Analysing Dam Effects on Fish Assemblage in Tagus Catchment Rivers (Central Spain)

Joaquín Solana-Gutiérrez, Diego García-de-Jalón, Carlos González-Alonso, Javier Cortázar

Escuela Técnica Superior de Ingenieros de Montes

UNIVERSIDAD POLITÉCNICA DE MADRID - EFI+ CONSORTIUM

Contact e-mail: joaquin.solana@upm.es

Analysing Dam Effects on Fish Assemblage in Tagus Catchment Rivers (Central Spain)

1. **OBJETIVES**
2. **FOREGROUNDS**
3. **LOCATION & DATABASE**
4. **METHODS**
5. **RESULTS**
6. **DISCUSSION**
7. **CONCLUSION**

OBJECTIVES

- The present study is focus on rivers belong to the **Tagus catchment** in Central Spain
- **Evaluate the effects** in terms of European Index Fish (Pont, 2009)
- To analysis the effects produced by **dam regulation** on fish assemblages
  - Up-stream assemblages / Down stream assemblages
- **Assemblages fish** variables:
  - Density of Habitat intolerant species
  - Density of O2 intolerant species
  - Density of lithophilic species
  - Richness of rheophilic species

FOREGROUNDS

- **European Fish Index EFI+**

- Between 2001 and 2009 the EC funded FAME and EFI+ project for **developing, evaluating and implementing new standardised fish-based methods to assess the ecological status of running waters** in Europe. The main output of these projects was the European Fish Index (EFI+).

- EFI+ is the first standardised fish-based assessment method applicable across a wide range of European rivers. The EFI+ employs a number of **environmental descriptors to predict biological reference** conditions and then **quantifies the deviation of the fish community structure** from these reference conditions on a statistical basis.

FOREGROUNDS

- The selection of metrics is based on the examination of metric responses to each of the pressures. The pressure indexes are considered in addition:
  - **Total pressure** index which combines the influence of all types of pressures
  - **Water alteration** index which considers eutrophication, organic pollution and organic siltation
  - **Habitat alteration** index which considers the local alteration of the habitat: riparian vegetation, embankment and in-stream habitat.
  - **Water abstraction** index which considers the water regulation by dam regulation, reservoirs, hydropeaking,..

FOREGROUNDS

European Fish Index: selected variables

From more than 50 different candidate variables obtained from more than 15000 sampling site across Europe, EFI+ project select only 4 variables with good performance to manifested human pressures:

- Abundance of **oxygen depletion intolerant** species.
- Abundance of **small** individuals (length<15 cm) belonging to species **intolerant to habitat degradation.**
- Richness of **rheophilic** reproduction habitat species.
- Abundance of species with **lithophilic** reproduction habitat.

FOREGROUNDS

- From the four metrics **two indices were established**, each composed of two different metrics. These can be computed depending on the river type of a given site (Melcher, 2006):

- **Salmonid Dominated Fish Assemblage Index** :

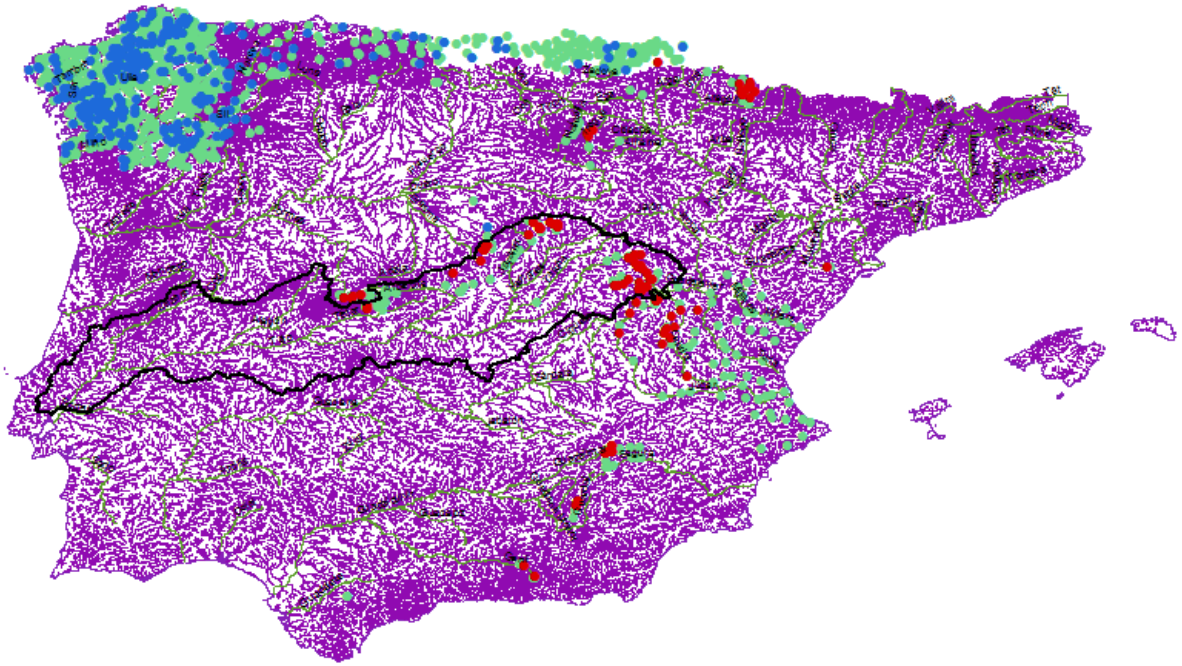
  - Salm.Fish.Index = (Ni.Hab.150 + Ni.O2.Intol) / 2

- **Cyprinid Dominated Fish Assemblage Index:**

  - Cypr.Fish.Index = (Ric.RH.Par + Ni.LITHO) / 2

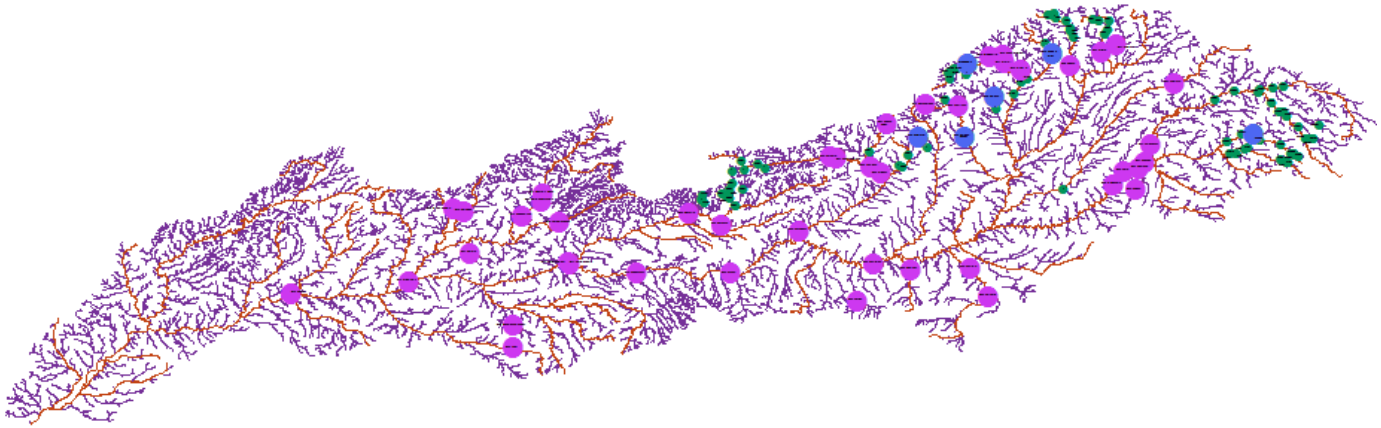
LOCATION

- Data are collected from 190 to 2009 in different rivers belong Tagus catchment.



LOCATION

- Dams in Tagus catchment (violet)
- Dams where has been conducted direct difference analysis (bleu), comparison the first downstream sampling site to the first upstream dam wall site



Tagus river catchment

DATA

- The database contains information about the fish assemblage, pressure level and environmental condition such as slope, altitude, and temperature for each site.
- The pressure levels are based on four groups of pressure established to describe the status of the levels of nutrients, toxic, morphological and hydrological impacts (specific pressure).
- 88 site in Tagus river catchment, 12 upstream dam wall, 76 downstream

ENVIRONMENT VARIABLES

- From these environment variables will obtained expected scores of fish assemblages variables which is made by generalised linear models. Needed variables can be categorical and numerical.

Variable	Modality
Water.source.type	Glacial
	Groundwater
	Nival
	Pluvial
Floodplain.site	No
	Yes
Natural.sediment	Boulder/Rock
	Gravel/Pebble/Cobble
	Organic
	Sand
	Silt
Geomorph.river.type	Braided
	Meandering regular
	Meandering tortous
	Naturally constraint
	Sinuous
Sampling.method	Wading or wading/boating
	Boating

Variable	Median	Minimum	Maximum
Latitude	46.26	36.77	68.80
Longitude	5.24	-9.25	29.65
Drainage area (km^2)	56.02	0.72	208,106.00
Distance.from.source (km)	13	0.50	1454.00
Actual.river.slope ($m.km^{-1}$)	9.13	0.001	323.63
Wetted.width (m)	6.00	0.70	658.00
Fished.area (m^2)	372	100	32,500
Temp.jan (°C)	1.60	-16.00	11.40
Temp.jul (°C)	17.80	8.60	25.10

EXPECTED VARIABLE MODELS

- By mean of generalised linear models were obtained expected variables related to fish assemblage. Next table is a scheme of what environment variables are considered to calculate the expected variables

Metric	Ni.O2.Intol	Ni.Hab.Intol.150	Ric.RH.Par	Ni.LITHO
Temperature July	+			
Annual Temp Range		+		+
Actual river slope	+	+	+	+
Natural Sediment	+	+	+	+
Syngeomorph1	+	+		
Syngeomorph2		+	+	+

OBSERVED FISH ASSEMBLAGE DATA

- Data are collected from 1990 to 2009 in different rivers belong Tagus catchment. It was used **88 sampling sites**.
- Sampling were obtained by **electro-fishing**.
- All sampling data were entered in EFI+ software for obtaining the 4 observed, the 4 expected metrics and the 2 EFI+ index (http://efi-plus/boku/software/).

Observed Variables EFI+

- **Oxygen depletion intolerant species abundance** in number of individuals (Ni.O2.Intol) This metric deals with the guild: Species which are intolerant to low Oxygen concentration (O2), always more than 6 mg/l in water.

- **Abundance of individuals, with length < 15 cm, that belong to species intolerant to Habitat degradation** (Ni.Hab.Intol.150). The guild is: Species which are intolerant to Habitat degradation.

- **Richness (number of species) of Rheophilic reproduction habitat species** (Ric.RH.Par). The guild considered is: Species with preference to spawn in running waters.

- **Abundance (number of individuals) of species with Lithophilic reproduction habitat** (Ni.LITHO). The guild used is: Species which spawn exclusively on gravel, rocks, stones, rubbles or pebbles. Their hatchlings are photophobic.

METRICS CALCULATIONS

- **After standardisation and re-scaling the four variables became in metrics**

- The score (Miq) of each of the 4 metrics in a given river zone q (salmonid river zone or cyprinid zone) and a given eco-region j is obtained in the following manner for each site:

$$Miq = (Oi - Ei - Mjq) / Sq$$

(Oi) Observed variable

(Ei) Expected variable

(Mjq) Median value of the residuals in the eco-region j and the river zone q in calibration sites,

(Sq) Standard deviation of the residuals in calibration site

The last two parameters depend on the ecoregion of sampling site. This is due to adapt EFI+ to different European regions)

STATISTIC METHODS

1. A **correlation analysis** were made to find relationships between assemblages variables, factors and pressures.
    1.1. Observed variables
    1.2. Metrics= Expected-Predicted and rescaling

2. Finding **significant differences** between sampling upstream and downstream dam wall (t-Student, Mann-Whitney)

3. **Gradient analysis**; finding significant differences between an upstream dam wall sampling site and the next downstream dam wall sampling site.
    (t-Student of differences, sign test and sign ranked test)

R2 Pearson: OBSERVED VARIABLES VERSUS FACTORS & PREASSURES

	OBS_HINTOL	OBS_O2INTO	OBS_RHPAR	OBS_LITH
RICHESSE	**-0.2494**	**-0.3702**	**0.8609**	**0.2769**
CAPTURES	**0.3551**	0.1778	**0.4222**	**0.7041**
LATITUDE	-0.1659	-0.1647	0.1144	-0.1220
LONGITUDE	**0.3547**	0.2124	-0.0401	-0.1754
DISTANCE_SPRING	-0.1341	-0.2010	**0.4258**	0.0631
ALTITUDE	**0.3566**	**0.3516**	**-0.3023**	-0.2301
FISHED_ARE	-0.0394	-0.1976	0.0249	**-0.3852**
WETTED_WID	-0.2706	**-0.3949**	0.1826	-0.2046
B_BARRIER	-0.1439	-0.1629	0.0937	-0.0590
B_WATER_ABSTRACTION	-0.3212	**-0.3822**	0.2512	**0.3584**
B_CHANNELISATION	0.2347	0.2345	-0.0352	**0.2708**
B_CROSS	-0.0979	-0.0947	0.0031	-0.0188

Signification level <0.05 ; **Signification level <0.01 ;** **Signification level <0.001**

Correlation between **observed variables** and richness and captures

- RHPAR is independent of richness and abundance
- Richness are negative correlated with:
  - HINTOL (r=-0.2494,p=0.001)
  - O2INTO (r=-0.3702,p=0.001)
  - RHPAR (r=0.8609,p=0.001)
  - LITH (r=-0.2769,p=0.001)
- Captures are correlated with:
  - HINTOL (r=-0.3551,p=0.001)
  - RHPAR (r=-0.4222,p=0.001)
  - LITH (r=-0.7041,p=0.001)

- There are many relationship between geographical variables and metrics: Altitude, latitude, longitude, width of rivers, distance to source
- Three variables are sensitive to channelisation and water abstraction, but channelisation is not a strong pressure in this area.

R2 Pearson: METRICS versus FACTORS & PREASSURES

	MET_HINTOL	MET_O2INTO	MET_RHPAR	MET_LITH
RICHESSE	**-0.6390**	**-0.6958**	-0.0656	**-0.4832**
CAPTURES	**-0.4130**	**-0.4581**	-0.0031	-0.2434
LATITUDE	-0.3606	-0.2120	-0.1943	-0.1143
LONGITUDE	-0.0757	**0.3520**	-0.0488	0.0986
DISTANCE_SPRING	-0.3928	-0.1077	**0.3134**	0.0222
ALTITUDE	**0.4219**	**0.3673**	-0.1179	0.0253
FISHED_ARE	-0.1364	-0.0021	-0.1685	-0.0427
WETTED_WID	-0.3909	**-0.3056**	0.0106	-0.2257
B_BARIERS	-0.2408	-0.2627	0.0981	0.0406
B_WATER_ABSTRACTION	**-0.5683**	**-0.5537**	0.2925	0.1301
B_CHANNELIZATION	0.1091	0.0512	0.1922	0.1020
B_CROSS	-0.0045	-0.1361	-0.0565	-0.0211

Signification level <0.05 ; **Signification level <0.01 ; Signification level <0.001**

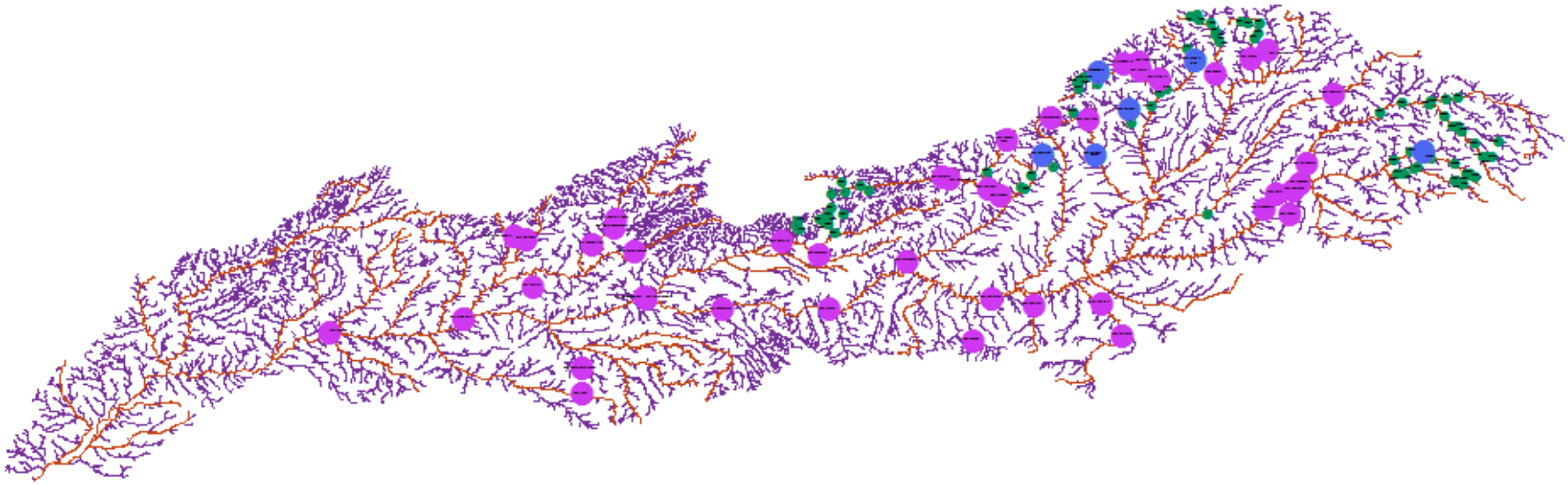
Correlation between **metrics** and richness and captures

- RHPAR is independent of richness and abundance

- Richness are negative correlated with:
  - HINTOL (r=-0.639,p=0.001)
  - O2INTO (r=-0.696,p=0.001)
  - LITH (r=-0.483,p=0.001)
- Captures are correlated with:
  - HINTOL (r=-0.413,p=0.001)
  - O2INTO (r=-458,p=0.001)
  - LITH (r=-0.243,p=0.022)

- Although, three out of four metrics are sensitive to water abstraction pressures
- However, there are many relationship between geographical variables and metrics: Altitude, latitude, longitude, width of rivers, distance to sources
- Nevertheless, metrics are more correlated than former variables

ANOVA between all sites upstream and all sites down stream dam wall

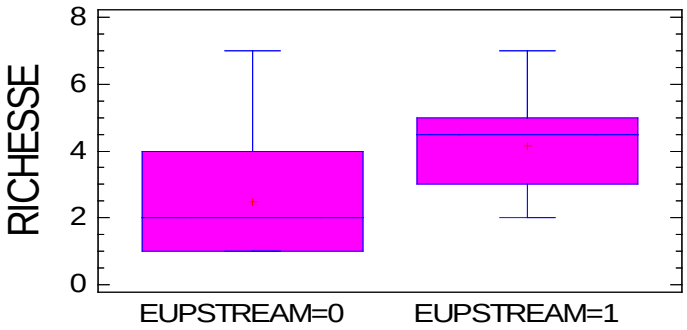


RICHNESS OBSERVED

	EUPSTREAM=0	EUPSTREAM=1
Count	76	12
Average	2.48684	4.16667
Median	2.0	4.5
Standard error	0.170132	0.405144
Stnd. skewness	2.73744	0.508482
Stnd. kurtosis	-0.23034	-0.0861582

95% CI for mean of EUPSTREAM=0: 2.48684 +/- 0.338922
95% CI for mean of EUPSTREAM=1: 4.16667 +/- 0.891717

Significant difference (Mann-Whitney, W=725.5, p=0.001)

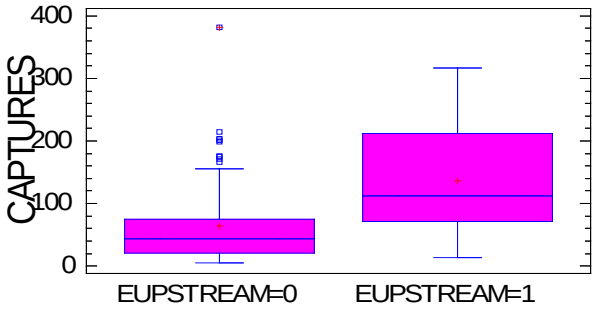


CAPTURES= ABUNDANCE OBSERVED

	EUPSTREAM=0	EUPSTREAM=1
Count	76	12
Average	63.8816	136.583
Median	43.0	112.0
Standard error	7.52465	27.1574
Stnd. skewness	7.99317	0.895102
Stnd. kurtosis	11.9853	-0.326159

95.0% CI for mean of EUPSTREAM=0: 63.8816 +/- 14.9899
95.0% CI for mean of EUPSTREAM=1: 136.583 +/- 59.7731

Significant difference Mann-Whitney (W = 697.5, p=0.003)

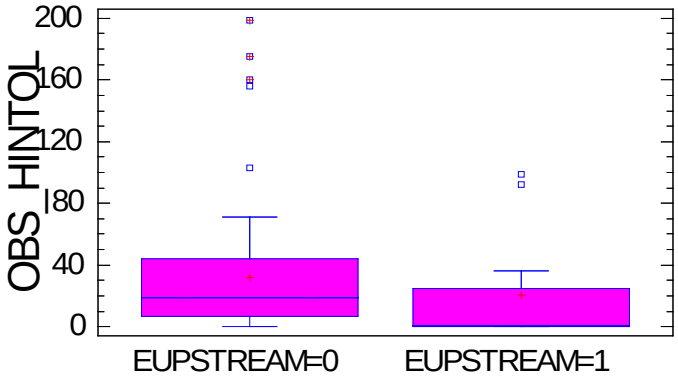


OBS_HINTOL=HABITAT INTOLERANT SPECIES OBSERVED

	EUPSTREAM=0	EUPSTREAM=1
Count	76	12
Average	31.7895	20.4167
Median	18.5	0.5
Standard error	4.58462	10.5762
Stnd. skewness	8.85305	2.48449
Stnd. kurtosis	12.2028	1.21297

95% CI for mean of EUPSTREAM=0: 31.7895 +/- 9.16928
95% CI for mean of EUPSTREAM=1: 20.4167 +/- 21.1524

Significant difference Mann-Whitney(W= 271.0, p= 0.024)

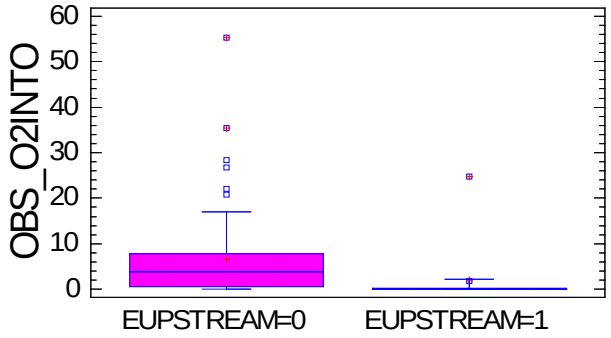


OBS_O2INTO= OXYGEN INTOLERANT SPECIES OBSERVED

	EUPSTREAM=0	EUPSTREAM=1
Count	76	12
Average	6.50202	2.26648
Median	3.80572	0.0
Standard error	1.04895	2.04846
Stnd. skewness	10.3959	4.84762
Stnd. kurtosis	19.924	8.35069

95.0% confidence interval for mean of EUPSTREAM=0: 6.50202 +/- 2.08961
95.0% confidence interval for mean of EUPSTREAM=1: 2.26648 +/- 4.50864

Mann-Whitney test to compare medians (W = 163.5, p=0.001)

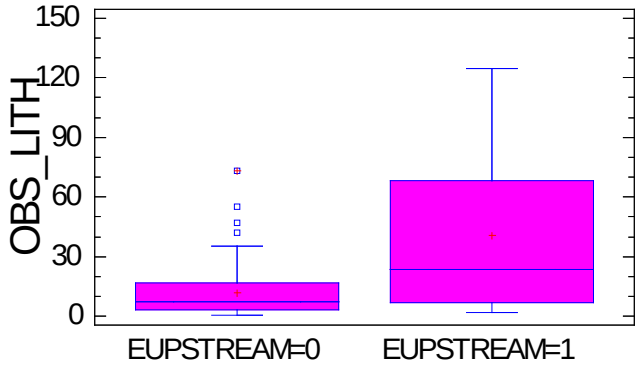


OBS_LITH= LITHOPHILIC SPECIES OBSERVED

	EUPSTREAM=0	EUPSTREAM=1
Count	76	12
Average	11.7058	40.654
Median	7.11251	23.4314
Standard error	1.51456	12.7542
Stnd. skewness	8.44203	1.5851
Stnd. kurtosis	12.2915	-0.0374324

95.0% confidence interval for mean of EUPSTREAM=0: 11.7058 +/- 3.01716
95.0% confidence interval for mean of EUPSTREAM=1: 40.654 +/- 28.0718

Mann-Whitney W test to compare medians (W = 652.5, p=0.017)

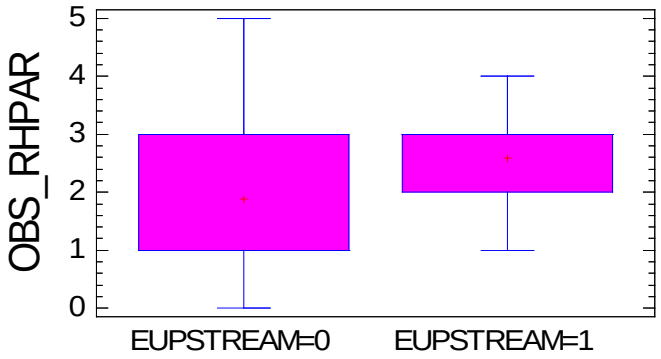


OBS_RHPAR= REOPHILIC SPECIES OBSERVED

	EUPSTREAM=0	EUPSTREAM=1
Count	76	12
Average	1.88158	2.58333
Median	1.0	3.0
Standard error	0.129733	0.228908
Stnd. skewness	3.07268	-0.459831
Stnd. kurtosis	-0.655688	0.23575

95.0% confidence interval for mean of EUPSTREAM=0: 1.88158 +/- 0.258441
95.0% confidence interval for mean of EUPSTREAM=1: 2.58333 +/- 0.503825

Mann-Whitney W test to compare medians(W = 642.5, p=0.0163062)

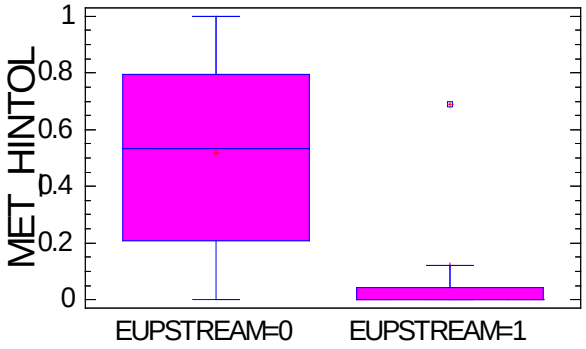


MET_HINTOL = HABITAT INTOLERANT SPECIES METRIC

	EUPSTREAM=0	EUPSTREAM=1
Count	33	6
Average	0.518693	0.121709
Median	0.533406	0.0
Standard error	0.0531655	0.113655
Stnd. skewness	-0.66397	2.4306
Stnd. kurtosis	-1.49024	2.96231

95.0% confidence interval for mean of EUPSTREAM=0: 0.518693 +/- 0.108295
95.0% confidence interval for mean of EUPSTREAM=1: 0.121709 +/- 0.292161

Mann-Whitney W test to compare medians (W = 26.0, p=0.004)



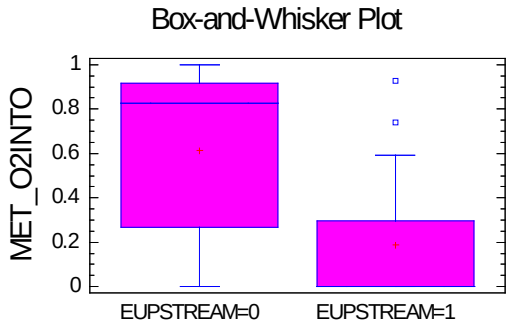
MET_O2INTO= OXYGEN INTOLERANT SPECIES METRIC

	EUPSTREAM=0	EUPSTREAM=1
Count	76	12
Average	0.611912	0.188159
Median	0.825213	0.0
Standard deviation	0.366528	0.347829
Stnd. skewness	-2.54048	2.11153
Stnd. kurtosis	-2.05766	0.400784

95.0% confidence interval for mean of EUPSTREAM=0: 0.611912 +/- 0.0837555
95.0% confidence interval for mean of EUPSTREAM=1: 0.188159 +/- 0.221001

T-Student = 3.74577 P-value = 0.000324596

Mann-Whitney W test to compare medians (W = 183.5 P-value = 0.000858198



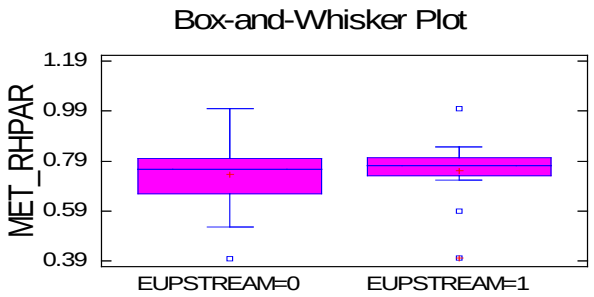
MET_RHPAR= REOPHILIC SPECIES METRIC

	EUPSTREAM=0	EUPSTREAM=1
Count	76	12
Average	0.736655	0.749755
Median	0.755374	0.770541
Standard error	0.0131832	0.0415593
Stnd. skewness	-0.774326	-1.54847
Stnd. kurtosis	0.945366	2.17137

95.0% confidence interval for mean of EUPSTREAM=0: 0.736655 +/- 0.0262623
95.0% confidence interval for mean of EUPSTREAM=1: 0.749755 +/- 0.0914716

t-Student = -0.354272 **P-value = 0.724002**

Mann-Whitney (Wilcoxon) W test to compare medians (W = 513.0, p=0.492)

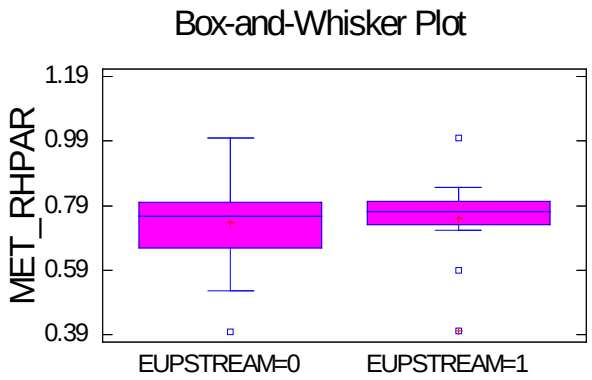


MET_LITH=LITHOPHILIC SPECIES METRIC

	EUPSTREAM=0	EUPSTREAM=1
Count	76	12
Average	0.766792	0.688214
Median	0.805235	0.792588
Standard error	0.0176187	0.0763099
Stnd. skewness	-9.95234	-2.42281
Stnd. kurtosis	16.0216	2.61127

95.0% confidence interval for mean of EUPSTREAM=0: 0.766792 +/- 0.0350983
95.0% confidence interval for mean of EUPSTREAM=1: 0.688214 +/- 0.167957

Mann-Whitney (Wilcoxon) W test to compare medians (W = 418.0,p=0.648408)



Preliminary effects

- **Captures** upstream were almost twice bigger (136) than downstream (64)
- **Conversely,** richness were an half upstream than downstream.

- All **observed variables** present significant differences in comparison between up and down stream dam walls.
  - Upstream wall abundance **in habitat intolerant species were reduced** in 11.38
  - Upstream wall abundance in **oxygen intolerant species were reduced** in 4.23
  - Upstream wall abundance in **lithophilic species were increment** in 28.94
  - Upstream wall richness in **reophilic species were increment** in 0.701, as average.

- However, only **oxygen intolerance abundance metric** and **habitat intolerant species abundance metric** were significantly reduced.

Gradient analysis: Direct comparison up and down dam wall sites

- In 5 rivers were evaluated the first sampling site up and down dam wall
  - Cuervo river
  - Aulencia river
  - Jarama river
  - Lozoya river
  - Manzanares river

RICHNESS

Sample mean = 0.8 ; Sample median = 1.0

t-test (t= 0.872, p= 0.432), sign test (r=0 , p = 0.999), signed rank test (r= 0.565, p= 0.571)

CAPTURES

Sample mean = -32.4 ; Sample median = -3.0

t-test (t = -0.573, p= 0.596), sign test (r= 0.0, p= 0.999), signed rank test (r= 0.269, p= 0.787)

OBS_HINTOL

Sample mean = -35.6, Sample median = -21.0
t-test (t = -1.791, p= 0.147), sign test (r= 0.5, p= 0.617), signed rank test (r= 1.078, p= 0.280)

OBS_RHPAR

Sample mean = 0.6 ; Sample median = 0.0
t-test (t= 0.738, p = 0.501), signed rank test (r= 0.0, p= 1.0), signed rank test (r= 1.078, p= 0.280)

OBS_LITH

Sample mean = -24.97 ; Sample median = -7.93269
t-test (t=-1.289, p= 0.266), sign test (r= 1.788, p = 0.073), signed rank test (r = 1.887, p= 0.059)

MET_O2INTO

Sample mean = -0.107447 ; Sample median = 0.0
t-test (t = -0.508, p=0.637), sign test (r= 0.0 , p= 0.999), signed rank test (r= 0.0, p = 0.999)

MET_RHPAR

Sample mean = -0.0897084 ; Sample median = -0.0901374
t-test (t= -4.292, p= 0.012), sign test (r = 1.788, p = 0.073), signed rank test (r=1.887, p = 0.059)

MET_LITH

Sample mean = -0.0810823 ; Sample median = -0.220132
t-test (t= -0.545, p = 0.614), sign test (r= 0.0, p = 0.999), signed rank test (r= 0.539, p = 0.589)

Rheophilic Metric	Lithophilic Metric	Wall	River
0.672013651	0.451065981	Up	Cuervo
0.807991322	0.79278973	Down	
0.715532664	0.969434191	Up	Aulencia
0.771543981	0.593267239	Down	
0.624746804	0.816917642	Up	Jarama
0.714884207	0.658454677	Down	
0.738161826	0.090365028	Up	Lozoya
0.769538408	0.468550771	Down	
0.86292317	0.77986783	Up	Manzanares
0.997962366	1	Down	

Preliminary conclusion

- Only richness of **reophilic metric** showed a significant difference. But it should be considered that this analysis has been made only with 5 pairs data.
- As a result rheophilic species downstream wall dam than upstream from dam wall.

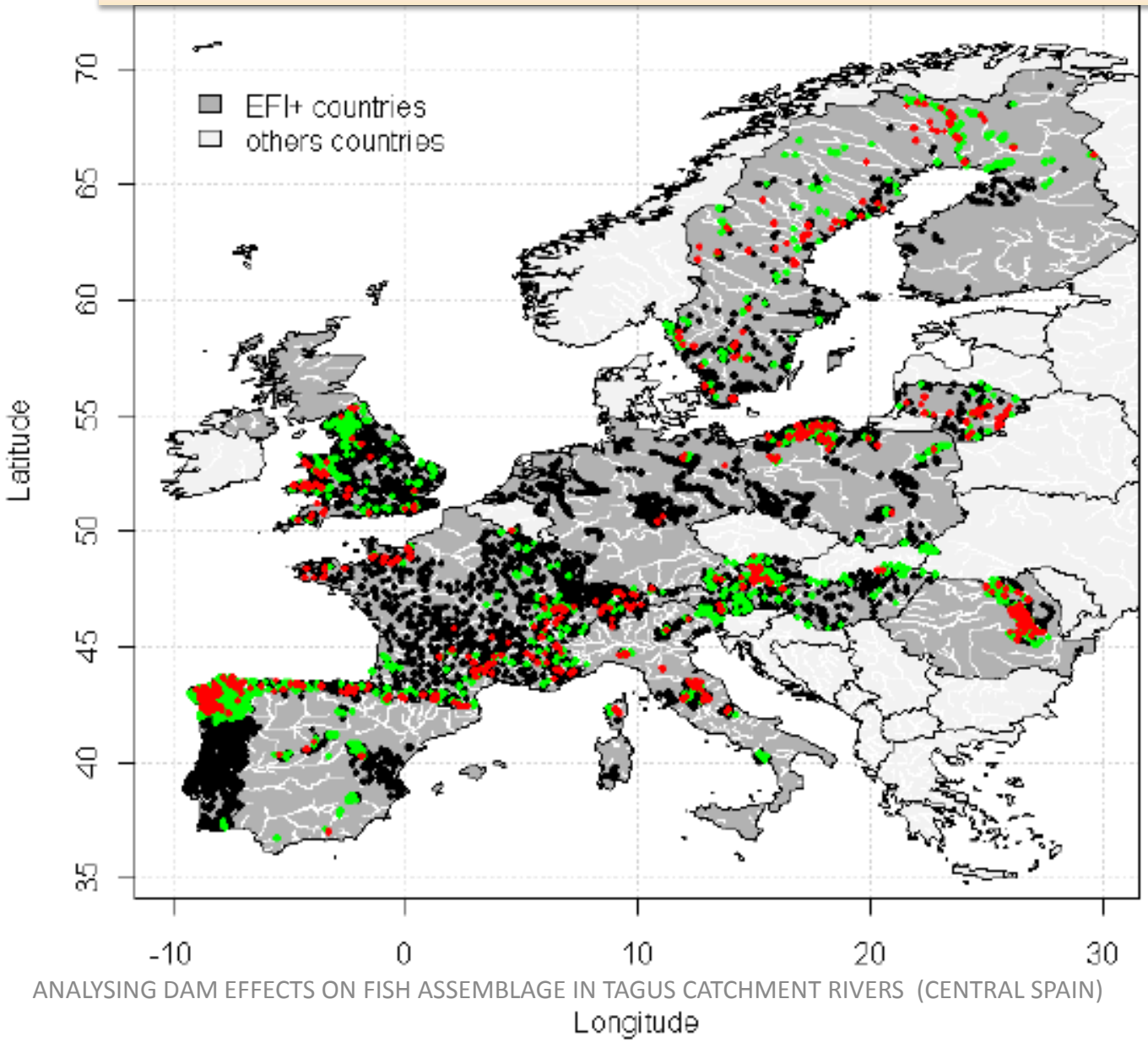
Conclusion

- The four variables analysed and the four metrics were significant for analysing the effects of dams. But **metrics showed better statistic quality**.
- **All four metrics were statistic significant** to analysis the effects of dams.
- Only the metric richness of **reophilic** showed a significant difference when a direct difference up and down were made.

Thank you for your attention

Joaquín Solana-Gutiérrez, Diego García-de-Jalón, Carlos González-Alonso, Javier Cortázar
Escuela Técnica Superior de Ingenieros de Montes
UNIVERSIDAD POLITÉCNICA DE MADRID - EFI+ CONSORTIUM
Contact e-mail: joaquin.solana@upm.es

SITES


EFI+ countries
others countries
Latitude
70
65
60
55
50
45
40
35
-10
0
10
20
30
Longitude

LASTEST 10 EFI+ CANDIDATE METRICS

Code	Description
Ni_INSE	Density of insectivorous species
Ni_OMNI	Density of omnivorous species
Ni_PHYT	Density of phytophilous species
Ns_BENT	Number of benthic species
Ns_RHEO	Number of rheophilic species
Ns_LONG	Number of long migratory species
Ns_POTA	Number of potamodrous species
perNi_LITH	Relative Abundance of lithophilous species
perNs_INTO	Relative number of intolerant species
perNs_TOLE	Relative number of tolerant species

Response of selected variables

Pressures	Ins150All	Ins150Large	rO2INT	rRH	DIADR	dHINT	rLIT
Pressure.Index.final	1	-	1	-	-	-	-
Water.alteration	1	1	1	1	-	1	-
Water.quality.index	-	-	1	1	-	1	-
Acidification	-	-	-	-	-	-	-
Eutrophication	-	-	-	-	1	-	-
Organic.pollution	1	-	1	-	-	-	-
Organic.siltation	1	1	1	1	-	1	1
Toxic.substances	1	-	-	-	-	-	-
Temperature.impact	1	1	1	1	-	-	1
Habitat.index	1	1	-	-	-	-	-
Channel.cross	1	1	-	-	-	1	-
Hydropeaking	-	-	1	1	1	-	-
Impoundment	1	-	1	1	-	-	-
Water.abstraction	-	-	-	-	-	-	-
Navigation	1	1	-	1	-	1	1
Velocity.increase	1	1	-	-	-	-	-
Hydro.mod	-	-	1	1	-	-	-
Sedimentation	-	-	-	-	-	-	-
Embankment	1	1	-	-	1	-	-
Instream.habitat	1	1	-	-	-	-	1
Riparian.vegetation	1	1	-	1	-	-	-
Colinear.connected.reservoir	-	-	-	-	-	-	-
Floodplain	-	-	1	1	-	-	1
Floodprotection	-	1	-	-	1	-	-
Barriers.river.segment.up	-	-	-	-	1	-	-
Barriers.river.segment.down	-	-	-	-	1	-	-
Barriers.catchment.down	-	-	-	-	1	-	-
Total	14	11	10	10	7	5	5