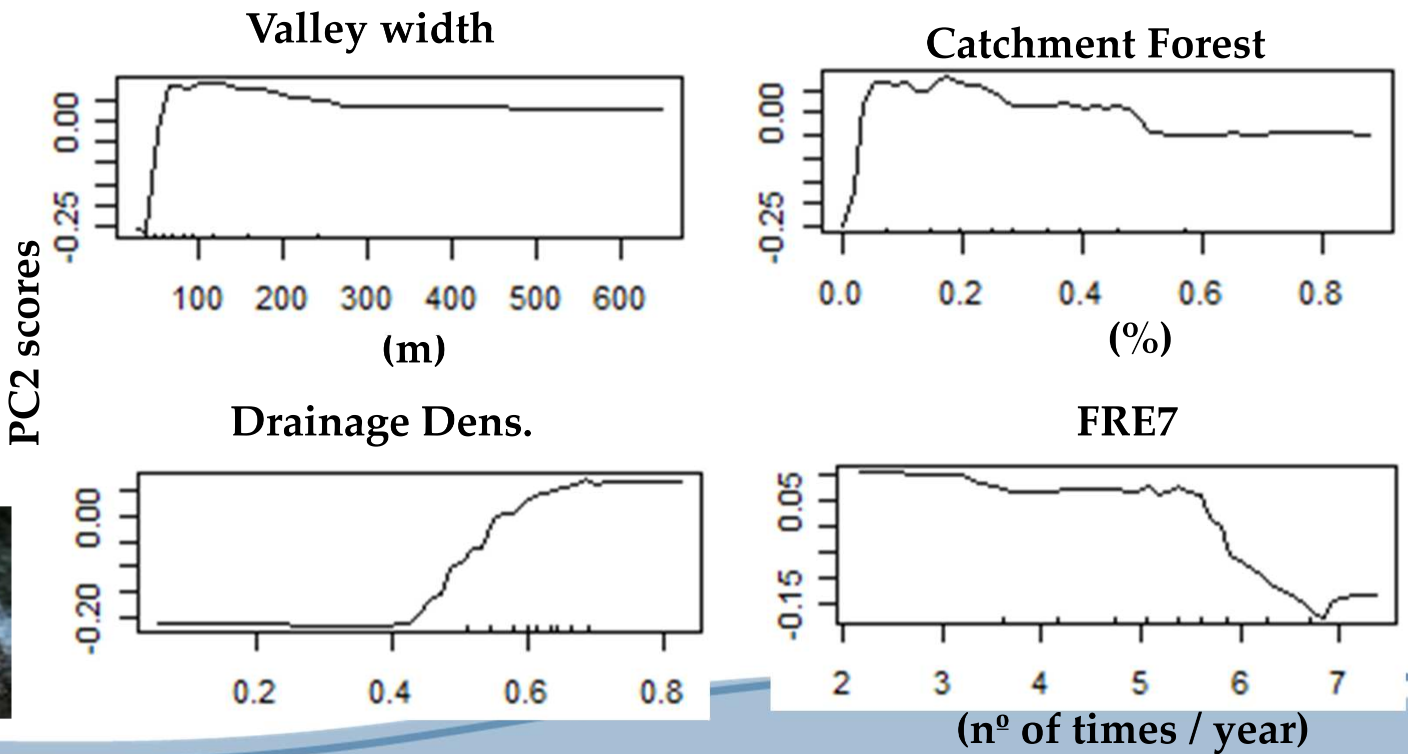
River reach hydraulic classification

Random Forest fitted models for PC2

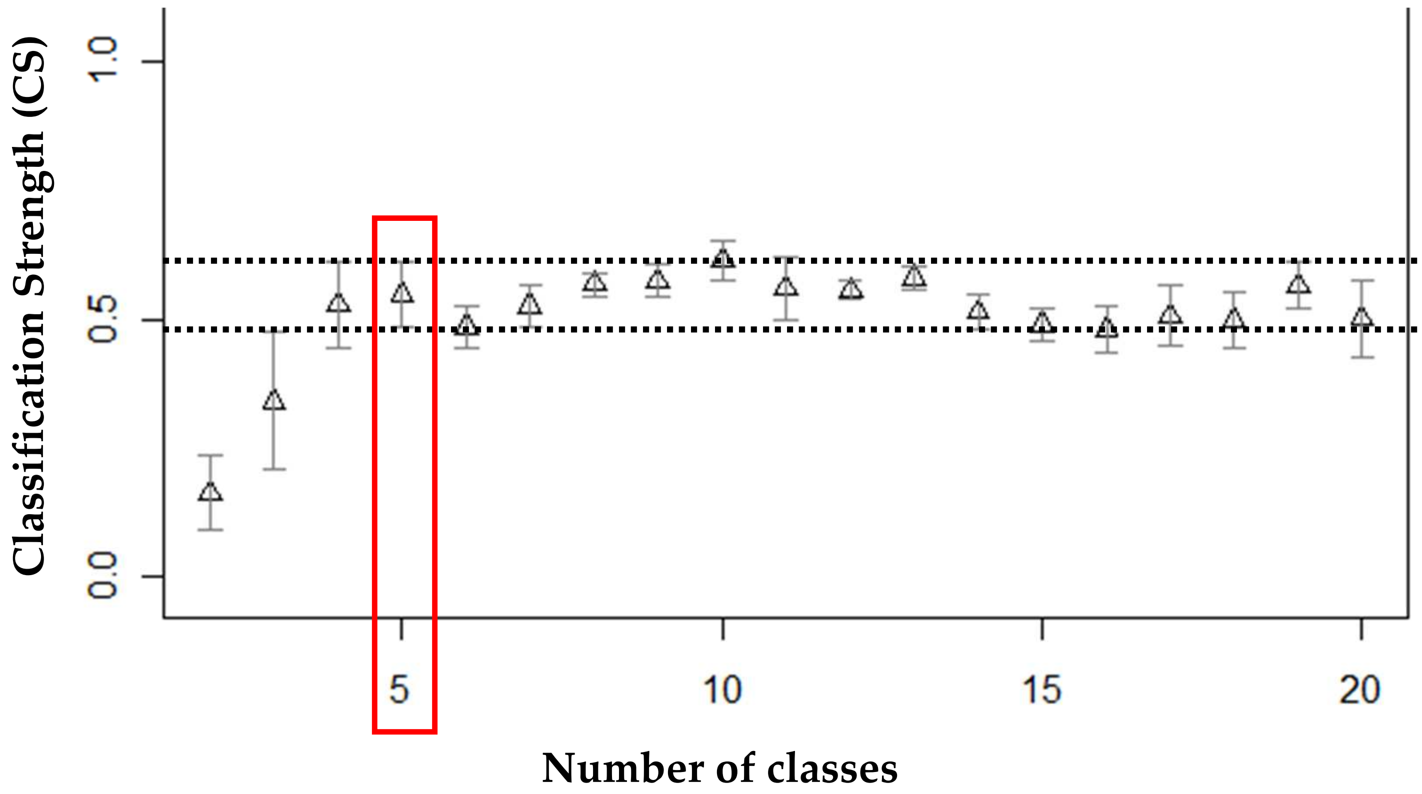


Best predictors for PC2

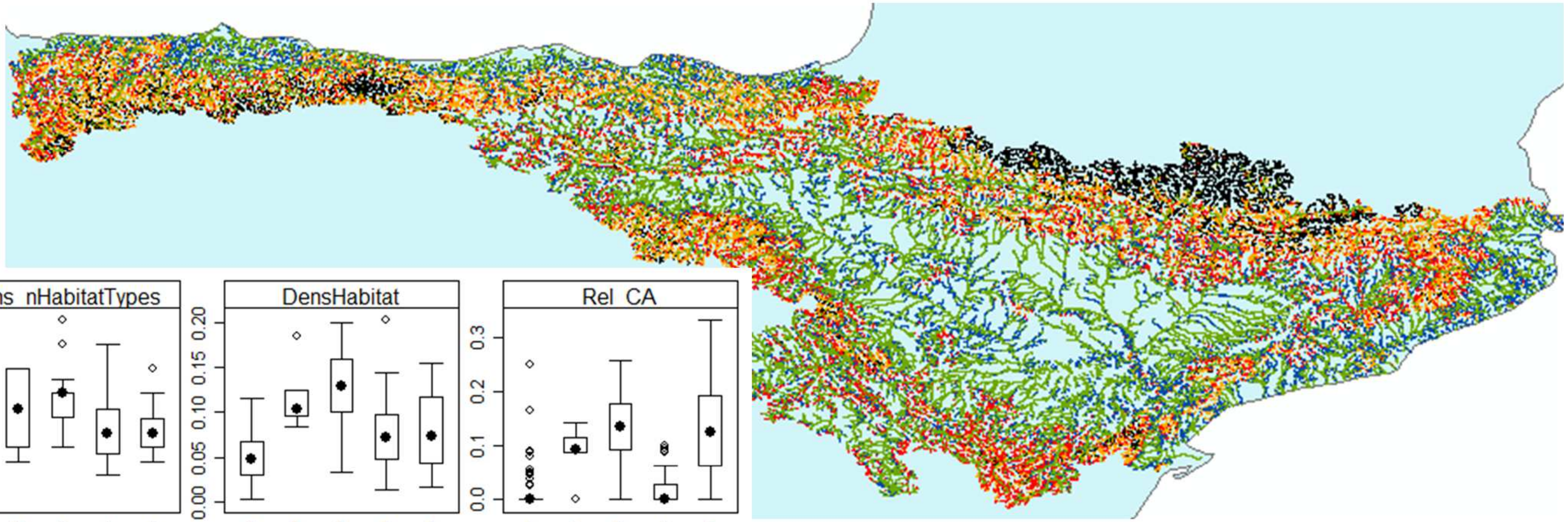


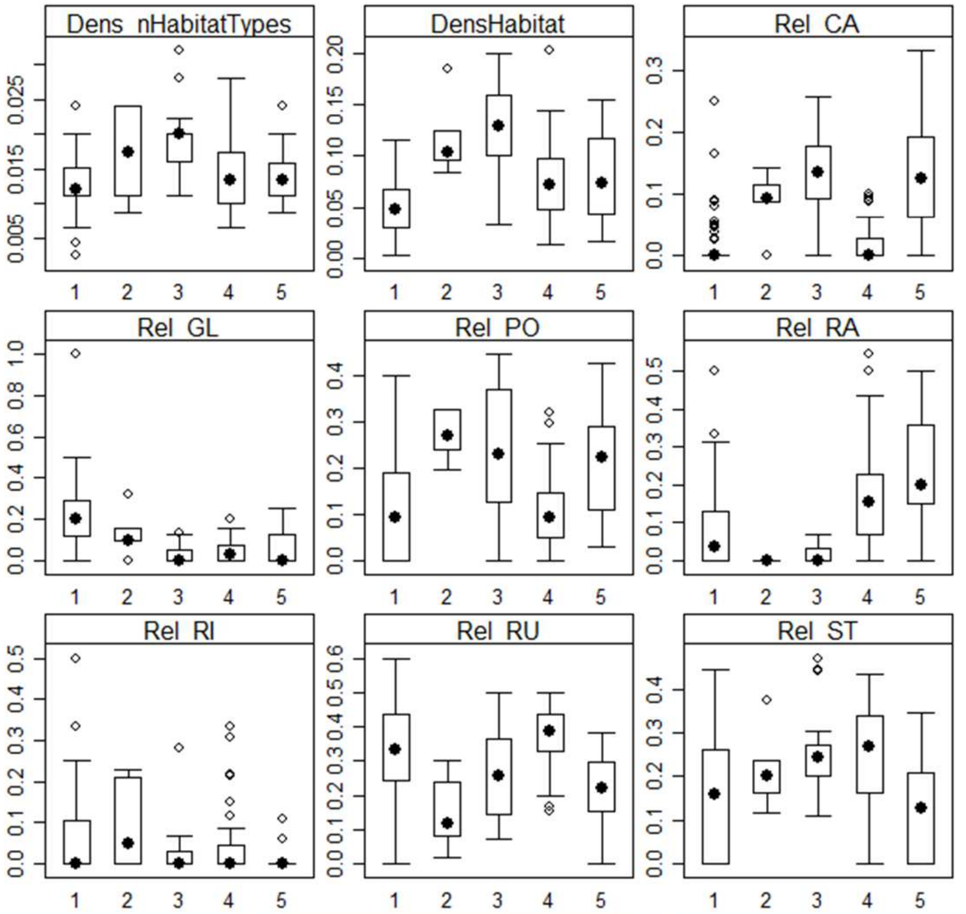


At the 5th level of the classification there is not statistical differences on CS with more subdivisions



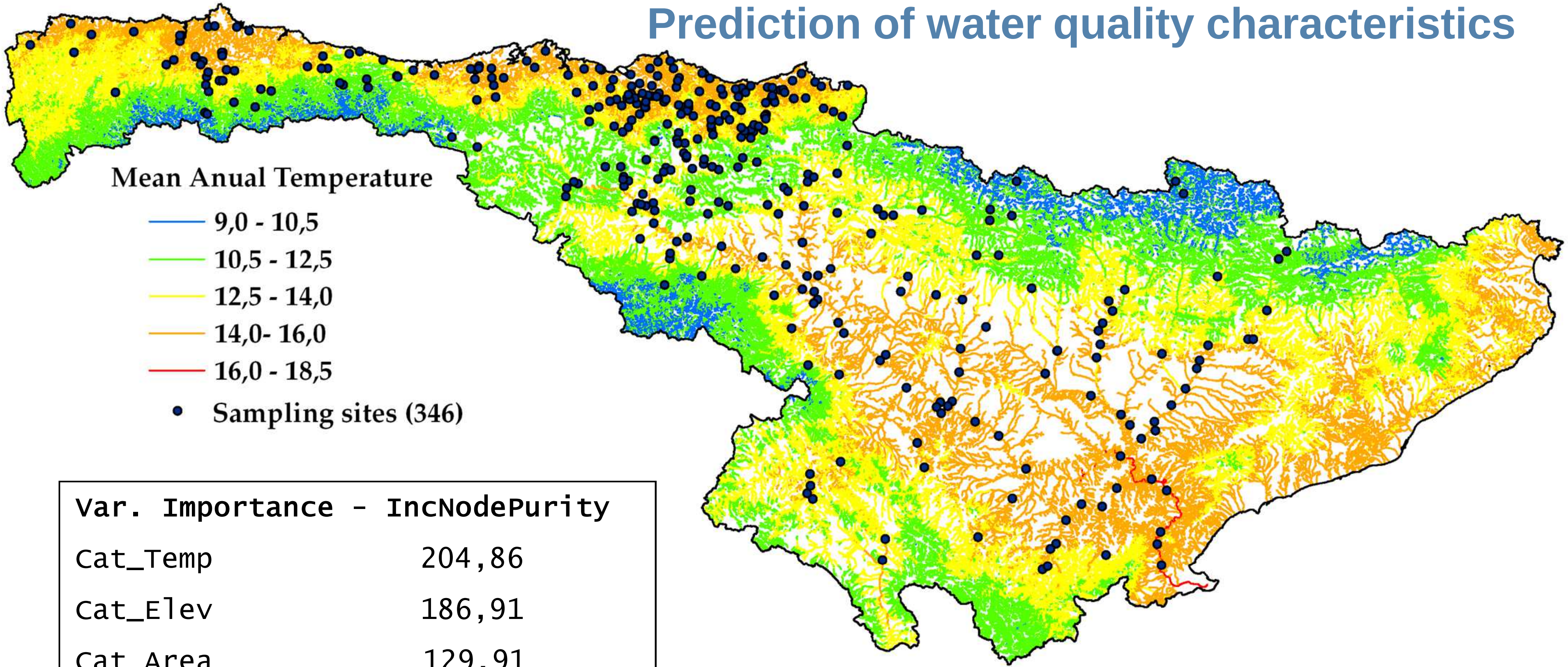
River reach hydraulic classification





At the 5th level of the classification river reach structure and composition changed gradually between types. The two extremes of the classification are represented by type 1 and 5…

Prediction of water quality characteristics



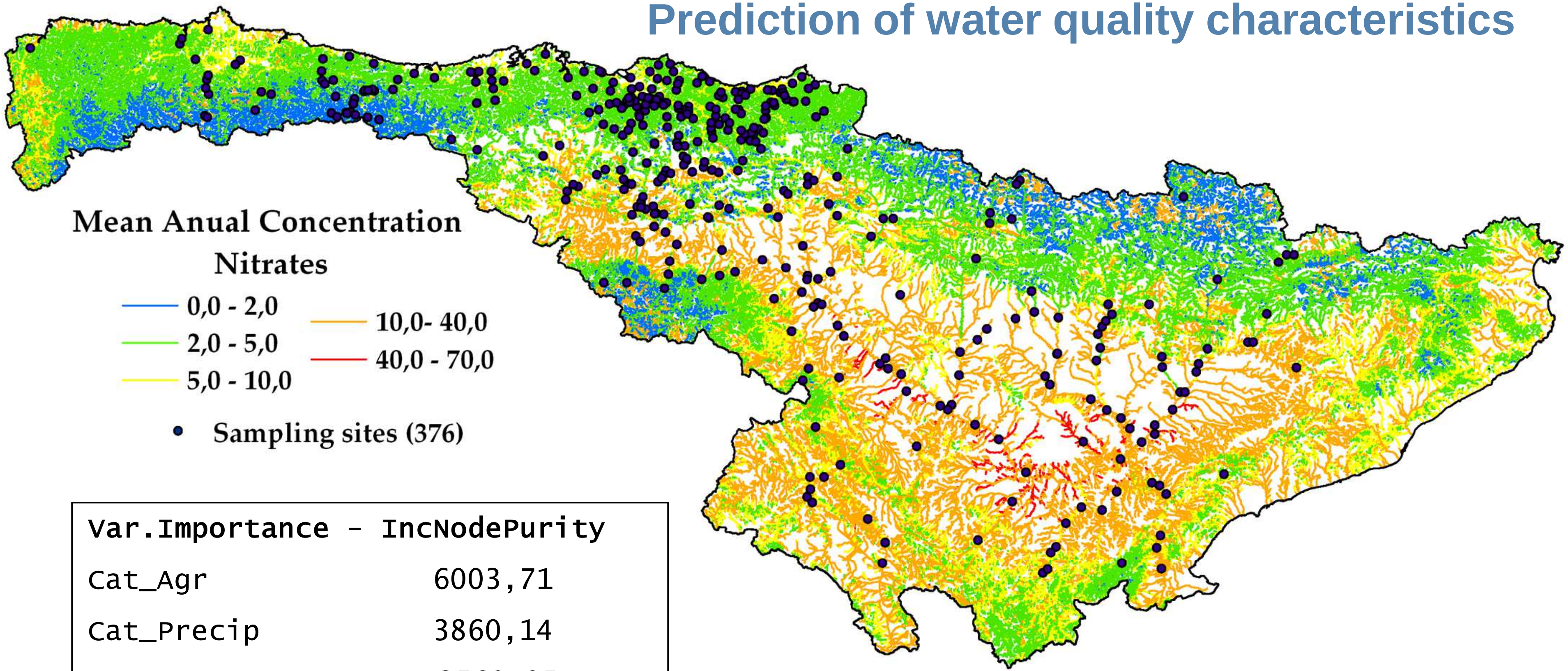
Var. Importance - IncNodePurity	
Cat_Temp	204,86
Cat_Elev	186,91
Cat_Area	129,91
Cat_BlForest	70,56
Mean_Flow	66,70
N_Floods	60,81
Seg_Slope	45,64
Flood_Duration	42,53
Cat_ConifForest	37,77
Pixel_Orientation	35,87

Number of trees: 500; No. of variables tried at each split: 4

Mean of squared residuals: **1,22**

% Var. explained: **55,25**

Prediction of water quality characteristics



Var.Importance - IncNodePurity	
Cat_Agr	6003,71
Cat_Precip	3860,14
Cat_Evapotrans	2560,95
Cat_Urban	1200,60
Cat_Pasture	1078,69
Cat_BlfForest	968,86
Cat_Elev	882,29
Seg_Agr	810,18
Cat_Area	698,63
Mean_Flow	645,74

Number of trees: 500; No. of variables tried at each split: 5

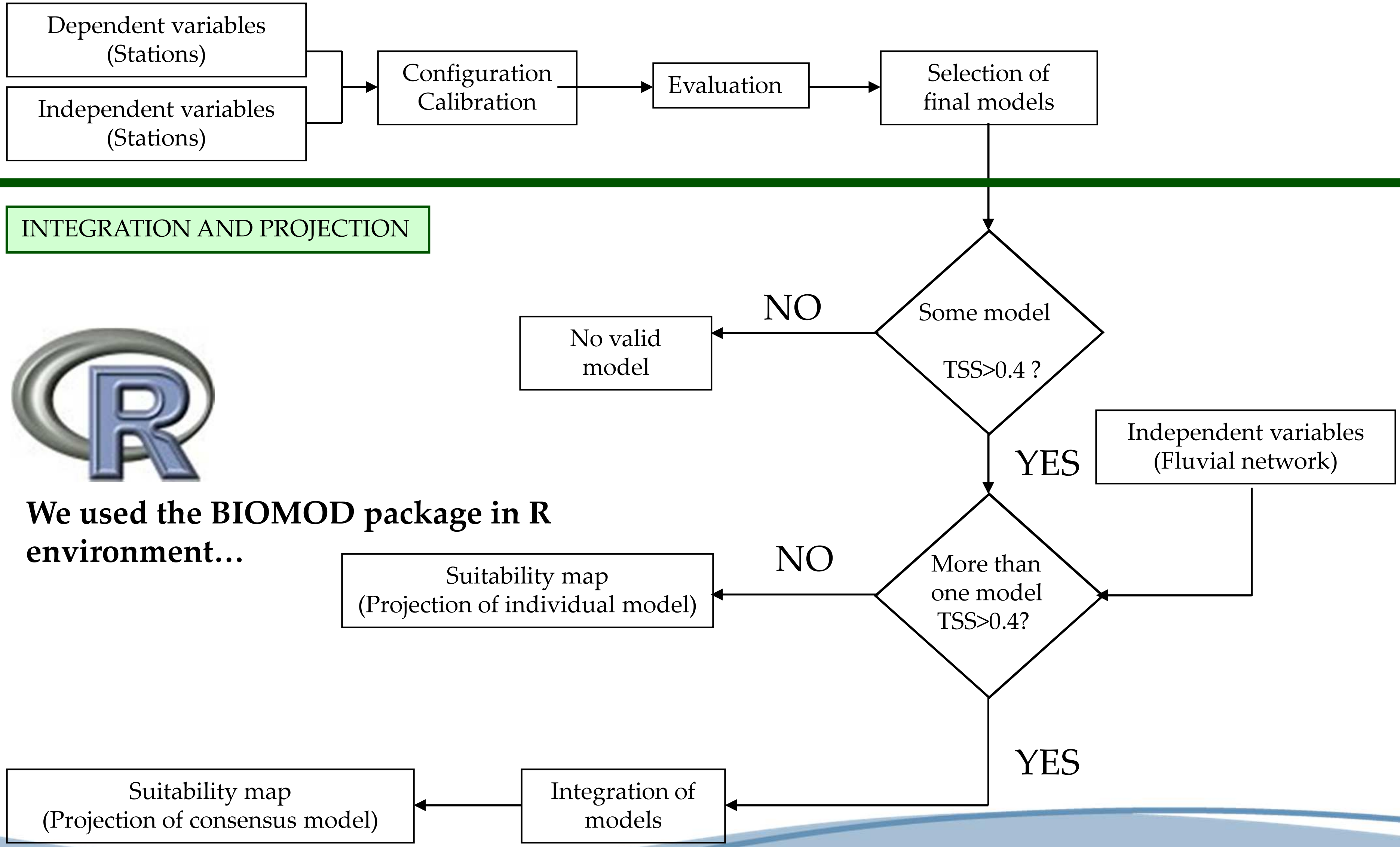
Mean of squared residuals: **36,38**

% Var. explained: **40,59**

Preliminary results on biological modelling…

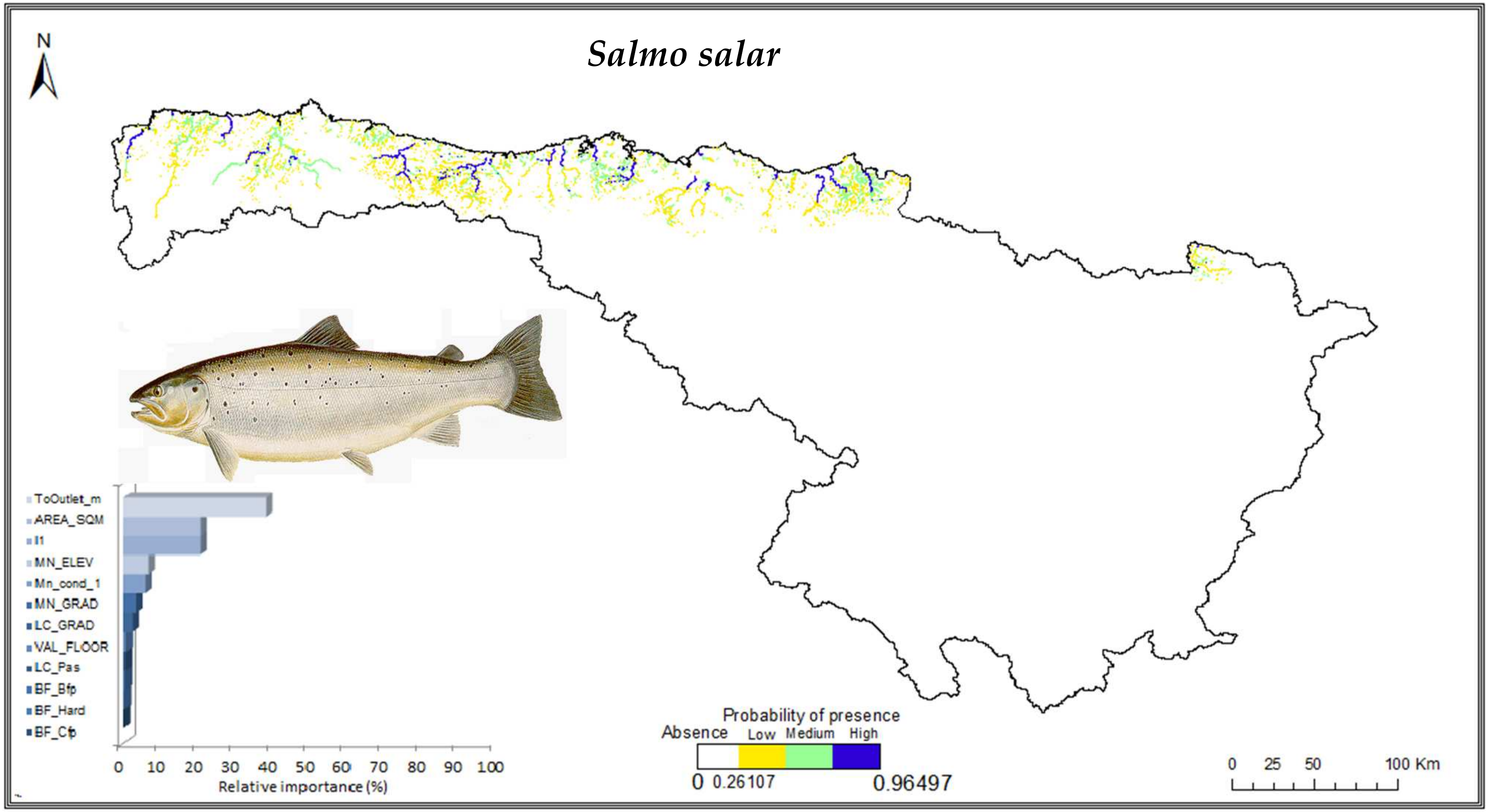
DEVELOPMENT OF INDIVIDUAL MODELS

INTEGRATION AND PROJECTION



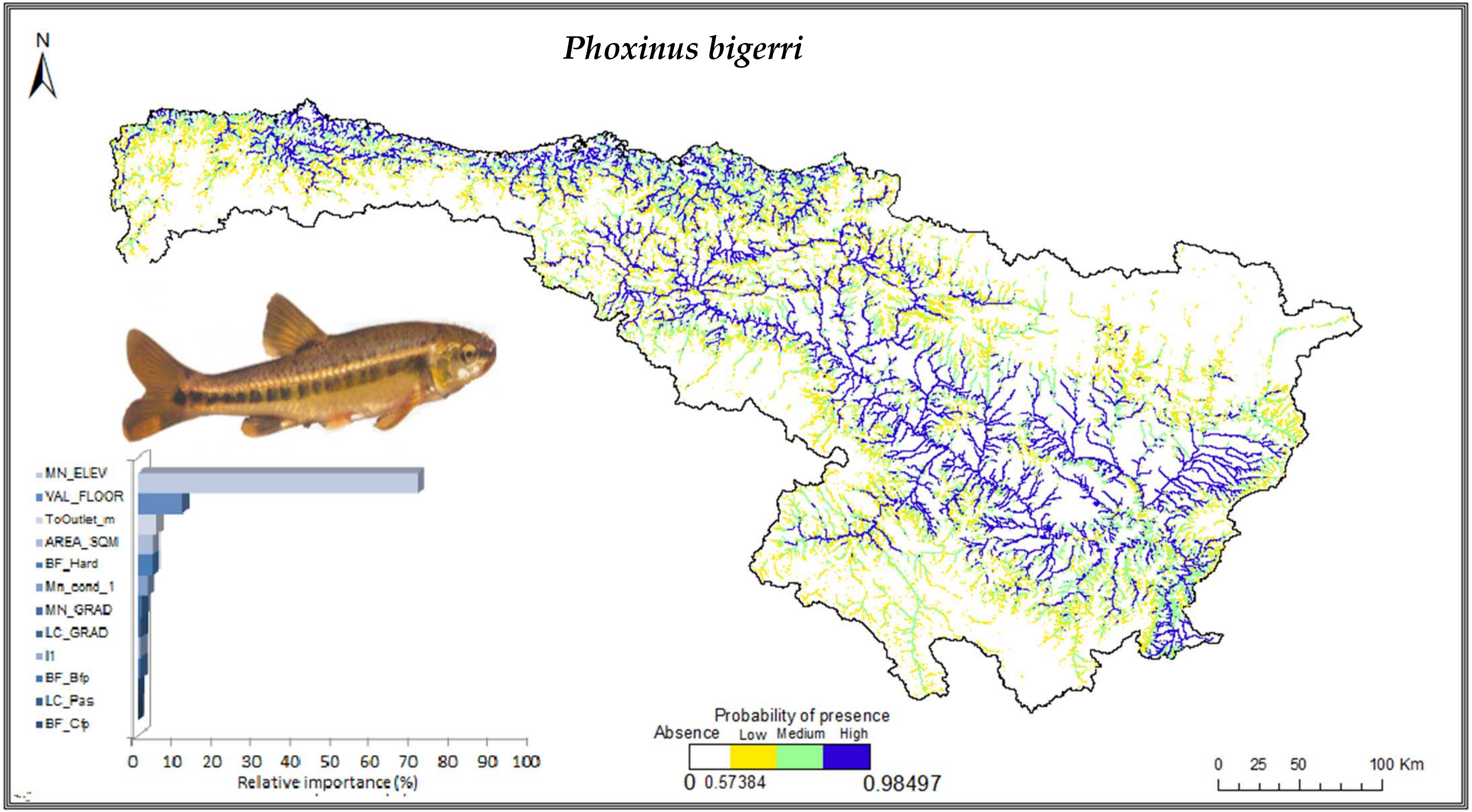
We used the BIOMOD package in R environment…

Preliminary results on biological modelling…



	High probability of presence
ToOutlet_m (km)	0 - 4,386
AREA_SQM (Km²)	0,03 - 1721,84
I1 (m³/s)	2,22 - 19,9

Preliminary results on biological modelling…



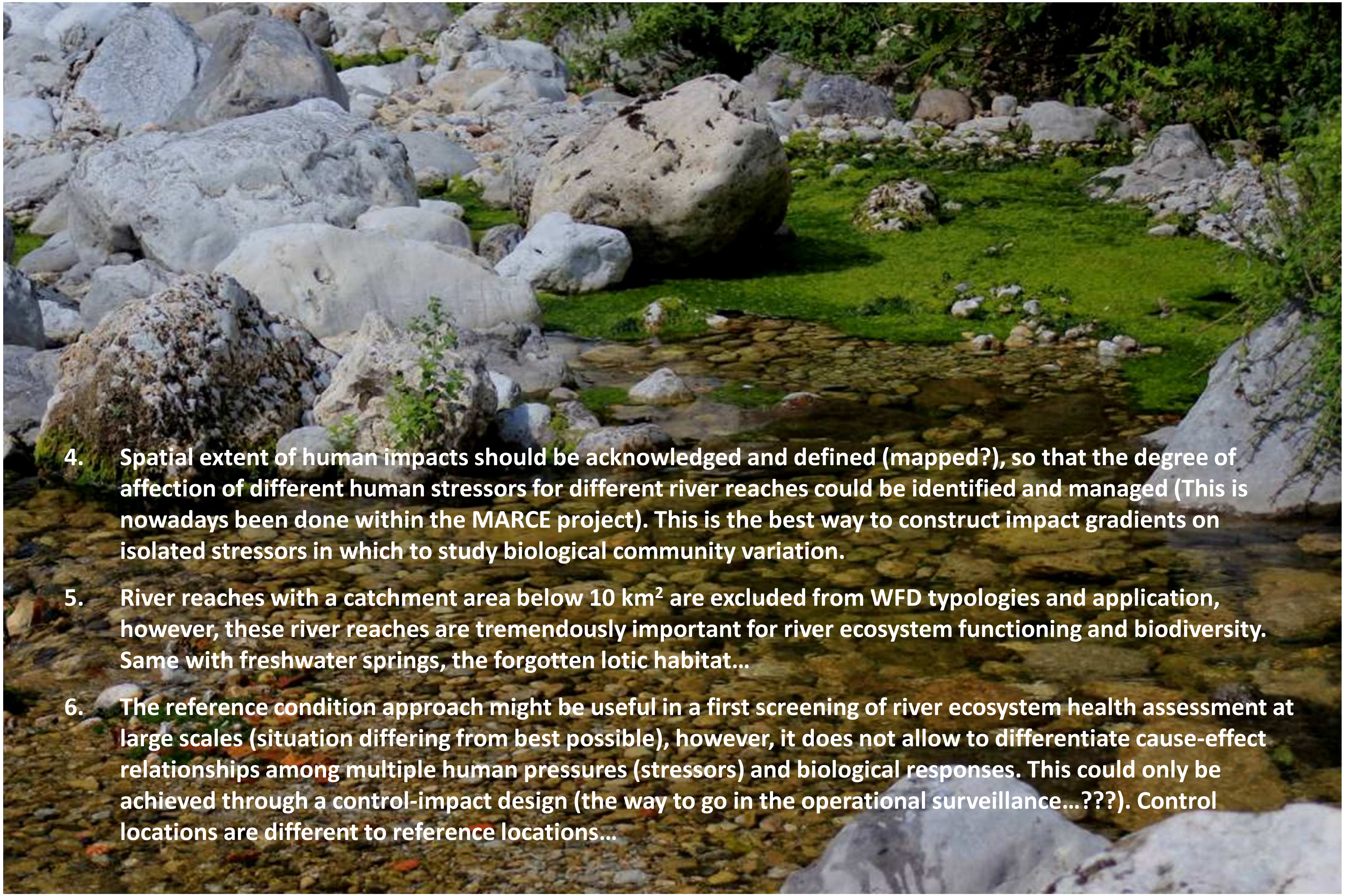
	High probability of presence
MN_ELEV (m)	29,94 - 1624,81
VAL_FLOOR (m)	21,2 - 9356,8

Some thoughts and suggestions derived from the experience acquired in the MARCE & RECORAM (results not presented here) projects:

1. The need to develop long term biological datasets so that hydro morphological databases can be matched to biological databases. This is basic to understand temporal variability of biological communities and its relationship to hydromorphological variability and the role played by rare taxa on ecosystem processes (functional reserves…?)

2. Biological responses to human pressures are habitat dependant (Álvarez-Cabria et al., 2010), therefore, river reach biological data should be collected and kept separately for different hydraulic units (i.e. pools vs runs). This will reduce variability and will help to understand human impacts on biological communities.

3. There is no need to record all taxa (fish, invertebrates or diatoms) from every monitored river reach to assess human impacts. Quantitative samples should be encouraged (pooled samples within mesohabitats!?), or even the use of artificial substrates in order to reduce environmental variability and narrow down the effect of different stressors



4. Spatial extent of human impacts should be acknowledged and defined (mapped?), so that the degree of affection of different human stressors for different river reaches could be identified and managed (This is nowadays been done within the MARCE project). This is the best way to construct impact gradients on isolated stressors in which to study biological community variation.

5. River reaches with a catchment area below 10 km^2 are excluded from WFD typologies and application, however, these river reaches are tremendously important for river ecosystem functioning and biodiversity. Same with freshwater springs, the forgotten lotic habitat…

6. The reference condition approach might be useful in a first screening of river ecosystem health assessment at large scales (situation differing from best possible), however, it does not allow to differentiate cause-effect relationships among multiple human pressures (stressors) and biological responses. This could only be achieved through a control-impact design (the way to go in the operational surveillance…???). Control locations are different to reference locations…