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"Integrated characterization, requalification and monitoring of Mediterranean freshwater systems: the case of the Odelouca River"

NWRM

1º WORKSHOP MEDITERRANEAN WORKING GROUP

28th - 29th January 2014

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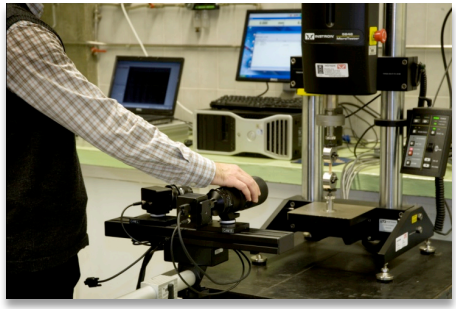
- Applied multidisciplinary research in agriculture and forestry production chains, integrated approaches to protect, improve and maintain ecosystems and promote sustainable natural resource management
  - Vision
    - Address stakeholders needs and contribute to the national economy, by innovative science and technology, and higher input efficiency to improve the competitiveness and sustainability in agriculture and forestry production chains
    - developing integrated approaches to protect, improve and maintain ecosystems and the services they provide and promoting sustainability in natural resource management
  - Mission
    - collaborating and consulting stakeholders, analyze and understand their needs, problems or constraints.
    - Multidisciplinarity and innovation to reply to these needs to create opportunities in national and regional agri-food and forestry production chains and in natural resources management, resulting in more competitive value chains, a better and sustainable environment and more developed societal knowledge.



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Laboratório de Ecologia Fluvial (LEF)

- Research and services
  - Characterisation, monitoring, inventorisation and restoration of aquatic ecosystems and ecosystem services
  - Aquatic fauna
    - macroinvertebrates and fish communities
  - Macrophytes and riparian vegetation
  - hydromorphological conditions
  - Habitat quality
  - River basin planning
  - Establishment and monitoring of environmental flow regimes
  - River restoration measures
    - with special focus on the use of bio-engineering techniques for habitat restoration and riparian buffer zones
    - Adaptation and mitigation measures

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Odelouca River (Algarve, S. Portugal)

- An intermittent Mediterranean river
  - Home to 2 critically threatened endemic fish species
    - Iberian Chub - *Squalius aradensis* (Coelho et al., 1998)
    - Iberian nase *Iberochondrostoma almacai* (Coelho, Mesquita & Collares-Pereira, 2005)
  - Extensive mature riparian galleries
- Demand for water
  - Tourism, development
- Partially built dam completed and inaugurated in 2010
  - Valuable riparian galleries - flooded area
  - Mandatory compensatory restoration measures
    - offset construction impacts and loss of habitat

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Objectives

- Erosion control
  - stabilize river banks
- Improve structure of riparian vegetation
- Replace exotic plant species with native species
- Improve physical heterogeneity in the river channel
  - promote biodiversity
  - protect two endemic fish cyprinid species

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Requalification of the River Odelouca (Algarve Portugal)

- An integrated approach
  - Characterise and identify environmental gradients and drivers of change
    - Basin, reach, habitat
  - Identify Habitat quality/heterogeneity
  - Identify suitable indicator organisms to assess the success of requalification measures
  - Test restoration / rehabilitation scenarios
  - Implement and monitor programme of measures

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Participants in the Odelouca Project

- University of Trás-os-Montes e Alto Douro
  - CITAB
  - Fluvial Ecology Lab
- University of Lisbon
  - Instituto de Agronomia
- Águas do Algarve, S.A.

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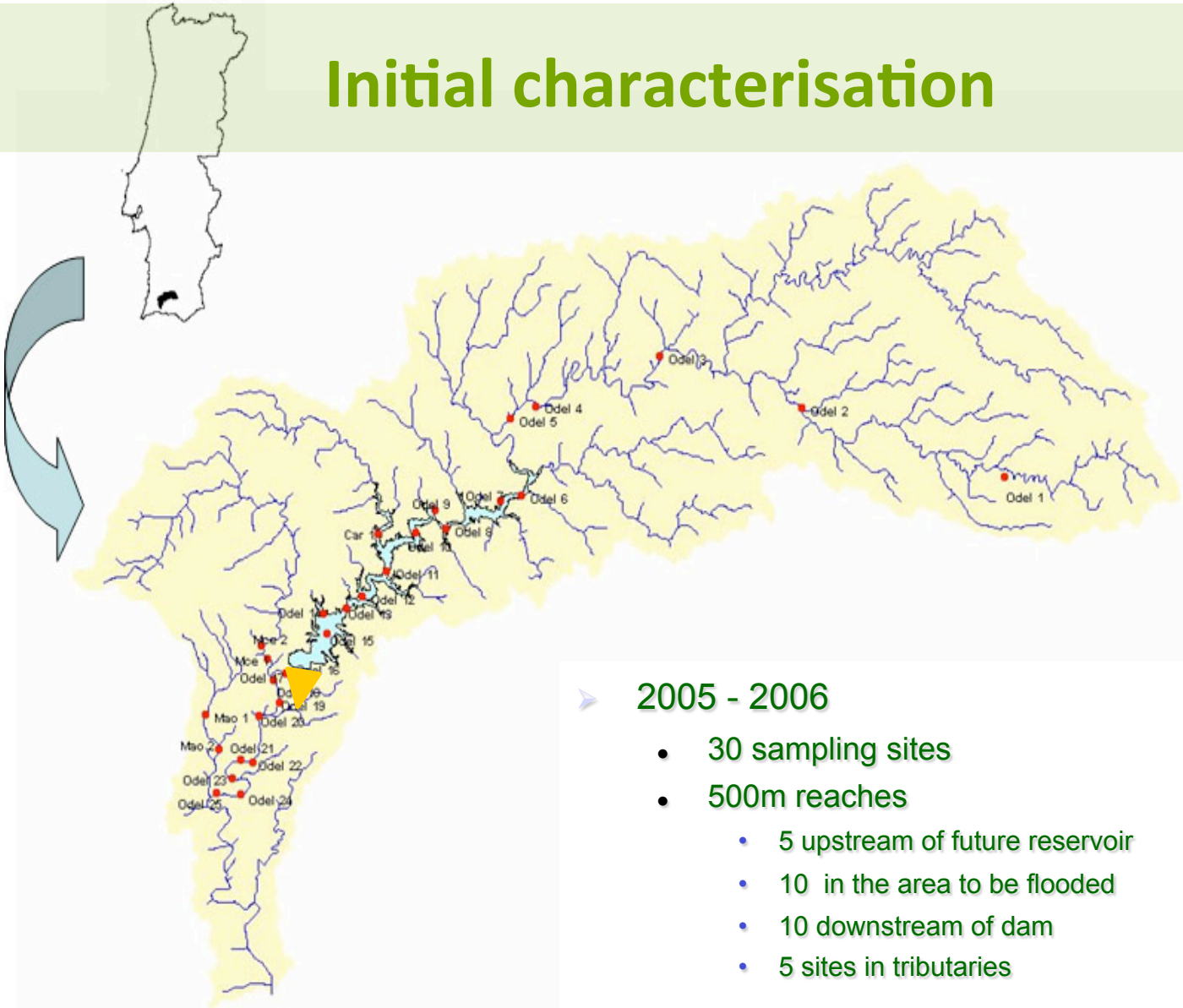
Initial characterisation



- 2005 - 2006
  - 30 sampling sites
  - 500m reaches
    - 5 upstream of future reservoir
    - 10 in the area to be flooded
    - 10 downstream of dam
    - 5 sites in tributaries

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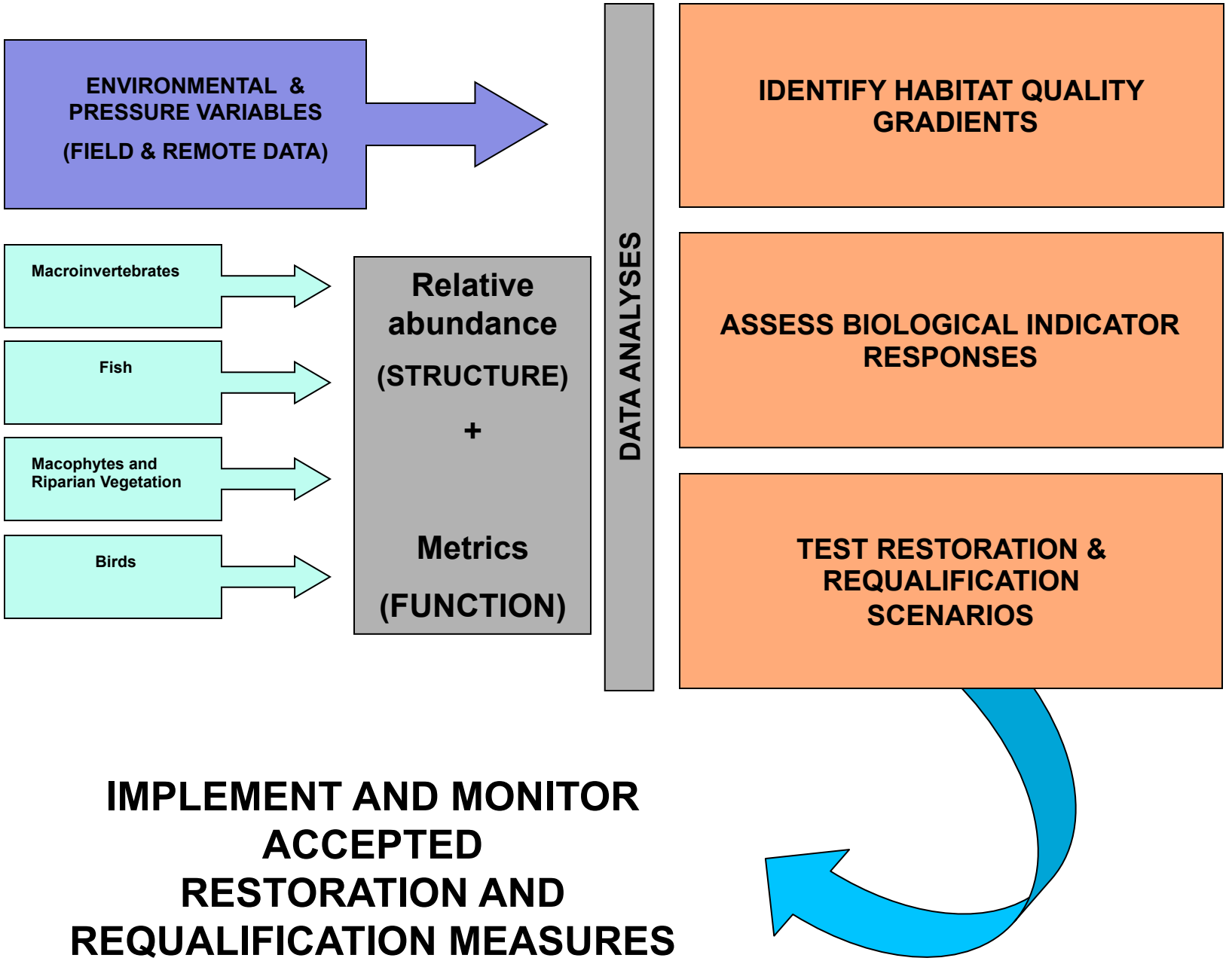

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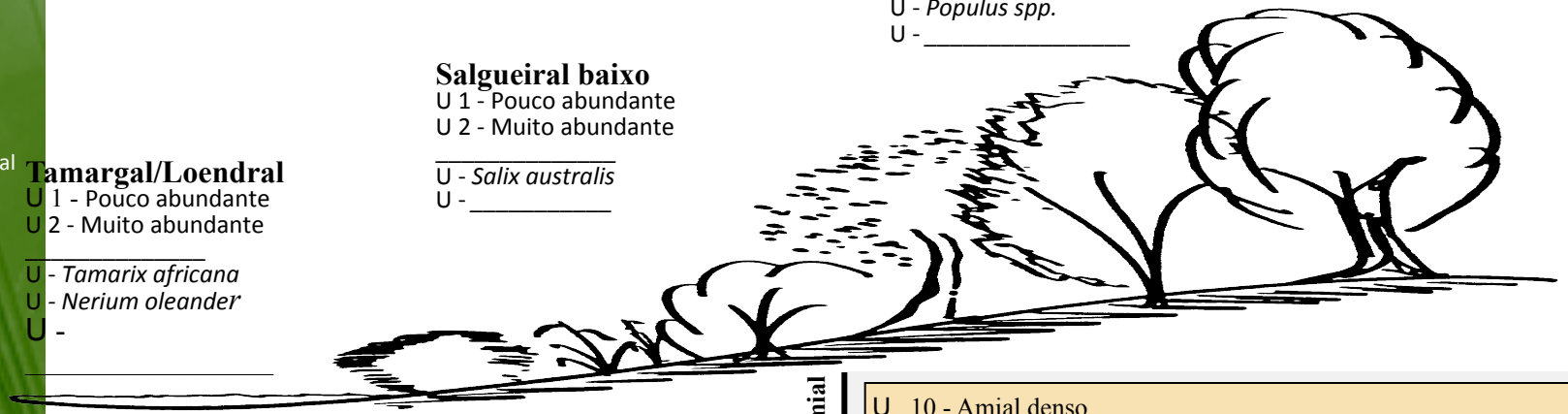
Salgueiral alto
U 1 - Pouco abundante
U 2 - Muito abundante
_____
U - *Salix atrocinerea*
U - *Salix alba*
U - *Populus spp.*
U - _____

Salgueiral baixo
U 1 - Pouco abundante
U 2 - Muito abundante
_____
U - *Salix australis*
U - _____

Tamargal/Loendral
U 1 - Pouco abundante
U 2 - Muito abundante
_____
U - *Tamarix africana*
U - *Nerium oleander*
U - _____



Freixial

- U 10 - Freixial denso dominante
- U 5 - Freixial aberto + juncais e pastagens húmidas (com *Scirpus holoschoenus* e *Juncus effusus* + *Agrostis stolonifera* + *A. pourretii*)
- U 1 - Silvado + *Oenanthe crocata* + *Juncus inflexus* ou *Salix australis* secundário
- U 0 - Rapado, com ruderais

Salgueiral alto

- U 10 - Salgueiral denso
- U 5 - Salgueiral aberto + juncais e pastagens húmidas (com *Scirpus holoschoenus* e *Juncus effusus* + *Agrostis stolonifera* + *A. pourretii*)
- U 1 - Silvado + *Juncus inflexus* + *Oenanthe crocata* + *Apium graleolens* (juncal invadido e ruderalizado)
- U 0 - Rapado, com ruderais

Amial

- U 10 - Amial denso
- U 5 - Amial aberto + *Salix australis*
- U 1 - Comunidades da *Magnocarici-Phragmitetea*
- U 0 - Rapado, com ruderais

Salgueiral baixo

- U 5 – *Salix salviifolia* subsp. *australis*
- U 1 - Comunidades de *Thypha*, *Phragmites*, *Sparganium*, *Iris*, *Scirpus lacustris* ssp. *lacustris* (*Magnocarici-Phragmitetea*)
- U 0 - Rapado, com ruderais

Tamargal

- U 5 - *Polygono-Tamariceto*
- U 1 - *Paspalum paspalodes* + *Cynodon dactylis*
- U 0 - Rapado, com ruderais

Valor Global:

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RHS Survey Format

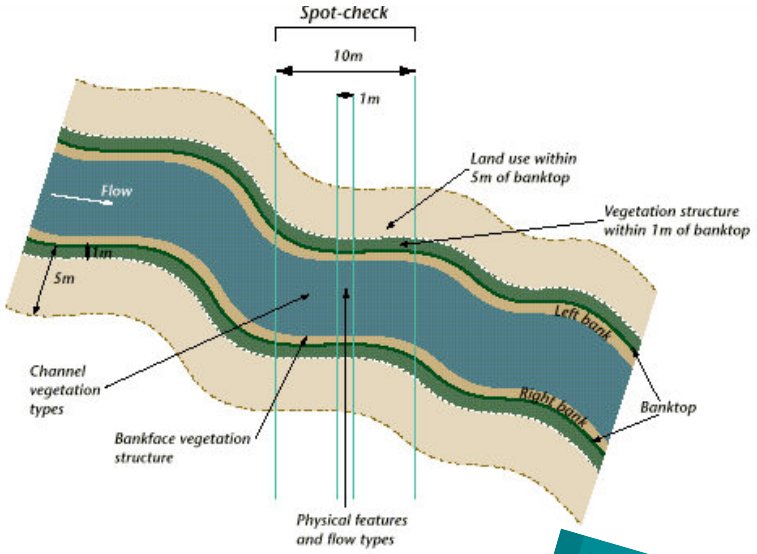
- 500m reach
- Two main sections

SPOT-CHECKS

- 10 equally spaced transects (50m)

SWEEP-UP

- summary data for whole reach



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Habitat Quality Assessment and Habitat Modification Score

Table 1. List of the recorded RHS features used to derive the Habitat Quality Assessment (HQA) and Habitat Modification Score (HMS) indices

Recorded feature	Basis for attribution of HQA score
Flow type	Diversity of flow types
Substrate (river bed)	Predominant natural substrate types
Channel features	Presence and extent of recorded 'natural' features, e.g. exposed bedrock and boulders, vegetated rock
Bank features	Presence and extent of recorded 'natural' features, e.g. eroding cliff, point and side bars
Bank vegetation	Presence and complexity of vegetation
Point bars	Count of total number of point bars along reach
Instream vegetation	Number of types of vegetation present in the stream (filamentous algae do not score)
Land use within 50 m	Broadleaf woodland, native pinewood, moorland/heath and wetlands
Trees and associated features	Tree density and continuity; presence of associated features (hanging boughs, exposed bank-side roots, coarse woody debris, fallen trees)
Special features	Waterfall > 5 m high, braided or side channel, debris dams, natural open water
Recorded feature	**Basis for attribution of HMS score**
Reinforcement	Presence: bank or bed, partial or whole
Resectioning	Presence: bank or bed, partial or whole
Two-stage bank modification	Presence
Embankment	Presence
Poaching of bank	Presence (livestock or humans)
Set-back embankment	Presence
Two-stage channel	Presence
Plant management	Evidence of weed-cutting or bank-mowing
Culvert	Presence (major)
Dam, weir, ford	Presence (minor, intermediate or major)
Bridges	Presence (minor, intermediate or major)
Enhancements	E.g. presence of groynes (minor, intermediate or major)
Flow control	Site partially (<33%) or extensively (> 33%) affected
Realignment of channel	Site partially (<33%) or extensively (> 33%) affected

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Table 1 Environmental (E) and pressure (P) variables divided over three spatial scales (basin, reach and habitat) retained for subsequent statistical analyses after analysis for redundancy by comparing average Spearman Correlation Coefficients

Variable and spatial scale				Unit/expression	Data source
Basin					
E	1	Channel form	(CHAN_F)	1 = sinuate, 2 = constrained	GIS
E	2	Valley form	(VALFRM)	Class 0–4	GIS
P	1	Urban Area	(URB_A)	% Catchment area	GIS
P	2	Monocultures	(MONO_A)	% Catchment area	GIS
P	3	Agriculture	(AGRI_A)	% Catchment area	GIS
Reach					
E	3	Altitude	(ALT)	m.a.s.l	GIS
E	4	Number of bars	(BARS)	Count	RHS data
E	5	Average riparian width	(WDTRIP)	Metres	RHS data
E	6	Subchannels	(SUBCH)	Count	RHS data
E	7	Land use natural/semi-natural	(LU250_NAT)	Dummy variable	GIS 250 m bankside buffer
E	8	Land use scrub	(LU250_SCR)	Dummy variable	GIS 250 m bankside buffer
E	9	Average bank top height	(AVBKTP)	Metres	RHS data
P	1	Bank reinforced	(BK_RI)	Dummy variable	RHS data
P	2	Bank embanked	(BK_EM)	Dummy variable	RHS data
P	3	Land use agriculture	(LU250_AGR)	Dummy variable	GIS 250 m bankside buffer
P	4	Presence of Ford	(FORD)	Presence/absence	RHS data
P	5	Tipped debris	(TIP_D)	Presence/absence	RHS Data
P	6	Land use urban	(LU25 0_UR)	Dummy variable	GIS 250 m bankside buffer
P	7	Organic point discharge	(ORGP)	Count	GIS
Habitat					
E	10	pH	(PH)	Sorensen scale	Fish sampling site
E	11	Dissolved oxygen	(DO)	mg/l	Fish sampling site
E	12	Water velocity	(WVEL)	m s^{-1}	Macroinvertebrate sampling site
E	13	Conductivity	(COND)	µS/cm	Macroinvertebrate sampling site
E	14	Boulder/stone substrate	(BOLSTONB)	Visual estimate	Macroinvertebrate sampling site
E	15	Boulder/stone substrate	(BOLSTONF)	Visual estimate	Fish sampling site
E	16	Depth	(DEPTB)	Metres	Macroinvertebrate sampling site
E	17	Depth	(DEPTF)	Metres	Fish sampling site
E	18	Water temperature	(W_TEMPF)	° Celsius	Fish sampling site
E	19	Sand/silt substrate	(SASIC)	Visual estimate	Fish sampling site
E	20	Gravel substrate	(GRAV)	Visual estimate	Fish sampling site
P	8	Bank modification	(BNK_MOD)	Visual estimate	RHS/sample site
P	9	Channel modification	(CH_MOD)	Presence of features such as culverts, weirs or sluices	RHS/sample site
P	10	Banktop landuse agriculture	(BT_AG10)	Class	10 m bankside buffer
P	11	Banktop landuse pasture	(BT_RP10)	Class	10 m bankside buffer
P	12	Banktop landuse forestry	(BT_FR10)	Class	10 m bankside buffer

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Principal Components Analyses

- Environmental gradients
  - Scale-dependent longitudinal differences
    - separate narrower higher lying sites and tributaries with good quality habitats from more open degraded sites lower downstream.
  - Large scale pressures describing changes in land use
    - related to agriculture with associated physical impacts to bank side and channel

	ENVIRONMENT			PRESSURE		
		Axis 1	Axis 2		Axis 1	Axis 2
BASIN	VALLEY FORM	1	0.004	MONOCULTURE	**-0.963**	0.19
				AGRICULTURAL LAND-USE	-0.281	**-0.95**
REACH	ALTITUDE	**-0.712**	0.650	BANK REINFORCED	0.511	-0.38
	DEPOSITION BARS	**0.655**	**0.613**	BANK EMBANKED	**0.845**	0.50
	RIPARIAN WIDTH (M)	**-0.772**	0.013			
	NATURAL LAND-USE	-0.526	0.241			
HABITAT	WATER VELOCITY	**-0.749**	**-0.660**	BANK MODIFICATION	**0.659**	**0.713**
	pH	**-0.800**	0.599	BANK TOP - AGRICULTURE	-0.068	0.578
				BANK TOP - PASTURE	**0.888**	-0.427

Hughes SJ, Santos JM, Ferreira MT, Caraça R, Mendes AM, (2009) Freshwater Biology. 54, 2383–2400.
Hughes SJ, Santos JM, Ferreira TM, Mendes A M (2010) Environmental Management. 46(2): 285-301.

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Habitat quality gradients

- KT Method
  - Identify and group similar fluvial reaches
    - **H**omogenous **P**hysiogeographical **U**nits
      - » Geographic and hydrogeomorphological variables
        - » Hierarchy (Strahler), geology, precipitation & altitude
  - Assess units - presence of anthropogenic pressures (K_i)
    - Urban area, roads, point source pollution, agricultural land use, hydromorphological alteration
  - Conservation index (KT)
    - $KT = \sum Ki \,/\, nKi$

Cortes R, Oliveira S, Cabral D, Santos S, Ferreira MT (2002). Archives für Hydrobiology, 13: 209-224.

Fernandes MR, Ferreira MT, Hughes SJ, Cortes RV, Santos JM, Pinheiro P (2007). Recurso Hídricos. 28(3): 15-24

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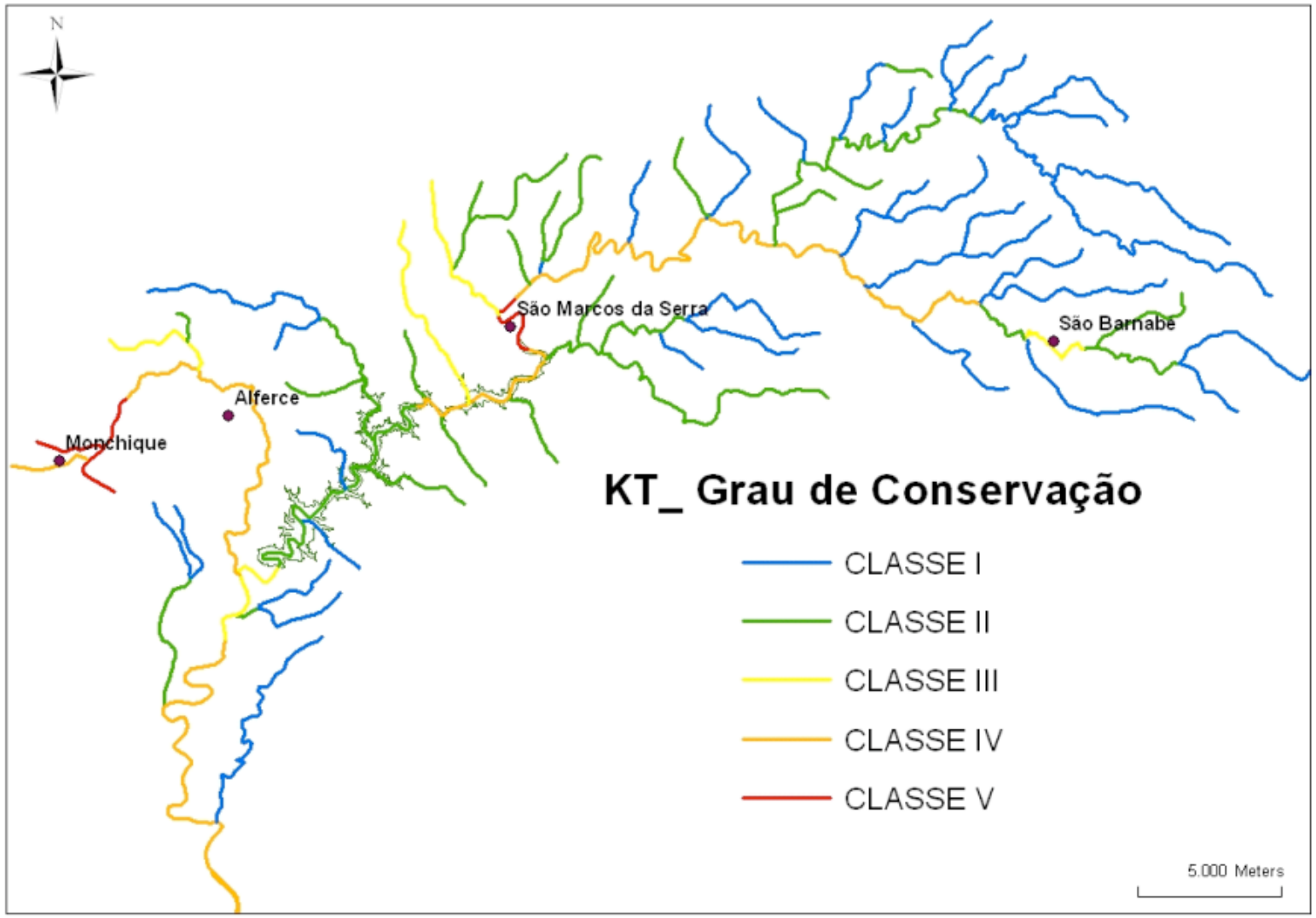

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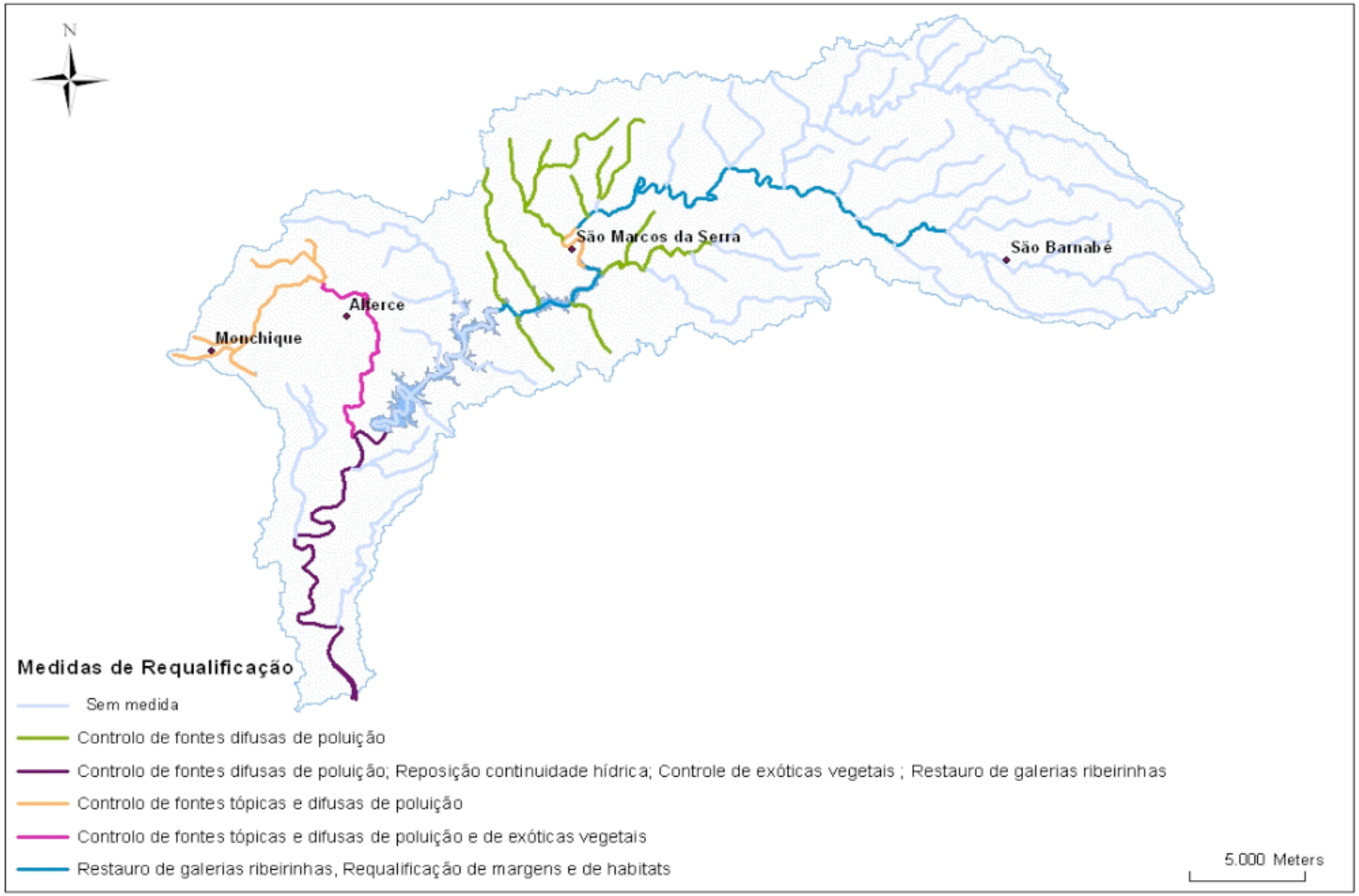
Using KT to Develop Appropriate Requalification Measures



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Identifying indicators

- What are organism groups responding to?
  - Natural or pressure gradients
- Structure or function?
  - Benthic macroinvertebrates
  - Fish
  - Birds
  - Macrophytes

Hughes SJ, Santos JM, Ferreira MT, Caraça R, Mendes AM, (2009) Freshwater Biology. 54, 2383–2400.
Hughes SJ, Santos JM, Ferreira TM, Mendes A M(2010) Environmental Management. 46(2): 285-301.

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Indicator organisms

- Fish and birds
  - Large, mobile organisms
    - good links with physical disturbance and key environmental variables
- Macroinvertebrates
  - Flow regime

Hughes SJ, Santos JM, Ferreira MT, Caraça R, Mendes AM, (2009) Freshwater Biology. 54, 2383–2400.
Hughes SJ, Santos JM, Ferreira TM, Mendes A M(2010) Environmental Management. 46(2): 285-301.

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Restoration scenarios

- Habitat suitability curves (HSC)
  - target species
    - Iberian nase *Iberochondrostoma almacai*
    - Iberian chub *Squalius aradensis*
  - juveniles and adults
- Weighted usable area (WUA)
  - quantity of area suitable for habitat
    - depth, velocity and substrate suitability indexes.
- 5 potential habitat enhancement scenarios
  - River 2D
  - Discharge values 0.1 - 8.0 m^3/s,
    - range of the ecological flow regime to be released by the dam

Boavida I, Santos JM, Lourenço J, Cortes R, Ferreira MT, Pinheiro A, (2008). 4th ECRR Conference on River Restoration Italy.

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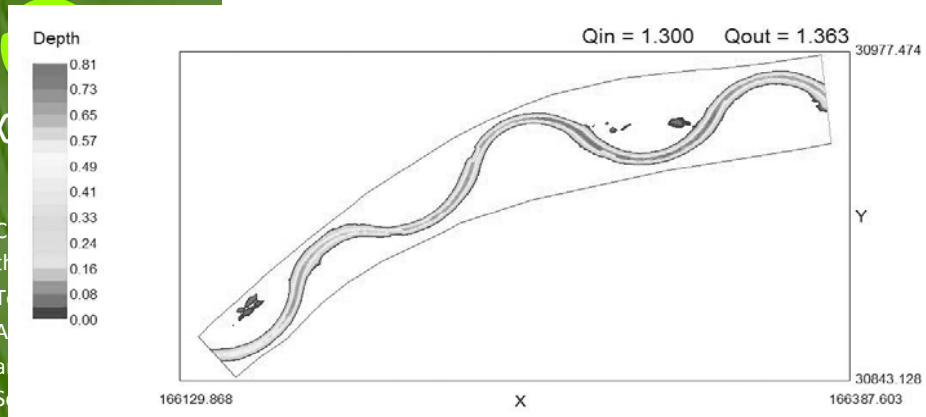
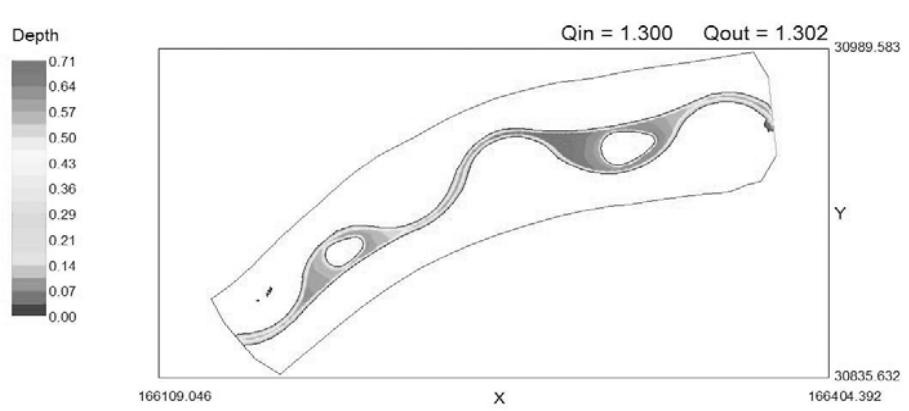
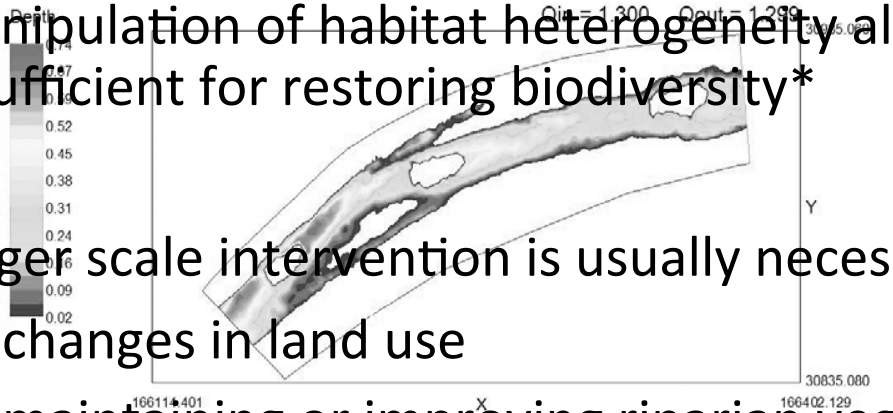
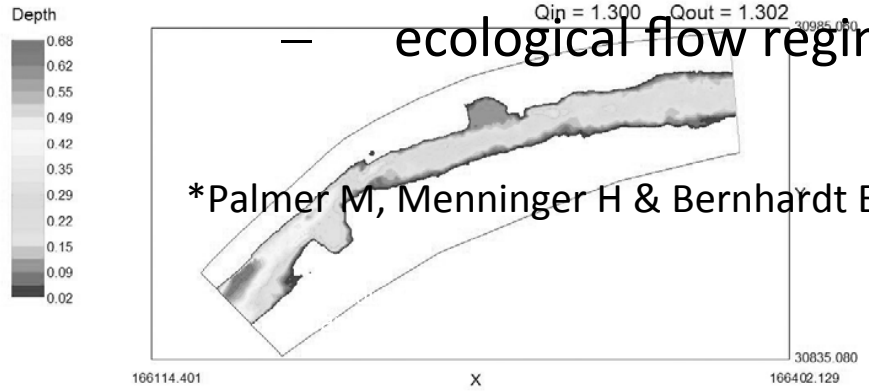
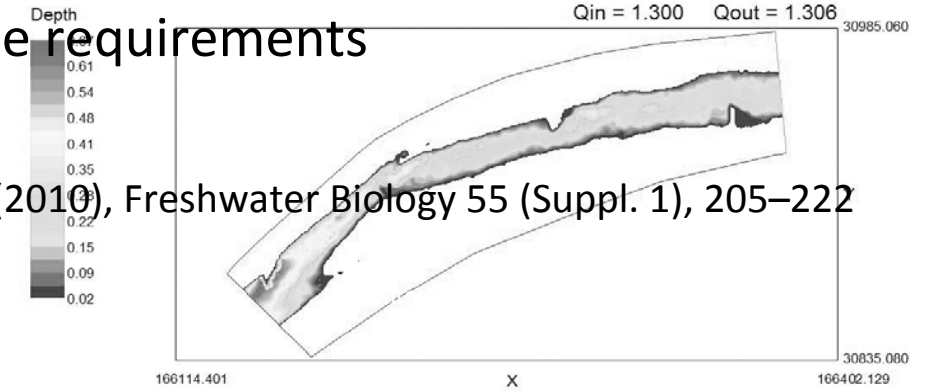




- Manipulation of habitat heterogeneity alone is usually insufficient for restoring biodiversity*
- Larger scale intervention is usually necessary
  - changes in land use
  - maintaining or improving riparian vegetation
  - ecological flow regime requirements







*Palmer M, Menninger H & Bernhardt E (2010), Freshwater Biology 55 (Suppl. 1), 205–222

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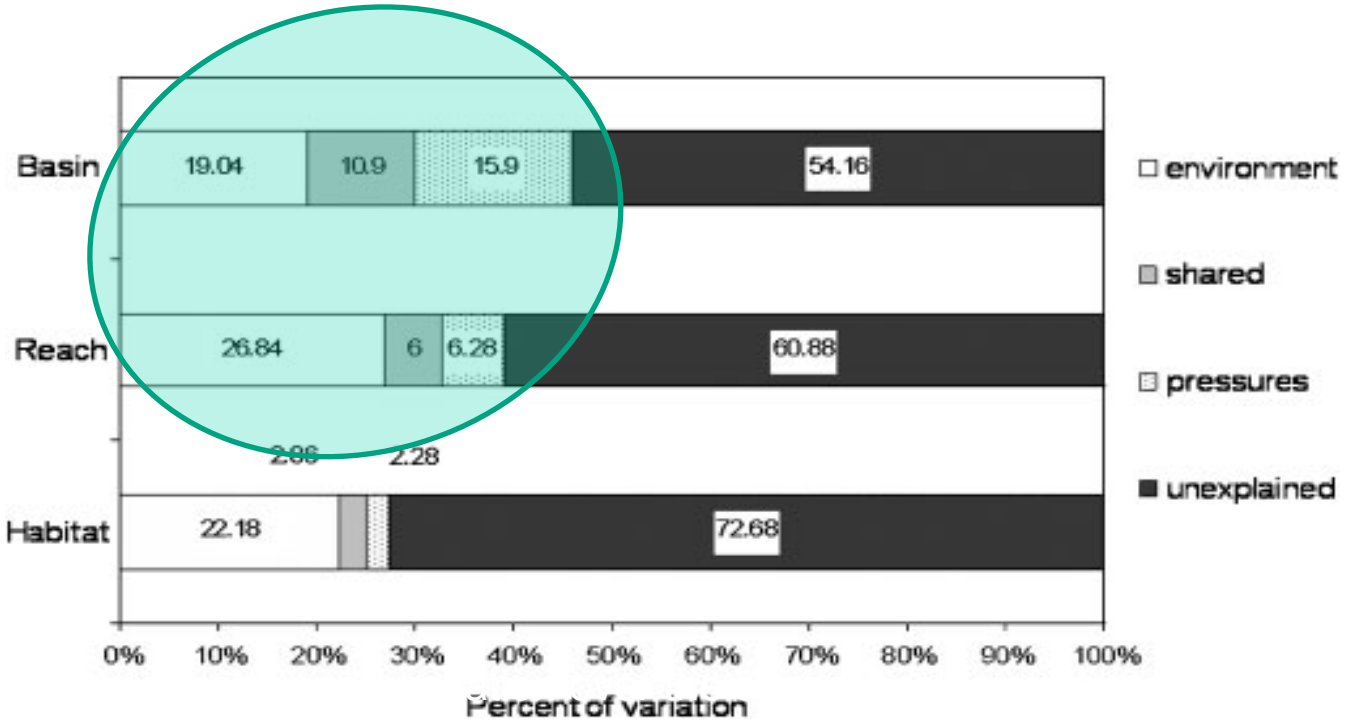
The importance of spatial scale



Hughes, SJ, Ferreira MT Cortes RV (2008). Aquatic Conservation: marine and freshwater ecosystems 18: 742-760

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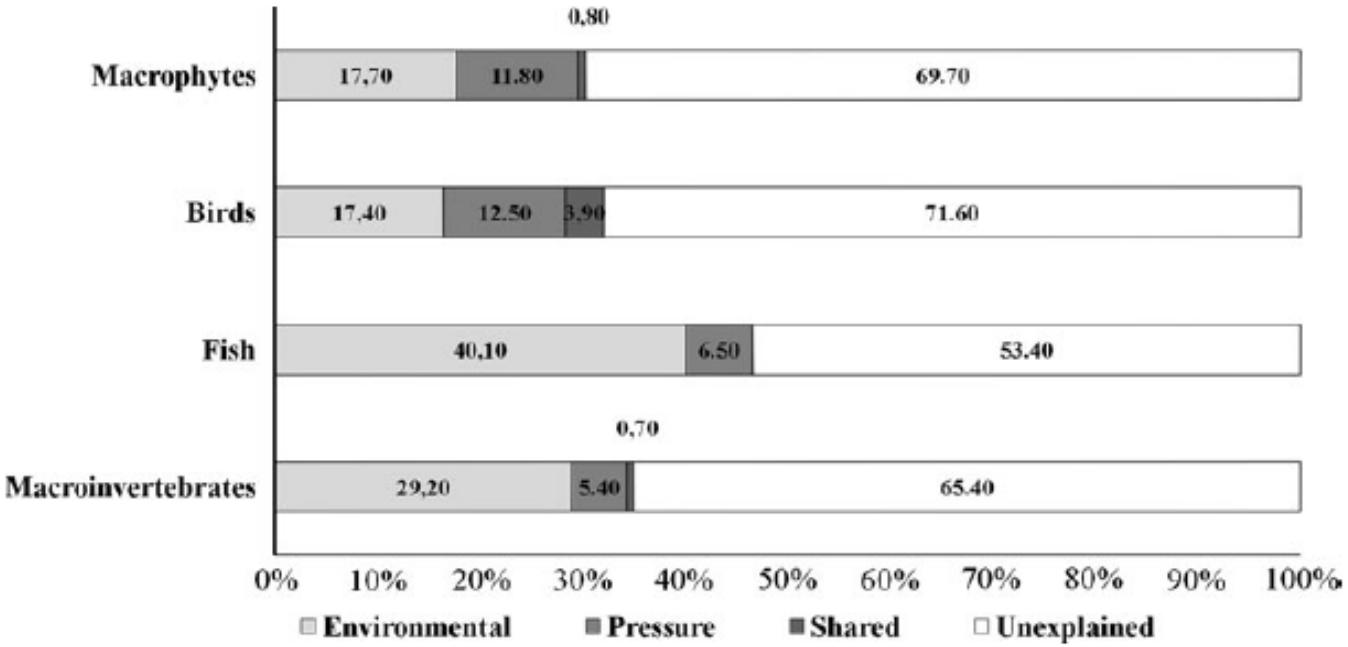
Different indicator responses



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The next steps.....

- Project RICOVER
  - INTERREG – SUDOE
  - Contracted monitoring
- Pilot projects on the Odelouca
  - Environmental Flow Regime
  - Habitat heterogeinity
    - Biodiversity
    - Endemic fish species
  - Bio-engineering
    - Bankside and channel intervention
  - Eradication of invasive plants
    - Acacia and *Arundo donax*
  - Propagation and planting of native species

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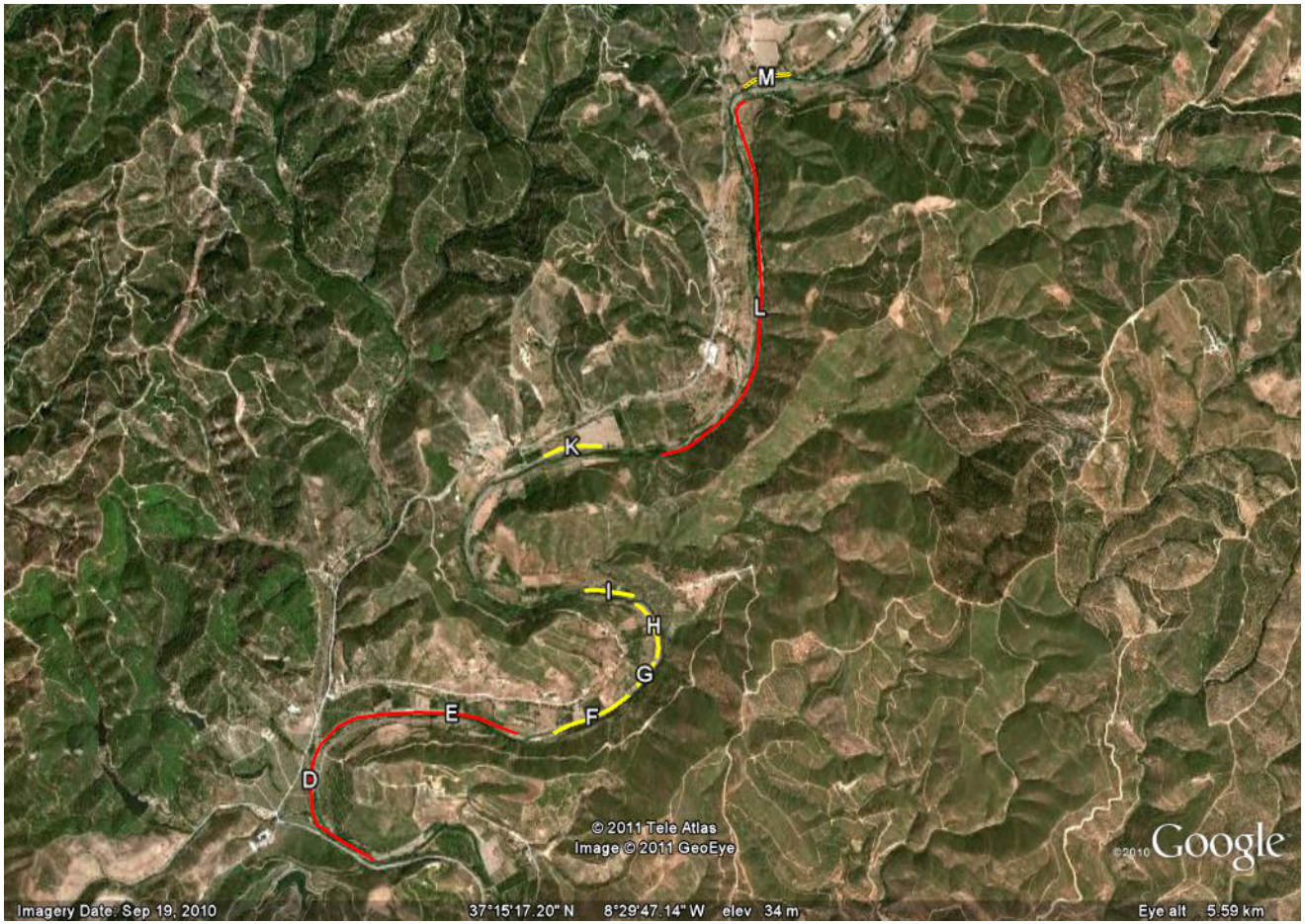
Requalification: Bioengineering and Monitoring



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November 2011 – February 2012

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Reach "M"

- Right bank: intense degradation & erosion forming a vertical slope which leads to incipient riparian vegetation.
- Left bank with native vegetation.
- Gabions installed with vegetation (live stakes of *Salix*) to increase bank stability.

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Reach "K"

- Right bank: intense degradation & erosion – steepness results in weak riparian vegetation; presence of *Arundo donax*.
- Left bank: accumulated coarse substrate; no riparian vegetation
- Geotextile placed along the right bank and planted with native riparian plants
  - Tamarix, Oleandar, buckthorn and ash

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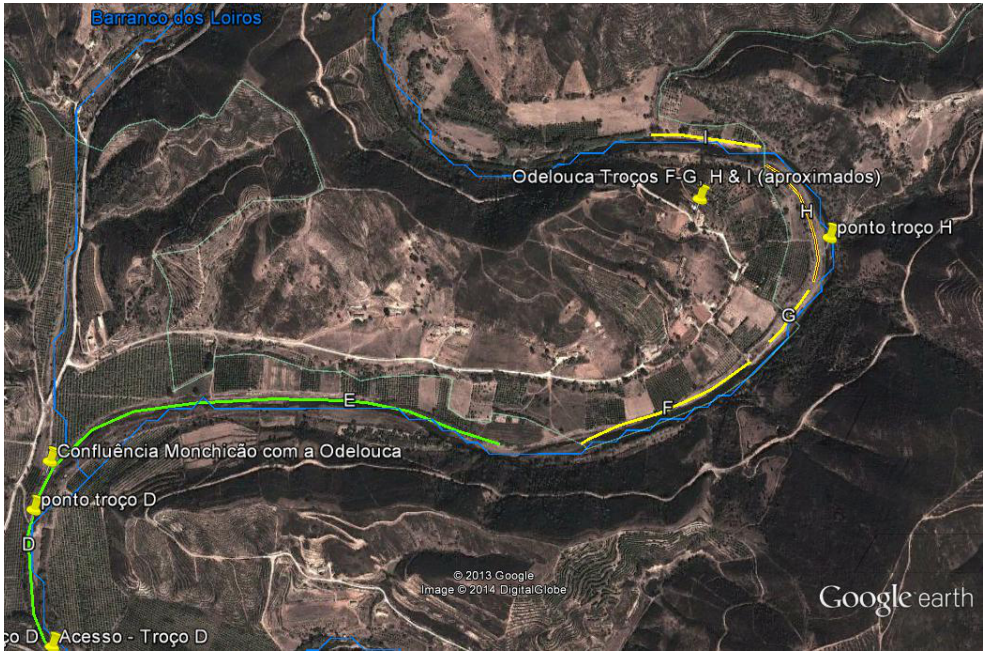
Reaches “F”, “G”, “H” and “I”

- Presence of invasive Giant Reed – *Arundo donax*
- Steep eroding bank profiles
- Lack of habitat heterogeneity
- Construction of a crib wall
- Construction of artificial islands
- Geotextile pretreated with herbicide and planted with native riparian plants
  - Tamarix, Oleandar, buckthorn and ash



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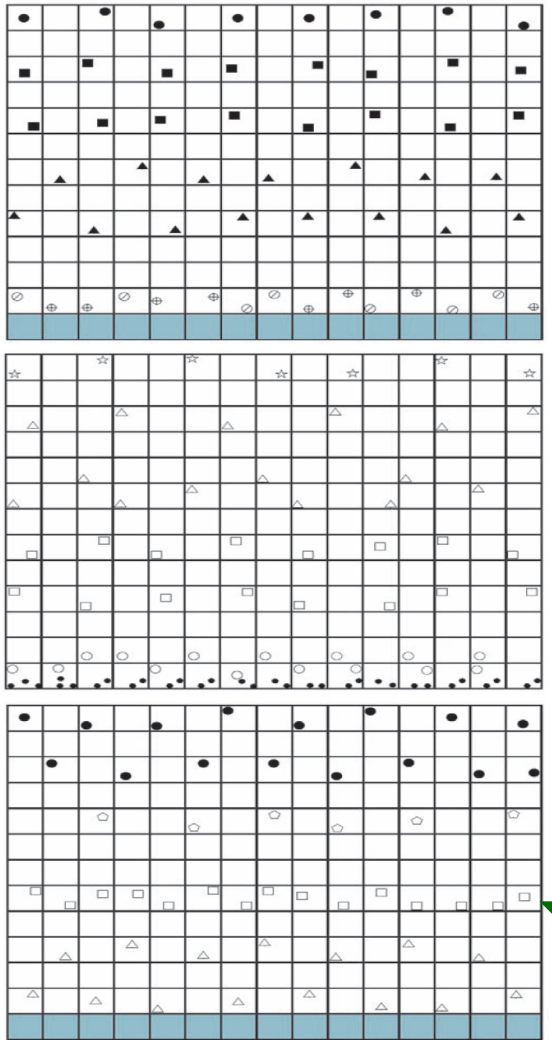
Planting in modules

MÓDULO 1 Soto Cenajo, Moratalla (Sector 2)	
●	*Ulmus minor*
■	*Fraxinus angustifolia*
▲	*Populus nigra*
⊘	*Salix purpurea*
⊕	*Salix elaeagnos*

MÓDULO 2 Soto Candelón, Abarán (Sector 3)	
☆	*Celtis australis*
△	*Populus alba*
□	*Tamarix canariensis*
○	*Nerium oleander*
✹	*Iris pseudacorus*

MÓDULO 3 Soto Arboleja, M. Segura (Sector 3)	
●	*Ulmus minor*
⬠	*Phoenix dactylifera*
□	*Tamarix canariensis*
△	*Populus alba*



Upstream-downstream

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Bank consolidation and weed control

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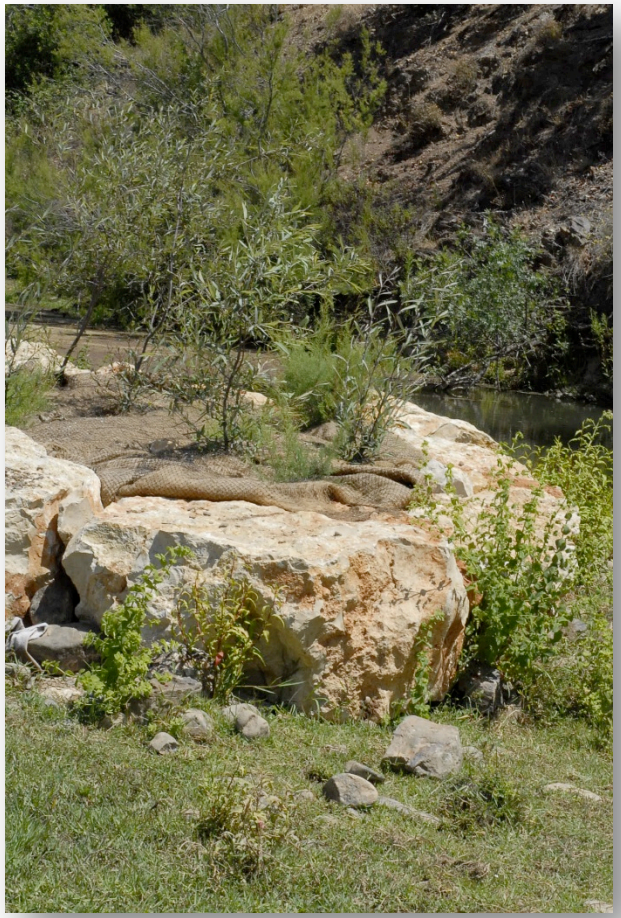
Vegetated Islands



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Ecological Quality

	Montante		Jusante				
Nome da Estação	**Azilheira**	**Sapeira**	**Monchique**	**Troço M**	**Troço H**	**Troço DM**	**Troço D**
Classificação Biológica	Excelente	Excelente	Excelente	Excelente	Excelente	Bom	Bom
Classificação Hidromorfológica	-	-	Bom ou Inferior	Bom ou Inferior	Bom ou Inferior	Bom ou Inferior	Bom ou Inferior
Classificação do Estado Ecológico	Excelente	Excelente	Bom	Bom	Bom	Bom	Bom

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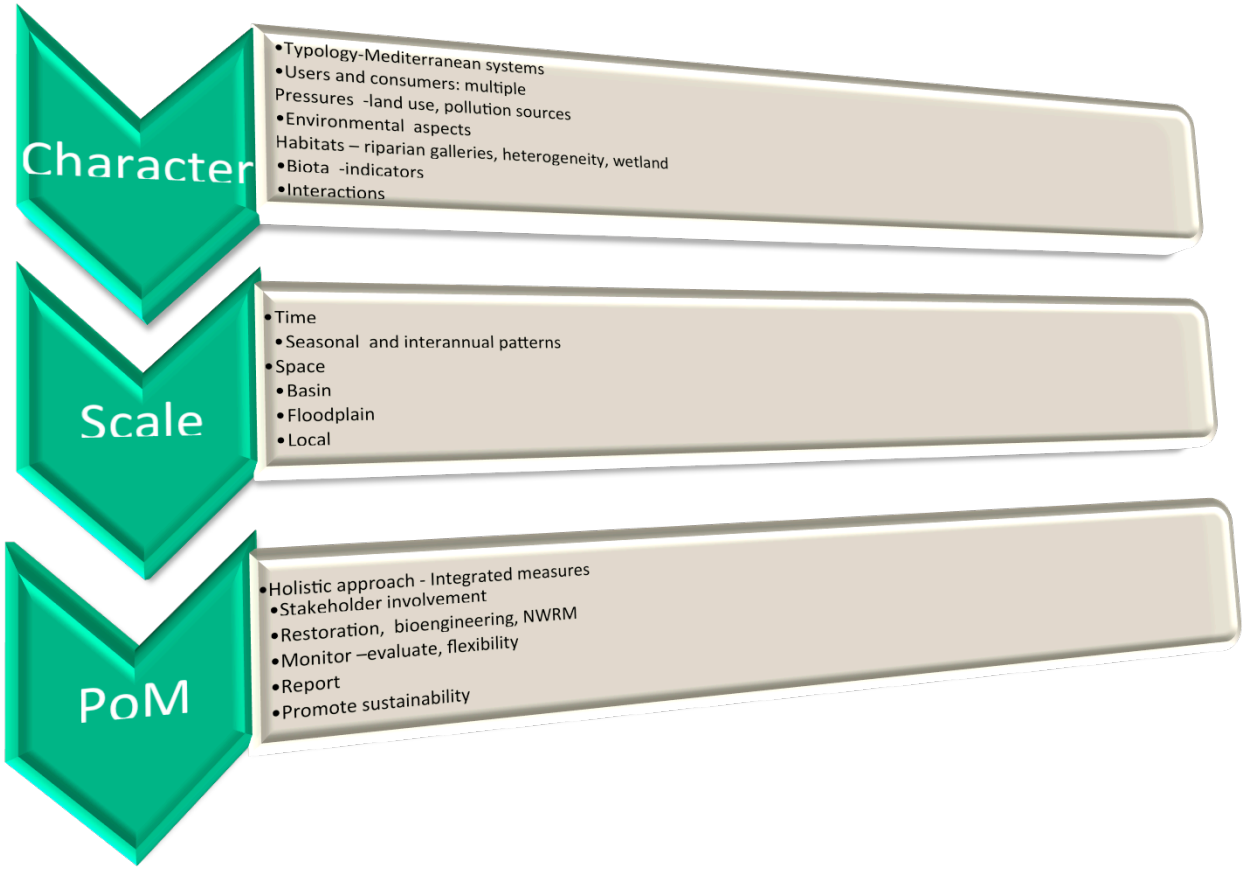
Summary

Sustainability in the hydrological cycle and all it supports



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Samantha Jane Hughes *shughes@utad.pt*

THANK YOU

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