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Project INHABIT - LIFE08 ENV/IT/000413

Local hydro-morphology, habitat and RBMPs: new measures to improve ecological quality in South European rivers and lakes

ACTION GROUP D1: Demonstration actions on classification and uncertainty

- Action D1_IRSA (month 20-36): *Demonstration actions on classification and uncertainty by IRSA*
- Action D1_ISE (month 20-36): *Demonstration actions on classification and uncertainty by ISE*
- Action D1_PI (month 20-36): *Demonstration actions on classification and uncertainty by ARPA Piemonte*
- Action D1_SA (month 20-36): *Demonstration actions on classification and uncertainty by RAS*

Deliverable D1d5

English version

Final report on classification uncertainty and correlated suggestions to improve RBMPs

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Local hydro-morphology, habitat and RBMPs: new measures to improve ecological quality in South European rivers and lakes

ACTION GROUP D1: Demonstration actions on classification and uncertainty

Deliverable D1d5

English version

Final report on classification uncertainty and correlated suggestions to improve RBMPs

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Brugherio, 13 December 2013

SUMMARY

EXTENDED ABSTRACT

The present Deliverable offers a final framework of INHABIT steps for rivers. The content is part of action group D1, aiming at virtually stepping over classification of water bodies and identifying those features (i.e. metrics and habitat characteristics) representing key aspects in structuring basin management plans.

The present Deliverable contains seven papers representing the procedure followed by the project for the definition of tools and guidelines for a more effective evaluation of anthropic alteration and, consequently, for a more incisive definition of restoration measures for ecological quality. The presented papers will be evaluated for a possible inclusion in the CNR-IRSA 'Notiziario dei metodi Analitici', due for publication in March 2014.

The first paper is an introductory overview on habitat themes, including interactions between natural and anthropic variability and river restoration. The second paper goes at the heart of INHABIT topics, describing the environmental gradients defining benthic communities of considered Sardinian rivers. This second paper aims at identifying, in particular, which biological metrics have to be considered for an effective characterization of anthropic pressure gradients. Based on these considerations, in the third paper the relations between gradients of anthropic and habitat pressures and single biological metrics are analysed in detail, in order to define a conclusive framework on which metrics should be used to identify specific pressures and, thus, to plan specific measures.

One of the main INHABIT project results did confirm the key role exerted by hydraulic conditions (proportion between lentic and lotic areas in stream) in structuring benthic communities and, consequently, influencing ecological status assessment. For this reason, it has been reckoned as important to present a paper dealing with the definition of the hydrological state in a temporary river. Hydrological state (HS) in a river does represent the deviation of the observed, potentially altered, hydrological regime from a natural unaltered condition. Definition of HS is of great relevance for the evaluation of the ecological status in a water body, due to the fact that hydrological regime have an influence – and control – the development of biological communities. Furthermore, having habitat been characterized by means of CARAVAGGIO method, a paper is specifically dedicated to a presentation of CARAVAGGIO method, describing its main potential areas of application. A further paper presents the results obtained in the activities of analysis of the present management plan for water resources in Mulargia basin. The objective of such activities has highlighted possible conflicts in the use of the water resource, following the implementation of policies for river habitat protection. Such aspects are of particular relevance for the correct management of river ecosystems. The final paper gives a concise view of the main INHABIT themes and outcomes, by providing a series of overview tables. In the paper possible connection with other environmental issues and Directive are also highlighted, with reference to topics potentially deserving further investigations and dedicated projects.

This Deliverable is drafted in two different versions, Italian and English. The two versions are different in terms of number of papers included. In some cases it has been considered as more appropriate to include the English version of the paper in different Deliverable, in order to maintain consistency with the Deliverable objective, as in the case of paper D1d5.4 whose topics were presented during the first INHABIT project international workshop (Barcelona, October 2012). Papers have the same number in the two versions, followed by 'en' in the English version.

D1D5.1EN – INHABIT GENERAL FRAMEWORK FOR HABITAT MEASURE OPTIMIZATION FOR THE IMPROVEMENT OF ECOLOGICAL STATUS IN RIVERS

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1. INTRODUCTION

To prevent the deterioration of ecological status in surface water bodies, protecting and improving them, have always been considered a central theme in European environmental policy. The evaluation of pollution and the resulting effects on ecosystems are not new in the European scenario. Since the 70ies we have dealt in various ways with the development of assessment systems able to detect the effects of anthropogenic disturbance on aquatic ecosystems and specific policy proposals have been issued since then to improve the status of water bodies (Feld et al., 2011).

In this context, the issue of Directive 2000/60/EC - WFD has set new approaches for the assessment of ecological status, also establishing the centrality of the Biological Quality Elements for this purposes. The WFD has also recognized the importance of habitat and hydromorphological elements in the interpretation of the processes structuring biological communities.

Moreover, the majority of European river basins are affected by a combination of pressures that does involve - in addition to the alteration of water quality - habitat degradation. Habitat degradation includes simplification of habitat structure, presence of physical barriers preventing dispersal ability of aquatic organisms and flow alteration (Friberg, 2010).

In aquatic ecosystems management and for a proper setting of measures to improve the quality of water bodies, it is vital to identify the effects of individual pressure on biocoenoses (Ormerod et al., 2010). In particular, flow related aspects (i.e. connected with the amount of water) may be particularly relevant in Mediterranean area, where the rivers can experience significant variations in flow. In the Mediterranean context in particular, the temporal and spatial variability can entail extra challenges in the development of systems for assessing the ecological status (Dallas, 2013).

For the assessment of ecological status, a correct discrimination of natural factors influencing biological community from those related to anthropogenic stress is therefore crucial in order to properly define protection and mitigation measures. The importance of hydraulic conditions is considered by the scientific community as one of the most important factors structuring aquatic biocoenoses. Notwithstanding this and despite the crucial role played by habitat, in terms of flow characteristics, in influencing quality assessments, habitat features are only seldom taken into account in classification systems.

It is important to underline how implementation of habitat and local hydromorphology features in classification methods should be considered all over Europe. These aspects should also be considered in the process of setting RBMPs and measures planning.

The concept of river restoration is directly connected with these topics. In particular, excluding the restoration of water quality, river restoration is generally addressed to the manipulation of habitat structure and flow in order to mitigate the effects of anthropogenic disturbance (Feld et al., 2011).

Within this framework, INHABIT project, aims at achieving a better understanding of which aspects of habitat are more relevant for aquatic biocoenoses and classification of ecological status.

The present paper describes in a nutshell the general INHABIT framework for rivers, approaching the complex subject of the interactions between the effects of natural variability and anthropogenic disturbance on biotic communities.

The text is intended to support the reading of the papers included in the Deliverable, each dedicated to a specific issue addressed in the project. The water bodies considered for describing INHABIT framework are located in Sardinia (see also Erba et al., 2011 and INHABIT D1d5.2, 2013).

2. GENERAL FRAMEWORK

2.1 Theoretical basis of INHABIT project

The project INHABIT has focused its attention to the analysis of habitat related issues, and how these may affect the assessment of ecological status and the evaluation of effectiveness of protection / restoration measures; more in general, INHABIT considers how habitat features are related to biological communities (i.e. macroinvertebrates). Investigated river sites were selected to represent a gradient of morphological alteration, degradation of land use and habitat. At the same time they were not altered in terms of poor water quality (i.e. water bodies are generally characterized by good water quality). Figure 1 summarizes the overall picture of the features concurring in the definition of the ecological status, highlighting the aspects directly considered by INHABIT project. Displayed features are known in literature as - directly or indirectly - affecting biocoenoses composition changing habitat availability (e.g. Feld et al., 2011; Naura et al., 2011; Rui et al., 2011). Within the project the relationships between biological metrics and key habitat features have been analysed, in order to quantify the influence of these aspects on biological metrics and, if necessary, suggest possible adjustments for classification systems. Both natural (e.g. INHABIT I3d1.2, 2013) and anthropogenic (e.g. INHABIT D1d5.2, 2013; INHABIT D1d5.3, 2013) variability was then assessed for the features marked in bold in Figure 1.

It is important to stress that before drawing any inference about the environmental status, it would be appropriate to quantify the natural variability of the aspects considered as relevant for biological communities (e.g. flow types, substrate types, deposit / erosion features, habitat diversity, etc.), also when anthropogenic impacts are negligible. Such quantification is crucial for the definition of classification uncertainty.

Habitat features have been quantified by means of the CARAVAGGIO method allowing the collection of the following information:

1) type and grade of morphological alterations (HMS); 2) diversification, and quality of river and perifluvial habitats (HQA); 3) type of land use (LUI); hydraulic habitat in terms of lentic-lotic character (LRD).

We examined the relationship between the mentioned habitat elements and invertebrate communities, in terms of classification metrics and additional metrics, that can be calculated on the basis of the obtained taxalist and potentially providing additional information, in terms of relationship with habitat descriptors. Although most of the obtained results focused on relationships between biological metrics (or benthic taxa) and CARAVAGGIO descriptors, it is important to highlight that the CARAVAGGIO allows the collection of a wide variety of features, not necessarily merged into ‘single value' descriptors. Each of such features may also be analyzed accordingly.

Although it was not among the main objectives of INHABIT project to test the effectiveness of ecological quality restoration measures, some proposals have been suggested in order to identify how alterations removal or modulation of water release - from the viewpoint of ecological flows - may improve habitat quality (INHABIT I3d1, I3d2.2, 2013). Within INHABIT conceptual framework, some elements commonly included in river restoration actions were also considered (see next chapter), in order to verify how INHABIT project results can comply with 'river restoration' approaches, considering, however, the goal of the project for the proposal of RBMPs additional measures.

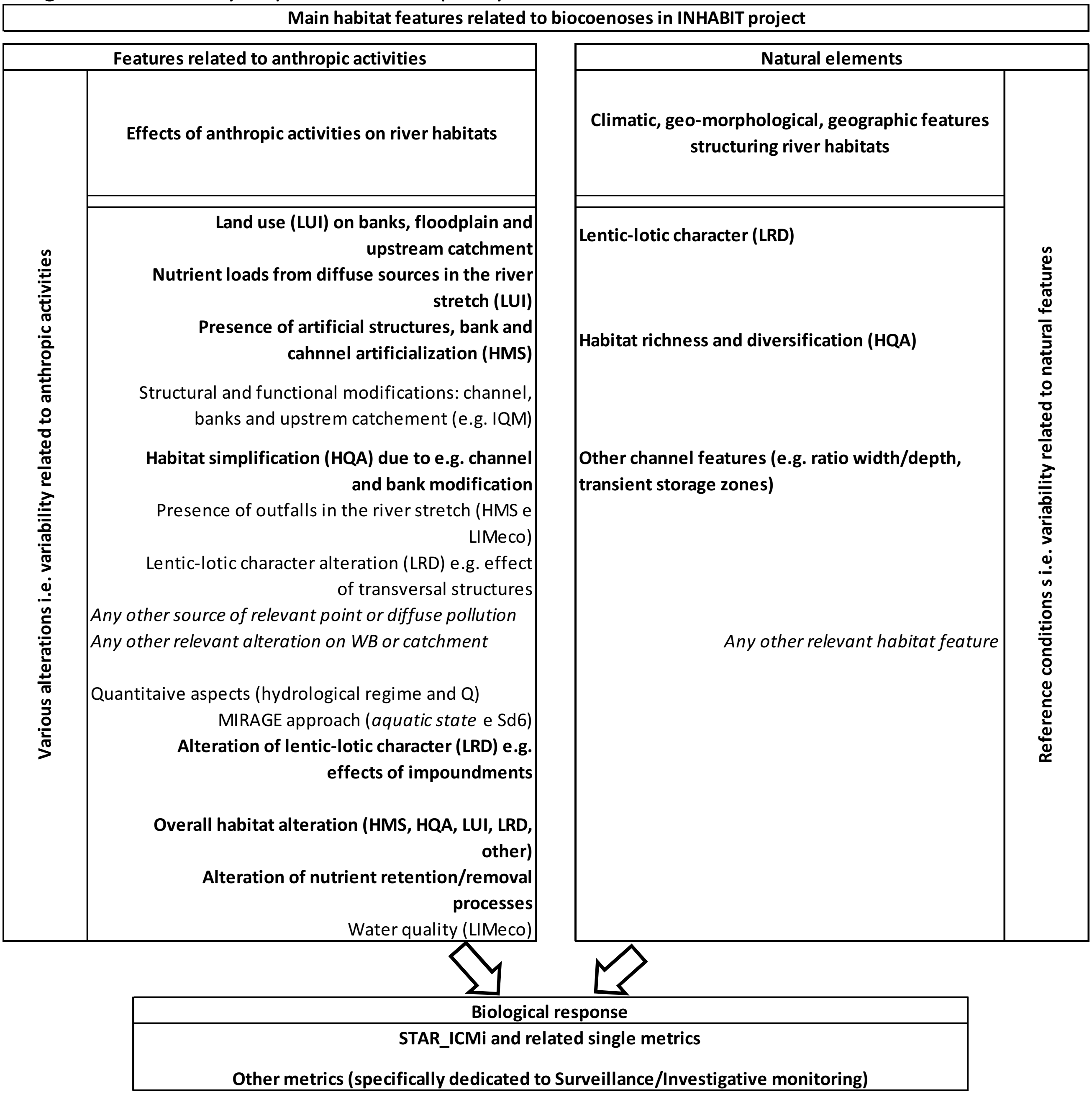

Fig. 1. Main overall habitat features considered in INHABIT project. In the left side of the diagram artificial features causing direct or indirect alteration of habitat characteristics are reported. In the right side of the diagram natural elements defining the overall habitat features observed in relatively

"undisturbed" conditions (e.g. in reference conditions). In bold: features explicitly considered in INHABIT.

3. TOWARDS AN EFFECTIVE CONNECTION BETWEEN HABITAT MEASURES AND THE VERIFICATION OF THEIR EFFICACY

The concept of ' river restoration ' has become important in recent years in relation to the procedures of environmental monitoring. In particular, river restoration projects are a common practice especially in the U.S. and have more recently become established in Europe (Feld et al. , 2011). Water pollution, the intensive use of floodplains and habitat degradation does affect most European rivers. The river functionality can be severely impaired by many human factors affecting water bodies. Loss of species can be experienced and exploitation of water resources may fatally compromise water uses. WFD was issues in order to set protection and restoration objectives of water bodies and requires the achievement of good status for all water bodies by 2015. If the goal cannot be achieved, ecological quality restoration measures must be put in place. Within this perspective, 'river restoration' has gained greater relevance by aiming at satisfying regulatory requirements and measures planning.

Within this context, WISER project **(http://www.wiser.eu/results/conceptual-models/index.php)** suggested a number of conceptual models aimed at summarizing three of the main categories of restoration measures feasible in riverine areas (Figure 2). The models aim in particular to illustrate the relationships between the restoration measures, i.e.: riparian buffers, improvement of channel mesohabitats and impoundments removal and their effects on aquatic habitats and biological communities (BQE), benthic algae, macrophytes, benthic invertebrates and fish. Literature references used to derive the models are mostly related to studies explicitly associated to actions habitat restoration and several, more theoretical works were not considered.

Regarding the use of these conceptual models for the purposes of INHABIT project, three important aspects have to be considered:

- the lack of explicit connections between elements in the models / explanatory diagrams, does not mean that the interaction between the two elements is not important, but that no literature reference was not found on the matter;
- some status indicators, among those considered, are entirely missing or only partially considered. Among these - particularly relevant for INHABIT subjects - : nutrient removal, flow heterogeneity, variability of water depth, habitat complexity;
- Although the models allow to derive useful information for other BQEs, results here presented will focus primarily on benthic invertebrates, for which sufficient data are available to formulate considerations and derive reliable conclusions.

Conceptual models delivered by WISER may provide useful information for river restoration (Feld et al., 2011). However, WISER project has also highlighted how:

- Very often, only effects related to 'taxa richness' - often in a qualitative way - are quantified for benthic invertebrates, while other aspects of the benthic community remain unexplored;
- Very often the effects of restoration are unproven, and effective improvement is not directly verifiable;
- Even when the effects of restoration have been quantified, models often cannot predict how and what specific management actions affect the biotic communities.

Although as already stated, INHABIT project has not developed dedicated restoration measures, it is possible to consider that for the features highlighted in bold in Figure 2, considered as combined into indices, INHABIT has been able of quantify the relationship between biological metrics and habitat features. Such results are presented in this Deliverable and may be used to acquire supporting information for water bodies management planning, as specified in the individual papers.

4. DEVELOPMENT OF TOPICS OF SPECIAL INTEREST FOR DATA INTEGRATION OF HABITAT *SENSU LATO* IN WATER BODIES MANAGEMENT

The contributions presented in this Deliverable, listed in Annex 1, are considered as directly connected each other in terms of evaluation of biological response to habitat features.

Specifically, elements related to the observed variability in the studied river systems, will be considered, both related to natural factors (e.g. climate, seasonality, hydrology) and anthropogenic disturbance (INHABIT D1d5.2 , 2013). New approaches more information will be considered, in comparison with previous deliverables, already dealing with such topics. Paper INHABIT D1d5.2 2013 aims at describing environmental gradients structuring macrobenthic communities in the investigated Sardinian rivers. The main results show as , even when anthropogenic disturbance is present, lentic lotic character plays the most important role for the biocoenosis. Only secondarily, communities respond to habitat alteration. As further investigation, invertebrates communities have also been considered in terms of biological metrics (INHABIT D1d5.2 , 2013). In this case, we wanted to investigate what metrics respond to what habitat features, forcing the metrics response to the available habitat features (RDA multivariate analysis). The results confirm the ability of the considered classification system (STAR_ICMi and metrics components) in detecting anthropogenic pressures. Problematic issue is that it is awkward to separate the combined effects of pressure into each single factors. Notwithstanding this, regression analyses dedicated to the most important metrics detected in the RDA, have highlighted how some of the metrics have a better response to the different alteration factors (INHABIT I3d1.2 , 2013) and can therefore be used to verify the effectiveness of the measures.

Also, since flow variations can be particularly relevant in the Mediterranean area in particular, the way adopted by MIRAGE project to consider flow characteristics is presented (INHABIT D1d5.4 , 2013), including some references to the effects of water abstraction. Since, in the context of INHABIT, habitat features were characterized by means of method CARAVAGGIO, a paper (INHABIT D1d5.5, 2013) was dedicated to the presentation of the CARAVAGGIO method. An important aspect in the management of water resources is to analyse how to handle conflicts related to the use of water resources. A contribution has therefore been dedicated to the presentation of these topic (INHABIT D1d5.6 , 2013) .

Lastly, the main results obtained by the project (INHABIT D1d5.7 , 2013) are summarized and grouped in the following themes: Habitat, refining of MacrOper system, self-purification capacity and effectiveness of measures .

	Water quality improvement in low energy watercourses by means of restoration activities on buffer strips		
	Single habitat features	**Single features variability**	**Complex habitat features**
Status variables	**Shading**	**Flow types diversification**	**Nutrinets concentration (P/N)**
	Presence and inclusion of POM *(Particulate organic matter)*	**Variability of water depth**	**Presence of fine sediments**
	Bank structure		**Temperature**
	Channel forms		Energy/food availability
	LWD *(Large woody debris)*		**Refuge availability**
			Habitat quality and complexity

Improvement of channel mesohabitats		
Single habitat features	**Single features variability**	**Complex habitat features**
Placing of **CPOM**	**Flow types heterogeneity**	**Number and surface of pool areas**
Placing of **boulders**	**Flow reduction**	**Variability of channel depth and width**
Removal of **bank and channel reinforcements**		**Bank stability**
Placing of **gravel/substrate** for fish spawning		**Bars accumulation**
and:		**Substrate diversification**
Placing of **flow groynes/deflectors**		**Habitat diversification**
Building of ***groynes*/gabions**		**Nutrient retention/*Uptake length***

Impoundments removal in low energy watercourses	
Single habitat features (plus connectivity restoration)	
Upstream	**Downstream**
Sediments granulometry	
Channel width	
Flow diversification	**Pool areas**
Water depth	**Depth variability**
Water temperature	**Presence of grave bars**
Oxygen	**Substrate clogging**
	Turbidity

Fig. 2. Scheme of status variables considered in WISER project (http://www.wiser.eu/, WISER, contract No. 226273) for riparian buffer restoration, channel mesohabitat improvement, impoundments removal and effects on overall river habitats and biological communities (BQEs) benthic algae, macrophytes, benthic invertebrates and fish. In bold: features explicitly considered in INHABIT (if only part of the text is in bold: feature considered with a different approach).

5. FINAL REMARKS

Areas in which the project INHABIT may have provided innovative elements and may have covered aspects usually neglected, as also put in evidence by WISER project are listed here below:

The project INHABIT provides elements allowing the identification of biological metrics responding to specific habitat features and human pressure. Such metrics can therefore be selected as more appropriate in order to verify the effectiveness of the measures.

The project INHABIT has investigated the relations between biological metrics and flow variability; this aspect is often overlooked in the classification systems.

The relationship between metrics and biological variability of flow has allowed the quantification of effects when water abstraction is present.

Lastly, INHABIT project has investigated the relationship between habitat features and river functionality for what the removal of nutrients is concerned, providing important information on how to improve river functionality.

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We sincerely thank colleagues, contractors and students who have provided, in various ways, support for the implementation of INHABIT project.

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Annex 1. List of papers presented in Deliverable INHABIT D1d5.

Coding	Title
D1d5.1	INHABIT general framework for habitat measure optimization for the improvement of ecological status in rivers
D1d5.2	Selection of representative biological metrics associated with environmental gradients in temporary streams (Sardinia, Italy): a challenging task for the evaluation of ecological status
D1d5.3	INHABIT: Pressure-Response relationship in Mediterranean temporary streams (Sardegna, Italy)
D1d5.6	A System Dynamic Model to assess the acceptability of river habitat conservation policies
D1d5.7	Local hydromorphology, habitat and Management plans: general framework of INHABIT main results - Rivers

D1D5.2EN – SELECTION OF REPRESENTATIVE BIOLOGICAL METRICS ASSOCIATED WITH ENVIRONMENTAL GRADIENTS IN TEMPORARY STREAMS (SARDINIA, ITALY): A CHALLENGING TASK FOR THE EVALUATION OF ECOLOGICAL STATUS

Authors:

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SUMMARY

The present study is an improvement of knowledge on the use of biological metrics, based on macroinvertebrate communities in Mediterranean temporary rivers (Sardegna, Italy).

The main aim of our study was to select a subset of biological metrics able to (i) discern the different types of disturbance and (ii) respond to the different habitat features present in the study area.

Deciphering how, and under what circumstances, stressors interact and identifying anthropogenic versus natural components (e.g. hydrological regime, flow variation, habitat availability and diversification, habitat hetereogeneity) in a river ecosystems could be considered as a daunting task not only for a correct evaluation of the ecological status but also for helping managers in better identifying the efficacy of restoration measures.

1. INTRODUCTION

Evaluate and predict exactly the effects of different anthropogenic pressures that could insist in an aquatic ecosystem is considered to date a daunting task for both water researchers and managers.

According to Downes 2010 poor information about causality means managers cannot know what rehabilitation or amelioration should be attempted.

One of the main difficulties in detecting correctly the cause-relationship among environmental factors and biological responses is that the different anthropogenic drivers (stressors) present in a system may interact in multiple-ways that are even more unpredictable (Palmer & Yan, 2013). Particularly, interaction among drivers may vary depending on (i) the identity (origin) and intensity of each individual stressor (Lafferty & Kuris, 1999; Hoverman & Relyea, 2007), (ii) the number and combination of drivers (Crain et al., 2008), (iii) the temporal pattern of occurrence (Molinos & Donohue, 2010), (iv) the characteristics and features of the impacted ecosystem (Fitch & Crowe, 2011); (v) the biological response metric examined (Christensen et al., 2006).

In addition, such difficulties increase if we consider that some of the environmental drivers (e.g hydrology, morphology) are naturally influenced (regulated) by larger scale factors, such as geology, orography and the climate present in a data area (Wasson et al., 2002). Based upon the hydrosystems hierarchical control concept, such factors may be considered as main drivers that regulate the morpho-dynamic process and the relative hydro-chemical features of a river’s reach and, consequently, the relative biocoenoses present in a system (Wasson et al., 2006).

Therefore, deciphering how, and under what circumstances, stressors interact and identifying (discerning) anthropogenic versus natural components (e.g. hydrological regime, flow variation, habitat availability and diversification, habitat hetereogeneity) in a river ecosystems could be considered as a daunting task not only for a correct evaluation of the ecological status but also for helping managers in better identifying the efficacy of restoration measures.

For instance, in Mediterranean climate regions, It's widely accepted that streams and rivers are physically, chemically and biologically shaped by high seasonal variability in flow and interruption of superficial water for several months during the dry period (Gasith & Resh 1999; Bonada & Resh 2013).

Therefore, in such peculiar Hydro-ecosystems, environmental factors related to habitat availability also in term of hydrological character (lentic-lotic) could be play a major role and may have great influence on the current systems for the evaluation of the ecological status (CNR-IRSA, 2004; Buffagni et al., 2009; INHABIT I3d1.2 ; Hughes et al., 2010).

Particularly, the use of type-specific assessment systems (as required by the EU Directive2000/60/EC) could limit partially the problems of incurring errors in the assessments due to the natural variability. However, this is not enough, largely in Mediterranean area, where a better quantification of natural variability is required as priority.

Among freshwater organisms that could be considered for biological monitoring, macroinvertebrates are historically the most utilized (Bonada et al., 2006a). In tables 1 and 2 we reported in synthesis the main advantages and difficulties in their utilization in respect to the biomonitoring aspects (Rosenberg & Resh, 1993; Mandaville 2002).

Table 1. Main advantages in the utilization of macroinvertebrates for bioassessment

Advantages
Ubiquitous organism (affected by perturbations in many different habitats)
High number of taxa (the large number of species produces a range of responses)
Long Life-cycle (they integrate conditions temporally)
Sedentary behavior (they stay put, which allows determination of the spatial extent of a perturbation)
Easy sampling methodology
Exhaustive taxonomic information T (presence of a large number of identification key guide in literatures)
Knowledge of response to stress types for many species (literatures informations)

Table 2. Main difficulties in the utilization of macroinvertebrates for bioassessment

Difficulties to take in account
The distribution and abundance of macroinvertebrates may be affected by factors in addition to the perturbation in question;
The distribution and abundance of macroinvertebrates vary seasonally
They move in case of disturbance presence (drift)
May not respond to disturbance of interest for human species (human pathogens)

The main aim of our study was to select a subset of biological metrics, based on macroinvertebrate communities, able to (i) discern the different types of disturbance and (ii) respond to the different habitat features present in the study area (Mediterranean streams of Sardegna, Italy). The relationship among the selected biological metrics and the environmental descriptors utilized will be analysed in details in INHABIT D1d5.3 (2013).

2. METHODS

2.1 Study area

Environmental and species assemblage data were collected from about 35 different streams in different hydrological conditions (spring, summer and winter) during the years 2004, 2011 and 2013 for a total of 71 samples. Data were provided by INHABIT (Tab. 1) and MICARI (Tab 2.) projects. Stream reaches were selected covering the whole quality range present in the geographic area (Sardinian island, Italy) from "reference sites" to human-impacted sites.

More details on study area are reported in Erba et al., 2011 and Cazzola et al., 2012.

Macroinvertebrates were sampled quantitatively following a multi-habitat scheme (CNR-IRSA, 2007) according to the WFD 2000/60/CE requirements and in line with the national legislative (DM 260/2010).

In these protocols microhabitats are sampled proportionally to their presence within a site (25‑50 m). A total of 20 sampling units were collected within each site using a Surber net (area 0.05m2; mesh size 0.5mm): 10 sampling units located in the pool area and 10 in the riffle. The macroinvertebrate taxa were identified mostly at family level using the available identification key-guides (Sansoni, 1988, Campaioli et al., 1994), except for Ephemeroptera, which were treated at the operational unit or species level where possible (e.g. genus or species level how indicated in Tab. 4).

2.2 Environmental descriptors

CARAVAGGIO protocol was used to characterize anthropogenic pressures (habitat and hydromorphological) at reach scale (500m). Based on data collected with CARAVAGGIO several environmental descriptors (HMS,HQA,LUI and LRD) were calculated. Details on such environmental descriptors are fully reported in Buffagni et al 2010.

In addition, the water samples were collected simultaneously with biological samples. On the basis of the concentration of several physical-chemical parameters the LIMeco descriptor was calculated according to the Italian decree DM 260/2010. The parameters considered in the calculation of LIMeco were: oxygen saturation deficit [O%], ammonia nitrogen [N-NH4], nitrate nitrogen [N-NO3], total phosphorous [TP]. LIMeco score ranges from 0 to 1, where 1 represents high water quality. We reported in synthesis the environmental descriptors utilized in Table 3.

In addition, environmental variables that could determine differences in river type (e.g distance source, width) were also taken into account. More details on sampling protocols and data utilized are present in Cazzola et al. (2012b) e Demartini et al. (2012).

Table 3. Environmental descriptors utilized and relative spatial scale investigated.

Descr.	**Pressure**	**Scale**
HMS	Morphological alteration	reach (500m)
LUI	Land USe	reach (500m)
LIMeco	Water pollution	Sampling site
HQA	Habitat diversification	reach (500m)
LRD	Lentic-lotic character (discharge regime)	reach (500m)

Tab. 1 - Sampling sites provided by INHABIT project.

Cod	Stream	Site	Sampling date month/year	Stream reach CEDOC Sardegna	Code ID CEDOC	RAS Type
S1	Barrastoni	Barrastoni	5/2011	Riu Barrastoni	0164-CF001000	21EF7Tsa
S2	Liscia	Valle Lago	5/2011	Fiume Liscia (-02)	0164-CF000102	21IN7Tsa
S3	Cialdeniddu	Cialdeniddu	5/2011	n.d.	n.d.	n.d.
S4	Safaa	Ref	5/2011	Riu della Faa	0170-CS0001	n.t.
S5	Sperandeu	Ref	5/2011	Riu Sperandeu	0171-CF000100	21EF7Tsa
S6	Baldu	Monte Culvert	5/2011	Riu di Baldu	0164-CF000800	21EF7Tsa
S7	Baldu	Down Culvert	5/2011	Riu di Baldu	0164-CF000800	21EF7Tsa
S8	Terramala	Valle Ponte	5/2011	Canale Terramala	0177-CF002500	21EF7Tsa
S9	Terramala	Ref	5/2011	Canale Terramala	0177-CF002500	21EF7Tsa
S10	Saserra	Ref	5/2011	Fiume Posada (-01)	0115-CF000101	21EF7Tsa
S11	Posada	Valle Guado	5/2011	Fiume Posada (-02)	0115-CF000102	21EF8Tsa
S12	Lorana	Monte	5/2011	Riu Lorana	0102-CF003700	21IN7Tsa
S13	Posada Affluente	Posada Af	5/2011	Riu s'Astore	0115-CF001400	21EF7Tsa
S14	Rio San Giuseppe	Solago/Sarossa	5/2011	Riu Orvani	0102-CF002600	21IN7Tsa
S15	Lorana	Valle	5/2011	Riu Lorana	0102-CF003700	21IN7Tsa
S16	Cedrino Irgoli Affl.	Irgoli	5/2011	Riu Santa Maria	0102-CF000200	21IN7Tsa
S17	Flumineddu	Gorroppu	5/2011	Riu Flumineddu	0102-CF005500	21SS3Tsa
S18	Corr'e Pruna	Monte	5/2011	Riu Corr'e Pruna	0035-CF000200	21EF7Tsa
S19	Corr'e Pruna	Valle	5/2011	Riu Corr'e Pruna	0035-CF000200	21EF7Tsa
S20	Corr'e Pruna	Ponte	5/2011	Riu Corr'e Pruna	0035-CF000200	21EF7Tsa
S21	Solana	Solana	5/2011	Riu Solanas	0016-CF000100	21EF7Tsa
S22	Picocca	Ref	5/2011	Rio Picocca	0035-CF000102	21IN8Tsa
S23	Foddeddu	Valle	5/2011	Fiume Foddeddu	0073-CF000102	21IN8Tsa
S24	Porceddu	Porceddu	5/2011	Riu di Monte Porceddus	0035-CF000400	21EF7Tsa
S25	Museddu	Museddu	5/2011	Rio Is Arpas	0065-CS0001	n.t.
S26	Canale	Monte Dep.	5/2011	Riu Bau Samuccu	0067-CF000100	21IN7Tsa
S27	E Gurue	E Gurue	5/2011	Riu Pramaera	0074-CF000102	21SS2Tsa
S28	Tirso	Ref	5/2011	Fiume Tirso	0222-CF000101	21SR1Tsa
S29	Barrastoni	Valle Ponte	3/2013	Riu Barrastoni	0164-CF001000	21EF7Tsa
S30	Barrastoni	monte	3/2013	Riu Barrastoni	0164-CF001000	21EF7Tsa
S36	Tricarai	Valle ponte	3/2013	Riu Tricardi	0073-CF002100	21IN7Tsa
S37	Tricarai	Ref	3/2013	Riu Tricardi	0073-CF002100	21IN7Tsa
S39	Monte pecora		3/2013	n.d.	n.d.	n.d.
S44	Campu e spina		3/2013	n.d.	n.d.	n.d.

Tab. 2 - Sampling sites provided by MICARIproject.

Cod	Stream	Site	Sampling date month/year	Stream reach CEDOC Sardegna	Code ID CEDOC	RAS Type
M1	Girasole	Foce	02/2004	Riu Girasole (-02)	0073-CF001802	21IN7Tsa
M2	Girasole	Foce	06/2004	Riu Girasole (-02)	0073-CF001802	21IN7Tsa
M3	Girasole	Foce	08/2004	Riu Girasole (-02)	0073-CF001802	21IN7Tsa
M4	Mannu	Valle	08/2004	Flumini Mannu (-03)	0001-CF000103	21SS3Tsa
M5	Mannu	Villamar	06/2004	Flumini Mannu (-03)	0001-CF000103	21SS3Tsa
M6	Mirenu	Condotta	02/2004	Riu Girasole (-02)	0073-CF001802	21IN7Tsa
M7	Mirenu	Condotta briglia	08/2004	Riu Girasole (-02)	0073-CF001802	21IN7Tsa
M8	Mirenu	Monte Condotta	06/2004	Riu Girasole (-02)	0073-CF001802	21IN7Tsa
M9	Mulargia	B	02/2004	Riu Arroglasia ([1])	0039-CS0194	n.t. ([1])
M10	Mulargia	B	06/2004	Riu Arroglasia ([1])	0039-CS0194	n.t. ([1])
M11	Mulargia	B	08/2004	Riu Arroglasia ([1])	0039-CS0194	n.t. ([1])
M12	Mulargia	C Intermedio	08/2004	Riu Mulargia (-01)	0039-CF015401	21SS3Tsa
M13	Mulargia	C monte	02/2004	Riu Mulargia (-01)	0039-CF015401	21SS3Tsa
M14	Mulargia	C valle	06/2004	Riu Mulargia (-01)	0039-CF015401	21SS3Tsa
M15	Mulargia	D Foce	02/2004	Riu Mulargia (-01)	0039-CF015401	21SS3Tsa
M16	Mulargia	D Foce valle	08/2004	Riu Mulargia (-01)	0039-CF015401	21SS3Tsa
M17	Mulargia	D Ponte	06/2004	Riu Mulargia (-01)	0039-CF015401	21SS3Tsa
M18	Mulargia	ref	02/2004	Riu Bau Longu ([1])	0039-CS0186	n.t. ([1])
M19	Mulargia	ref	06/2004	Riu Bau Longu ([1])	0039-CS0186	n.t. ([1])
M20	Mulargia	ref	08/2004	Riu Bau Longu ([1])	0039-CS0186	n.t. ([1])
M21	Gorbini	Oleandro ref	02/2004	Riu Girasole (-01)	0073-CF001801	21IN7Tsa
M22	Gorbini	Oleandro ref	06/2004	Riu Girasole (-01)	0073-CF001801	21IN7Tsa
M23	Gorbini	Oleandro ref	08/2004	Riu Girasole (-01)	0073-CF001801	21IN7Tsa
M24	Leni	ref	06/2004	Riu Bidda Scema	0001-CF002800	21EF7Tsa
M25	Pelau	Ponte	08/2004	Fiume Pelau	0066-CF000102	21SS2Tsa
M26	Su Corongiu	Monte	06/2004	Fiume Fodeddu	0073-CF000102	21IN8Tsa
M27	Su Corongiu	Ponte	08/2004	Fiume Fodeddu	0073-CF000102	21IN8Tsa
M28	Su Corongiu	Valle	02/2004	Fiume Fodeddu	0073-CF000102	21IN8Tsa
M29	Su Lernu	Castagna	08/2004	Riu de su Piricone	0129-CF002200	21EF7Tsa
M30	Su Lernu	monte Padru	06/2004	Riu de su Piricone	0129-CF002200	21EF7Tsa
M31	Su Lernu	ref	02/2004	Riu de su Piricone	0129-CF002200	21EF7Tsa
M32	Su Lernu	ref	08/2004	Riu de su Piricone	0129-CF002200	21EF7Tsa
M33	Su Lernu	Ref monte	06/2004	Riu de su Piricone	0129-CF002200	21EF7Tsa
M34	Su Lernu	Valle	02/2004	Riu de su Piricone	0129-CF002200	21EF7Tsa
M35	Santa Lucia	Confluenza	02/2004	Riu Tricardi	0073-CF002100	21IN7Tsa
M36	Santa Lucia	Ponte	08/2004	Riu Tricardi	0073-CF002100	21IN7Tsa
M37	Santa Lucia	Ponte FS	06/2004	Riu Tricardi	0073-CF002100	21IN7Tsa

2.3 Data analysis

First of all, multivariate analysis was performed on biological data (taxalist). *Principal Component Analysis* (PCA) was chosen after considering the length of gradient (l.g <3) calculated with Dentrended Correspondence Analysis (DCA) according to the indication provided in Ter Braak e Prentice, 1988. Abundance of macroinvertebrate were (logx +1) transformed before the analysis. Interpretation of axis obtained (PCAs) was performed by looking ordination sites and taxa

along the environmental gradients and by means of Pearson correlations among PCAs, environmental descriptors and environmental variables.
Results are not presented in this contribute, since they confirmed how explained in details in CNR-IRSA (2004). Particularly, in line with literature, results confirmed that LRD and HQA descriptors could represent the primary drivers of macroinvertebrate community structure in both mesohabitat (Pool and Riffle), even in presence of multiple anthropogenic pressures.
Successively, Redundancy analysis (RDA) was performed in order to analyse which of biological metrics respond specifically to environmental gradients. RDA was chosen after considering the length of gradient (l.g <3) calculated with Detrended Correspondence Analysis (DCA) according to the indication provided in Ter Braak e Prentice, 1988.
Biological metrics were utilized as response variables, whereas environmental descriptors as predictor variables (e.g. Hering et al., 2006).
Biological metrics included in the analysis were transformed according to Clarke et al. 2006 before performing RDA. All the metrics considered and the way of mathematical transformation utilized are reported in Table 4.
The environmental descriptors used in RDA as constrictor variables (predictors) were: HMS, HQA, LUI, LRD and LIMeco. Thus, predictors utilized represent the environmental gradients in terms of both anthropogenic alteration (land use transformation, morphological alteration, habitat modification) and habitat availability (LRD, lentic lotic character and water quantity). LIMeco was also included as indicator of water pollution (organic pollution and nutrient enrichment).
In addition, supporting RDA results, we reported in Appendix A Person's correlation values among RDA scores (RDAs) and several environmental variables used for the characterization of river types.

All statistical analyses were performed with PAST ver.1.94b (Hammer, Harper & Ryan, 2001) and the "vegan" library (Oksanen, 2013) within the R statistical package (R version. 2.13.1).

2.4 Biological metrics: calculation and selection

A Large set of biological metrics were calculated for each samples (s Riffle =71; s Pool=71); the metrics tested were selected from literature and experimental data (un-published data) mainly on the bases of:

- the requirements of WFD Directive 2000/60 /CE (Tolerance, Richness, Abundance, Diversity)
- easier identification level (family level for all the taxa, except for Ephemeroptera that were identified at operational unit level)
- disturbance response known in literature

For each metrics tested, an indication of their response to stress and the relative references were reported in table 4.
To allows redundancy in the dataset (in presence of autocorrelation among similar metrics), we select a- a subset of representative metrics to include in RDA (see data analysis for details).
Selection of metrics was performed based on the followers criteria:

(i) Higher ecological value (literature information)
(ii) Affinity to anthropogenic stress to detect
(iii) Easier identification

.
The pool of metrics listed in tables 4 were derived in large part from those proposed by AQEM consortium (2002) as sensible to anthropogenic alteration.
Several metrics provided by AQEM were adapted in the local region (Sardegna).

In addition multimetric index (STAR_ICMi), was also calculated. The STAR_ICM index was developed during the intercalibration exercise between member states of EU (European Commission, 2008) and is based on family level identification.

However, as indicated in table 4 the Star_ICMi was not included in the RDA since was considered as a synthetic index, whereas we preferred to include in the analysis the singular metrics that compose the multimetric index.

In addition we included a few metrics provided by unpublished data that seems to respond to different environmental drivers.

Asterisks in table 4 indicate the biological metrics included in RDA

All the metrics were calculated using the softwares MacrOper.ICM (Buffagni & Belfiore, 2013) and the software ASTERICS (http://www.fliessgewaesser-bewertung.de/en/download/berechnung/)

Tab. 4 - Biological metrics based on macroinvertebrate communities analysed (*= subset of metrics included in RDA to avoid autocorrelation and redundancy in the data. see text for details)

Acronym	**Metrics**	**References**	**Main response**	**Metric type and trasformation**
DIPB_Siph_G*	Ab. Ceratopoginidae, Culicidae e Syrphidae e *Siphlonurus*	Buffagni et al., 2004	Organic pollution	
Amut*	Ab. *Baetis muticus*	Buffagni et al., dati non publicati	Generic	
LEPab*	Ab. Leptophlebiidae	Buffagni et al., dati non publicati	Generic	
SEL_T_GS*	Ab. Trichoptera (Brachycentridae, Goeridae,Sericostomatidae, Odontoceridae)	AQEM, 2002	Generic	
TAX_DIP	Ab. Selected Diptera (Dixidae, Empididae, Stratiomyidae, Dolichopodidae, Athericidae)	AQEM, 2002	Generic	
Sel_EPH_M*	Ab. Ephemeroptera selezioanti (*B. cfr. rhodani, Ecdyonurus,Habrophlebia*)	AQEM, 2002	Habitat/Morphology	
Sel_PLE_G*	Ab. Plecoptera selezionati (Nemouridae, *Leuctra*, Perlidae)	AQEM, 2002	Generico	
Sel_nonEPT	Ab. Non EPT (Ancylus, Lumbriculidae, Micronecta, Gyrinidae, Limnephilidae, Odontoceridae)	AQEM, 2002	Habitat/Morphology	
DUGLIM*	Ab. *Dugesia sp*. e *Lymnea sp.*	AQEM, 2002	Habitat/Morphology	Abundance Individuals (√√)
DIPab*	Ab. Diptera	AQEM, 2002	Habitat/Morphology	
TRIab*	Ab. Trichoptera	AQEM, 2002	Habitat/Morphology	
IND*	Total number of Individuals	AQEM, 2002	Generico	
Sel_EPH_GN*	Ab. Ephemeroptera (*Procloeon, Centroptilum, Ecdyonurus*)	AQEM, 2002	Generico	
Sel_TRI_GN*	Ab.Trichoptera (Odontoceridae, Limnephilidae, Polycentropodidae)	AQEM, 2002	Generico	
LEUCAL	*Ab. Leuctra sp*. e *Calopteryx sp*.	AQEM, 2002	Habitat/Morphology	
ELM	Ab. Elmidae	AQEM, 2002	Habitat/Morphology	
LUM	Ab. Lumbricidae	AQEM, 2002	Habitat/Morphology	
TUB	Ab. Tubificide	AQEM, 2002	Habitat/Morphology	
Sel_OLICHI_SA*	Ab. Naididae, Tubificidae e Chironomidae	Buffagni et al., dati non publicati	Habitat/Morphology	
Sel_TRI_SA	Ab, selected Trichoptera (Leptocaeridae+Rhyacophilidae+Glossosomatidae)	Buffagni et al., dati non publicati	Habitat/Morphology	
HEP_SA	Ab. Heptagaenidae (Electrogena)	Buffagni et al., dati non publicati	Habitat/Morphology	
BAE	Ab. Baetidae	Buffagni et al., dati non publicati	Temporaneity (Habitat and LRD)	
Baetis	Ab. *Baetis sp.*	Buffagni et al., dati non publicati	Temporaneity (Habitat and LRD)	
BAE_nonb	Ab. Baetidae non Baetis	Buffagni et al., dati non publicati	Temporaneity (Habitat and LRD)	
Foss*	Ab. Fossorials (Tabanidae+Tipulidae+Limonidae+Lumbricidae+Athericidae)	Femminella, 1996	Temporaneity (Habitat and LRD)	

Tab. 4 continues

Tab. 4 – continues from previous page

Acronym	Metrics	References	Main response	Metric type and trasformation
N_PLE	Number of Family di Plecoptera	AQEM 2002	Habitat/Morphology	Diversity (number of taxa), (√)
N_TRI	Number of Family di Trichoptera	AQEM 2002	Habitat/Morphology	
N_PT	Number of Family di Plecoptera e Tricotteri	AQEM 2002	Habitat/Morphology	
OU	Number of operational unit Ephemeroptera	Buffagni, 1997	Habitat/Morphology	
N_OCH*	Number of Family di Odonati + Coleoptera + Hemiptera Heteroptera	Bonada et al., 2006b	Temporaneity (Habitat and LRD)	
N_Fam*	Total Number of Family	Buffagni et al., 2005; AQEM 2002	Habitat	
N_EPT*	Number of Family di Ephemeroptera+Plecoptera+Trichoptera	Buffagni et al., 2005; AQEM 2002	Habitat	
%ARG	Clay preferences	AQEM, 2002	Habitat/Morphology	Percentage [%], arcsine(√(x/100))
FIL	Active filters [%]	AQEM, 2002	Habitat/Morphology	
BOR	Burrowing [%]	AQEM, 2002	Habitat/Morphology	
shred*	Shredders [%]	AQEM, 2002	Trofia	
pred*	Predatori[%]	AQEM, 2002	Trofia	
GrazScre*	Grazer and scrapers [%]	AQEM, 2002	Trofia	
EFE*	Ephemeroptera [%]	AQEM, 2002	Habitat/Morphology	
ASPT*	Average Score Per Taxon	Armitage et al., 1983; AQEM, 2002	Water Quality	Biotic Index, none (x)
MTS*	Mayfly Total Score	Buffagni, 1997	Generic	
MAS*	Mayfly Average Score	Buffagni, 1997	Habitat/Morphology	
BMWP	Biological Monitoring Working Party	Armitage et al., 1983; AQEM, 2002	Organic Pollution and Nutrient enrichment	
LIFE*	Lotic-invertebrate Index for Flow Evaluation	Extence et al., 1999	Temporaneity and hydrology	
Margalef*	Margalef Diversity Index	AQEM, 2002	Generic	
RETI	Rhithron Feeding Type Index	AQEM, 2002	Generic	
STAR_ICMi	STAR_ICMi	Buffagni & Erba, 2007	Generic	
GOLD*	1-GOLD	Pinto et al., 2004; Buffagni & Erba, 2007	Habitat/Morphology	
SHA*	Shannon Index	Buffagni & Erba, 2007	Generic	
EPTD*	log(SelEPTD+1)	Buffagni & Erba, 2007	Habitat/Morphology	
EPT_OCH	nEPT/(nEPT+nOCH): Number of Family di Ephemeroptera, Plecoptera, Trichoptera, Odonata, Coleoptera, Heteroptera	Bonada et al., 2006b	Temporaneity (Habitat and LRD)	Ratio (abundance), (√√)/(√√)
Baetis_BAE*	*Baetis*/Baetidae	Buffagni et al., unpublished data	Temporaneity (Habitat and LRD)	
BAEnonb_BAE	Baetidae (non *Baetis*)/ Baetidae	Buffagni et al., unpublished data	Temporaneity (Habitat and LRD)	
Baetis_BAEnonB	Baetis / Baetidae (non *Baetis*)	Buffagni et al., unpublished data	Temporaneity (Habitat and LRD)	
Foss_Baetis	(1+Fossorials)/(1+*Baetis*)	Buffagni et al., unpublished data	Temporaneity (Habitat and LRD)	

3. RESULTS AND DISCUSSION

RDA results were reported in Table 5 for pool and riffle respectively. In both analysis environmental descriptors, utilized for generate the main environmental gradients present in the study area, resulted significant constrictor variables (ANOVA test p<0.01). However only 25 % of variance in biological metrics were explained utilizing such descriptors.

Tab. 5 – Summary of Redundancy Analysis (RDA) based on biological metrics and environmental descriptors

	Pool		Riffle	
Part Var	Inertia	Proportion	Inertia	Proportion
Total	1.9425	1	1.9116	1
Const**.**	0.4712	0.2426	0.3924	0.2053
Unconst.	1.4713	0.7574	1.5192	0.7947

Tab. 6 - Summary of Redundancy Analysis (RDA) in Pool: Coefficients (Biplot scores) obtained for each of environmental descriptors utilized as constraining variables. In grassetto i valori di associazione più elevati. Higher values are reported in bold

Mesohabitat	*Pool*			
Results of RDA	RDA 1	RDA 2	RDA 3	RDA 4
Eigenvalue	0.23	0.09	0.08	0.04
Proportion Explained	0.12	0.05	0.04	0.02
P-value	<0.01	<0.01	<0.01	<0.01
constraining variables				
LRD	0.48	-0.48	**-0.71**	0.18
HQA	**-0.84**	0.17	-0.30	-0.42
HMS	0.66	**0.63**	-0.04	0.40
LUI	0.50	0.31	-0.04	0.47
LIMeco	-0.52	-0.27	-0.10	**0.68**

Concerning Pool mesohabitat (Table 6, Figure 1) **RDA1**, the axis that explain the major fraction of variance, synthetize the anthropogenic gradient of alteration. Unfortunately, since all the environmental descriptors utilized resulted associated in RDA1 it was impossible deciphering the different components of anthropogenic alteration.

RDA 2, resulted major influenced by morphological alteration constrained mainly by the HMS. Thus, biological metrics, that were more related to such axis, could be utilized as indicator of morphological alteration.

RDA 3, resulted influenced by hydrological features summarized in LRD descriptor. Particularly, LRD descriptor resulted an independent and orthogonally factors in respect to the other descriptors. Therefore, biological metrics more related to RDA3 could be utilized to provide information useful to describe the presence of water abstraction, flow variation and water quantity.

RDA 4, resulted associated to organic pollution and nutrient enrichment synthetized by LIMeco.

Moreover, the results reported in Appendix show that singular environmental variables provide minor information comparing to the environmental descriptors utilized.

Particularly, Pearson's correlation values obtained among each singular factor and the derived RDAs were largely <0.3; although N-NO3 resulted the variable with higher Pearson's correlation value, LIMeco descriptor received higher value in both pool and riffle (Tabella 6 e 7, RDA4).

However, only 25% of variance was explained summarizing the first four axis. The reason of such low percentage explained could be related to the fact that only few biological metrics specific to particular anthropogenic impact (derived by literature) were included in RDA in respect to the larger number of biological metrics that show a generic response to stress

(Table 4). Thus we overpass the % of variance since we were interested in detecting specific response to stress derived by singular biological metric.

Ordination obtained by the first three axis were plotted in Figure 1. Scores for each metrics were reported in Appendix B.

Sel OLICHI_SA, DipAb and IND were positive related to RDA1 (anthropogenic impact gradient), Thus they presented an increasing response to stress. On the other hand, sel_TRI_GN, ASPT, N_EPT were positive related to HQA and LIM, therefore their values decrease with increasing stress (Decrease Response).

GOLD, LEPab ed EPTD were negative related to RDA 2 (morphological impact gradient), whereas Sel_OLICHI_SA, Baetis_BAE e DUGLIM were positive related. Among this metrics, some of them were also related to RDA 1 and RDA3, indicating that such metrics could be influenced by generic alteration and hydrololgical character.

Concerning the specific relation to the lentic-lotic character (LRD) nOCH e pred (extreme bottom of the ordination plot) were positive related to LRD. Their values increase with increasing of lentic condition. On the other hand, Baetis/Baetidae, LIFE, SelEPH_M, Grazer/Screpers (extreme top of the ordination plot) risulted negative correlated with LRD.

We didn't considered relationship among metrics and RDA4, since this axis is expression or water quality (mainly organic pollution) and numerous studies have yet investigated such relationship (Zimmerman 1993, Sandin & Hering, 2004; Friberg et al., 2009). However, from the results reported in Appendix B it's possible select TRIab, Sel_TRI_SA e Sel_EPH_GN (extreme positive of RDA4) and Sel_TRI_GN, LEUCAL and pred (extreme negative of RDA4).

Concerning Riffle mesohabitat (tabella 7, Figura 2)**, RDA 1** resulted high related to HQA (sc=-0.87), followed by HMS (sc=0.58), LIMeco (sc=-0.58) e LUI (sc=0.52).

According to the results obtained in pool, RDA1 synthetize the anthropogenic gradient of alteration. Unfortunately, since all the environmental descriptors utilized resulted associated it was impossible deciphering the different components of anthropogenic alteration

RDA 2 was exclusively associated to LRD (sc=0.92), whereas **RDA 3** was negative associated to HMS (sc=-0.59).

Thus, LRD gradient was independent to the others gradient identified, confirming how obtained in pool.

Ordination of metrics and environmental descriptors, obtained by the first three axis, were plotted in Figure 2. Scores for each metrics were reported in Appendix C.

Tab. 7 -Summary of Redundancy Analysis (RDA) in Riffle: Coefficients (Biplot scores) obtained for each of environmental descriptors utilized as constraining variables. In grassetto i valori di associazione più elevati. Higher values are reported in bold

Mesohabitat	*Riffle*			
Results of RDA	RDA 1	RDA 2	RDA 3	RDA 4
Eigenvalue	0.21	0.07	0.05	0.04
Proportion Explained	0.11	0.04	0.03	0.02
P-value	<0.01	<0.01	<0.01	<0.01
constraining variables				
LRD	0.38	**0.92**	-0.01	0.1
HQA	**-0.87**	0.02	-0.23	-0.43
HMS	0.58	-0.18	**-0.59**	0.52
LUI	0.52	-0.04	-0.27	0.51
LIMeco	-0.58	0.24	0.32	**0.62**

Among the metrics that were most influenced by the environmental constrictors we could

select Sel_OLICHI_SA, DIPab e IND as positive correlated to RDA 1 (generic anthropogenic gradient), whereas nEPT, ASPT as negative correlated.
Similarly to pool results Sel_EPH_M, GrazScre, LIFE e Baetis_BAE, TAX_DIP, EPTD, N_OCH were strong related to RDA 2 (hydrological gradient, LRD)
RDA3, that in riffle analysis resulted associated to morphological degradation, was associated with
LEPab, GOLD, EFE e DUGLIM (similarly to pool)

Sel_EPH_GN, TRIab, Sel_TRI_SA, LEUCAL, EPTD, LEPab resulted associated with RDA 4 (organic pollution and water quality).

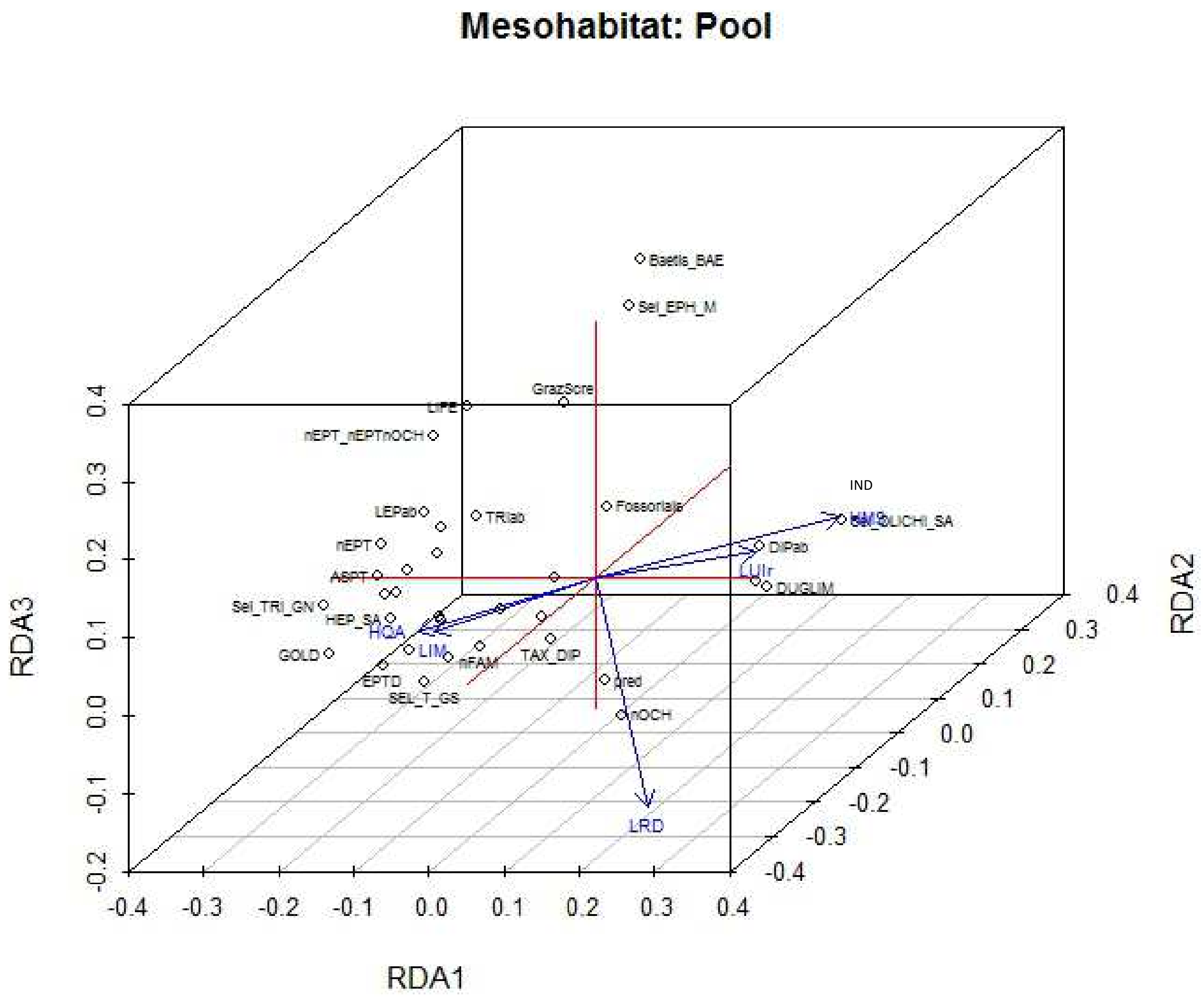

Fig. 1 – Redundancy Analisis in pool mesohabitat. Ordinations bi-plot for biological metrics and environmental gradients based on HMS, HQA, LUI, LIM e LRD descriptors. Acronyms used for metrics are reported in table 3

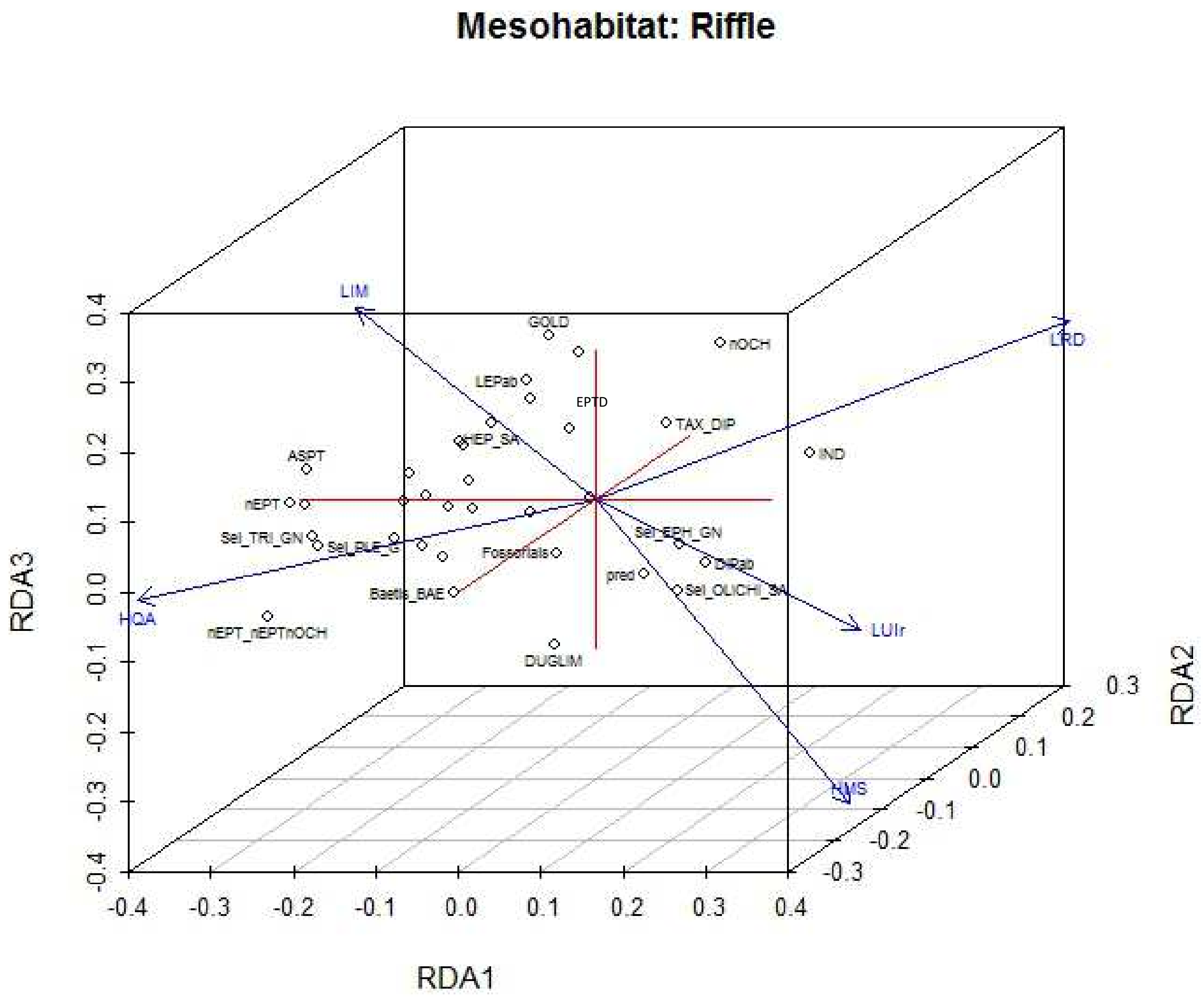

Fig. 2 – Redundancy Analisis in riffle mesohabitat. Ordinations bi-plot for biological metrics and environmental gradients based on HMS, HQA, LUI, LIM e LRD descriptors. Acronyms used for metrics are reported in table 3

4 CONCLUSIONS

In conclusion, our findings indicate how natural complexity inherent in these systems presents urgent challenges for ecological status assessment. Particularly, new tools able to discern anthropogenic stressors from those factors that naturally forced Mediterranean river systems are requested not only for a correct evaluation of the ecological status but also for helping managers in better identifying the efficacy of restoration measures.

Unfortunately, on the basis of our results, since all the environmental descriptors utilized resulted associated in RDA1 it was impossible deciphering the different components of the main anthropogenic alteration gradient.

In contrast to the results obtained from macroinvertebrate community analysis (CNR-IRSA (2004; Erba et al., 2012) LRD was not selected as the primary drivers of biological metrics. However LRD descriptor resulted an independent and orthogonally factor in respect to the other descriptors. Therefore, it was possible select metrics useful to provide information describing the presence of water abstraction, flow alteration and water quantity.

More in details, two main groups of metrics were identified: one reflecting the overall anthropogenic gradient of alteration, with some possibilities in discriminating particular anthropogenic stress (e.g. habitat alteration) and the other one reflecting exclusively the water level and the hydrological condition.

In particular, among biological metrics that were strong related to the anthropogenic stressor gradient we selected: ASPT, N_EPT, EPTD, GOLD (All metrics included in STAR_ICMi, the multimetric index utilized for the quality judgment in line with the national normative) and Sel OLICHI_SA, DipAb, sel_TRI_GN, e LEPab.

On the other hand, among biological metrics that seemed more related to water abstraction and water quantity we selected: number of Odonata, Coleoptera and Heteoptera (nOCH, positive correlated to LRD), the LIFE index and the ratio *Baetis*/BAETIDAE (negative correlated to LRD) , with particular efficiency for pool mesohabitatat.

Pool mesohabitat seemed potentially more appropriate to separate the gradient of alteration by the general hydrological gradient connected to LRD.

Acknowledgments

We would like to sincerely thank: Mariano Pintus, Maria Gabriella Mulas, Martina Coni, Roberto Coni, Giuliana Erbì, Elisabetta Massidda, Michela Olivari, Simona Spanu (Regione Sardegna) who contributed to sampling activities and data processing.

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Appendix A. Pearson's correlation coefficients (r-Pearson) among first 4 RDAs and several environmental variables (not included in RDA as constrained variables. Coefficient > 0.35 were reported in bold.

Mesohabitat	*Pool*				*Riffle*			
Environmenatl variables	**RDA1**	**RDA2**	**RDA3**	**RDA4**	**RDA1**	**RDA2**	**RDA3**	**RDA4**
Distance of Source	0.18	0.03	-0.06	-0.12	0.18	0.04	-0.10	-0.11
Slope *thalveg*	-0.28	-0.33	0.12	-0.08	-0.26	0.04	**0.37**	-0.13
Q_ist	-0.04	0.11	0.21	0.07	-0.04	-0.22	0.02	0.10
Suspended solids*	**0.42**	-0.23	-0.20	0.30	**0.44**	0.31	0.09	0.26
Mean Precipitation (Hystorical data series)*	**0.44**	-0.05	0.10	-0.24	**0.46**	-0.03	0.01	-0.24
Valley form	0.04	-0.04	-0.19	-0.10	0.02	0.15	-0.08	-0.12
Channel form	-0.11	-0.17	-0.03	-0.22	-0.07	0.07	0.14	-0.28
Mean substrate size)	-0.13	-0.08	-0.02	-0.06	-0.15	0.04	0.07	-0.07
Main channel width	0.15	**0.42**	0.00	0.09	0.07	-0.18	-0.42	0.20
Main channel mean depth	0.02	0.21	0.00	0.22	-0.03	-0.08	-0.18	0.28
Channel width	0.16	0.27	-0.07	0.27	0.08	-0.04	-0.30	0.35
Ratio Main channel width/total width	-0.15	-0.21	0.20	-0.05	-0.07	-0.07	0.33	-0.10
Mean bank width	**-0.36**	-0.21	-0.13	-0.23	**-0.38**	0.18	0.13	-0.26
Mean banktop height	0.06	0.28	0.03	0.25	0.04	-0.17	-0.20	0.28
Number of wetted channels	-0.06	-0.04	-0.27	0.00	-0.10	0.26	-0.08	-0.02
Water Temperature	0.23	0.20	0.06	0.26	0.23	-0.13	-0.13	0.28
Alkalinity (Alk)	**0.47**	**0.36**	0.08	**0.46**	**0.47**	-0.20	-0.26	**0.50**
Vmean_T	**-0.37**	**0.37**	0.15	0.05	**-0.36**	**-0.36**	-0.18	0.09
pH	0.14	0.10	0.10	**-0.44**	0.19	-0.17	-0.10	**-0.42**
O_2	-0.13	-0.02	0.19	-0.04	-0.12	-0.17	0.12	-0.04
$N\text{-}NO_3$	0.21	0.17	0.19	**-0.66**	0.29	-0.30	-0.14	**-0.62**
$N\text{-}NH_4$	0.27	0.25	0.10	-0.22	0.30	-0.21	-0.21	-0.18
$P\text{-}PO_4$	0.23	-0.08	0.10	-0.12	0.28	-0.03	0.07	-0.13
STAR_ICMi	**-0.53**	-0.03	-0.09	0.00	**-0.50**	0.16	0.10	-0.04

*Available data only for MICARI project

Appendix B. Biological metrics scores derived from RDA in Pool mesohabitat. The three values higher and lower (mean high association) for each RDAs were enhanced in colored cell

	RDA1	RDA2	RDA3	RDA4
SEL_T_GS	-0.27	0.08	-0.17	-0.04
DUGLIM	0.05	0.32	-0.16	0.09
nOCH	0.07	-0.07	-0.15	0.02
pred	0.02	-0.01	-0.13	-0.09
LEUCAL	-0.28	0.13	-0.11	-0.10
Amut	-0.20	0.01	-0.11	-0.01
MAR	-0.25	0.01	-0.10	0.01
nFAM	-0.16	0.01	-0.10	0.02
EPTD	-0.23	-0.09	-0.07	-0.05
Sel_EPH_GN	-0.10	0.04	-0.07	0.22
TAX_DIP	-0.02	-0.07	-0.05	0.08
DIPB_Siph_G	-0.13	0.01	-0.04	-0.03
Sel_PLE_G	-0.31	0.11	-0.04	-0.01
IND	0.17	0.07	-0.04	0.05
Sel_TRI_GN	-0.35	-0.02	-0.03	-0.20
ASPT	-0.31	0.04	-0.02	0.01
Sel_OLICHI_SA	0.21	0.20	-0.02	0.00
SHA	-0.27	-0.02	-0.01	-0.01
MAS	-0.16	-0.08	-0.01	0.09
DIPab	0.16	0.11	-0.01	-0.04
Sel_TRI_SA	-0.06	0.00	0.00	0.19
Fossorials	-0.10	0.20	0.00	0.13
nEPT	-0.32	0.07	0.01	-0.03
HEP_SA	-0.18	-0.16	0.02	0.08
shred	-0.26	0.10	0.02	0.08
MTS	-0.22	0.01	0.02	0.07
GOLD	-0.18	-0.31	0.04	0.07
TRIab	-0.19	0.06	0.05	0.14
EFE	-0.12	-0.26	0.09	0.03
LEPab	-0.17	-0.11	0.13	-0.03
nEPT_nEPTnOCH	-0.27	0.10	0.14	-0.03
LIFE	-0.22	0.10	0.18	-0.02
GrazScre	-0.04	-0.01	0.23	0.06
Baetis_BAE	-0.08	0.26	0.29	-0.05
Sel_EPH_M	0.02	0.05	0.33	-0.01

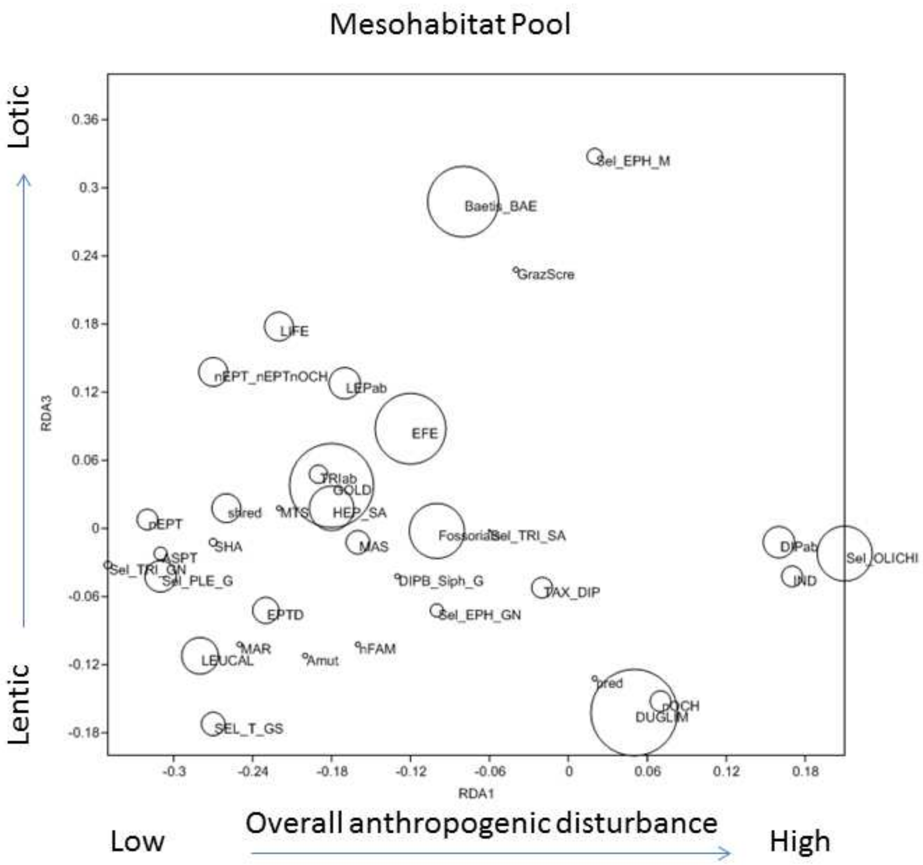

Fig. B1 - Bubble plot for Pool mesohabitat. In graph metrics scores associated with overall anthropogenic (RDA1) and hydrological gradients (RDA3) were plotted. In addition bubble size could be interpretable as association with hydromorphological association (RDA2). Singular values for each metrics were reported in Appendix B. For axis interpretation (RDAs) see details in Table 6 and figure 1.

Appendix C. Biological metrics scores derived from RDA in Riffle mesohabitat. The three values higher and lower (mean high association) for each RDAs were enhanced in colored cell

	RDA1	RDA2	RDA3	RDA4
DUGLIM	-0.06	0.01	-0.21	0.10
pred	0.01	0.10	-0.15	-0.03
Sel_OLICHI_SA	0.12	-0.04	-0.11	-0.03
Sel_EPH_GN	0.05	0.09	-0.11	0.16
Fossorials	-0.07	0.05	-0.10	0.12
nEPT_nEPTnOCH	-0.31	-0.16	-0.10	0.02
shred	-0.20	0.02	-0.09	0.03
LEUCAL	-0.22	0.02	-0.08	-0.11
SEL_T_GS	-0.26	0.03	-0.07	-0.03
Baetis_BAE	-0.08	-0.16	-0.06	0.04
DIPab	0.17	-0.07	-0.06	-0.02
Sel_PLE_G	-0.31	-0.04	-0.05	-0.05
Amut	-0.21	0.06	-0.04	-0.02
MTS	-0.25	0.04	-0.02	0.02
DIPB_Siph_G	-0.02	0.02	-0.01	-0.04
SHA	-0.22	0.02	-0.01	-0.05
nEPT	-0.36	-0.02	0.00	0.01
MAR	-0.27	0.07	0.00	-0.03
TRIab	-0.17	0.04	0.01	0.17
Sel_TRI_GN	-0.26	-0.15	0.01	-0.06
IND	0.21	0.09	0.03	0.04
nFAM	-0.22	0.10	0.03	-0.02
MAS	-0.22	0.10	0.04	0.00
TAX_DIP	0.00	0.16	0.04	0.02
Sel_TRI_SA	-0.11	0.14	0.04	0.26
ASPT	-0.32	-0.05	0.06	0.00
LIFE	-0.25	-0.18	0.07	0.04
EPTD	-0.17	0.16	0.07	-0.09
GrazScre	-0.04	-0.19	0.07	0.13
HEP_SA	-0.17	0.07	0.08	0.04
Sel_EPH_M	0.09	-0.30	0.11	0.07
nOCH	0.04	0.21	0.13	-0.04
LEPab	-0.05	-0.06	0.20	-0.07
GOLD	-0.10	0.08	0.20	0.08
EFE	-0.02	-0.01	0.21	0.04

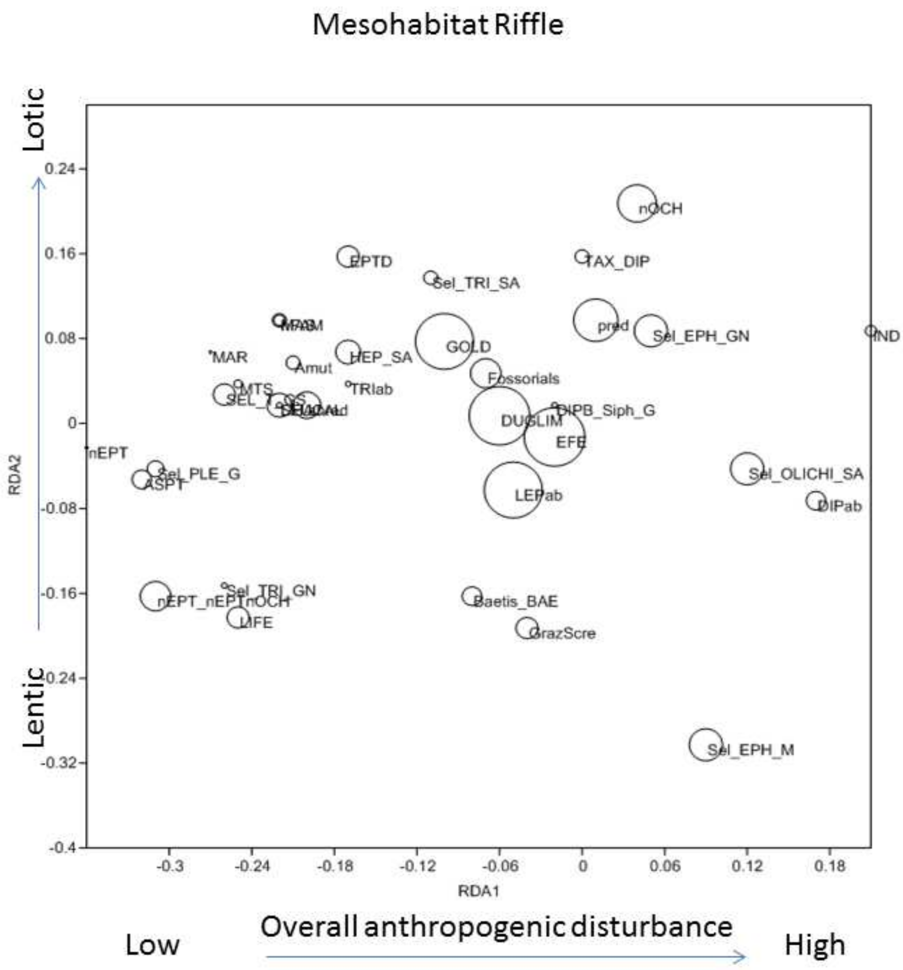

Fig. B1 - Bubble plot for Riffle mesohabitat. In graph metrics scores associated with overall anthropogenic (RDA1) and hydrological gradients (RDA2) were plotted. In addition bubble size could be interpretable as association with hydromorphological association (RDA3). Singular values for each metrics were reported in Appendix B. For axis interpretation (RDAs) see details in Table 7 and figure 2.

D1D5.3EN – INHABIT: PRESSURE-RESPONSE RELATIONSHIP IN MEDITERRANEAN TEMPORARY STREAMS (SARDEGNA, ITALY)

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1. INTRODUCTION

Since the early 1900's (Kolkwitz and Marson 1909) biomonitoring incorporated the use of stream organisms as a basis for pollution detection and to indicate the health of a given system.
The main advantage in the utilization of freshwater organisms for bioassessment is their possibility of integrate conditions temporally and, consequently, achieve a measure of ecosystem health across different spatial and temporal scales.
Generally, management measures to prevent and control water pollution are to date better understood and implemented. On the other hand, evaluate the effect of habitat modification is still scarcely investigated. Thus, it was the focus point of INHABIT project (INHABIT-LIFE08 ENV/IT/000413 www.life-inhabit.it).
One of the main matters related to biomonitoring practices (e.g. INHABIT D1d5.2en, 2013) is evaluate correctly the complexity of cause-relationship among biological indicators used (e.g macroinvertebrates), anthropogenic pressures present (e.g. morphological alteration, organic pollution) and habitat features (e.g lentic-lotic character). Different anthropogenic pressures present in a system may co-exist (multiple anthropogenic effect), interact with habitat features and provide effect on more than one of environmental variables accounted (Friberg 2010, Ormerod et al 2010, Larsen & Ormerod 2013). Consequently, biological indicators analysed may present synergic responses that are even more unpredictable and still scarcely understood (Larsen & Ormerod 2013).
Therefore, understand and evaluate exactly the origin of effects in presence of different anthropogenic pressures that could insist in an aquatic ecosystem is considered to date a daunting task not only for a correct evaluation of the ecological status but also for helping managers in better identifying the efficacy of restoration measures.
Particularly, in presence of multiple pressures is often difficult define exactly causal-relationship among specific alteration (environmental driver) and biological responses.
For example, several common methods used for biomonitoring practices (e.g. simple regression) focused exclusively on changes in the mean response between a biological metric and an environmental variable.
However, according to Cade & Noon (2003), statistical distributions of ecological data often have unequal variation (heterogeneous distributions) due to complex interactions between the factors affecting organisms that cannot all be measured and accounted for in statistical models. Unequal variation implies that there is more than a single slope (rate of change) describing the relationship between a response variable and predictor variables measured on a subset of these factors.
Therefore, In these situations, the concept of limiting factors is useful for data interpretation. Recently, several authors (Rosenbaum 1995, Cade and Noon 2003), suggested that if ecological limiting factors act as constraints on organisms, then the estimated effects for the measured factors were not well represented by changes in the means of response variable distributions, when there were many other unmeasured factors that were potentially limiting. In such case, focusing exclusively on changes in the mean response we can lead to underestimation, overestimation, or a failure to detect changes in heterogeneous distributions.

Thus, the "noise" introduced by the simultaneous presence of different stressors can affect the validity of a model (Canobbio et al., 2012).

Quantile Regression (Koenker & Basset, 1978), a method developed to estimate rates of change in all parts of the distribution of a response variable, has been proposed as well suited method to examine relationships between an environmental driver and a biological response in cases where other influencing factors are unmeasured and unaccounted for, as is often the case with ecological data.

In synthesis, main advantages provided by the use of quantile regression are:

- Quantile regression estimates multiple rates of change (slopes) from the minimum to maximum response, providing a more complete picture of the relationships between variables missed by other regression methods.
- Estimates are more robust against outliers in the response measurements.
- Residuals distribution assumption is not necessary.
- The ecological concept of limiting factors as constraints on organisms often focuses on rates of change in quantiles near the maximum response, when only a subset of limiting factors are measured.

The main aim of our study was to quantify the cause-relationships among a large set of biological metrics (commonly used in biomonitoring for the analysis of macroinvertebrate communities) and a series of anthropogenic pressures and habitat features (habitat diversification, lentic-lotic character, morphological alteration), by means of quantile regression across different Mediterranean streams and in presence of stressor gradients.

We developed a series of technical sheets for each biological metrics analysed (Appendix A), useful to (i) provide, not only to the technical operators but also to the water managements, elements to better understand which metrics to use depending on the presence of impact (ii) identify problems and verify the sensitivity of the different metrics used to different anthropogenic stressors, both central themes within the project INHABIT.

2. METHODS

On the basis of the results obtained by Redundancy analysis (RDA), presented in Pace et al. 2013, several biological metrics were selected to discern the different types of disturbance present in the investigated area.

In table 1 we reported the metrics selected, an indication of their response to stress and the relative references.

For each metrics the response to specific environmental descriptors (anthropogenic pressure and habitat features descriptors) was analysed.

The environmental descriptors tested were:

- **LIMeco**, based on physical-chemical variables provides an indication of water pollution;
- **HMS,** based on hydromorphological data (CARAVGGIO) provides indication of morphological alteration;
- **LUI,** based on hydromorphological data (CARAVGGIO) provides indication of land use alteration
- **HQA** , based on hydromorphological data (CARAVGGIO) provides indication of Habitat quality and diversification;
- **LRD** based on hydromorphological data (CARAVGGIO) provides indication of lentic-lotic character.

Table 1. Biological metrics selected for the Pressure-Response relationships analysis

Metric	Info	Taxa included
ASPT	Tolerance/ Armitage et al., 1983	Whole community
N_Fam	Number of Taxa	Whole community
N_EPT_Fam	Number of Taxa	Ephemeroptera, Trichoptera, Plecoptera
log(SelEPTD+1)	Abundance/ Buffagni & Erba, 2007	Ephemeroptera, Trichoptera, Plecoptera and Diptera
Shannon Diversity	Diversity	Whole community
1-GOLD	Abundance / Buffagni & Erba, 2007	Oligocheta, Gasteropoda e Diptera
STAR_ICMi	Multimetric / Buffagni & Erba, 2007	Whole community
nOCH	Number of taxa / Bonada et al., 2007	Odonata, Coleoptera, Heteroptera
Baetis_BAE	Ratio Baetis/Baetidae	Baetidae (Ephemeroptera)
LIFE	Habitat Preference/Extence et al., 1999	Whole community
Shredders	Trophic roles (ASTERICS software, http://www.fliessgewaesser-bewertung.de/en/download/berechnung/)	
LepAb	Abundance	Leptophlebidae (Ephemeroptera)
MTS	Buffagni, 1997	Ephemeroptera (Operational Unit)
Sel_OLICHI_SA	Abundance	Naididae, Tubificidae e Chironomidae
DIPab	Abundance	Diptera
DIPB_Siph_G	Abundance	Ceratopoginidae, Culicidae e Syrphidae

More details on study area, sampling methodologies and calculation of biological metrics are reported in Erba et al., 2011, Cazzola et al., 2012 and INHABIT D1d5.2en, 2013.

2.1 Data analysis

Models utilizing quantile regression, were recently developed and suggested (Cade et al., 2005) for investigate the complex relation species/habitat because of their strong connection with the ecological concept of limiting factors (Cade et al., 1999).

Two alternative hypothesis (H1 and H2) describing the relationship between the local abundance of an organism and an environmental variable (predictor) were presented in table 2. Particularly, a comparison between results obtained by Ordinary Least Squares (OLS) and Quantile (RQ) regression were presented for each Hypothesis:

For H1 (Central Response) both OLS and RQ give a good description of data.

For H2 (Limiting Response) the uses of RQ is advocated for a better description of the data.

More details are presented in Lancaster & Beleya (2006).

Table 2. Comparison of results provided by Ordinary Least Squares (OLS) and Quantile (RQ) regression

Model	Hypothesis	OLS	RQ
CR	H1: Density of organisms responds primarily to the environmental variable (predictor	High proportion of the variability explained by environmental variable (predictor), e.g. high R2 Realistic estimate of the density range provided by 95% CI	Upper and lower limits provide similar density estimates and are similar in shape, e.g. quantile regression ANOVA indicates similar model coefficients
Model	**Hypothesis**	**OLS**	**RQ**
LR	H2: Density of organisms is limited by several (unmeasured) factors, in addition to the environmental variable (predictor)	Small proportion of the variability explained by environmental variable (predictor), e.g. low R2 Underestimate of the density range provided by 95% CI	Upper and lower limits provide markedly different density estimates and may differ in shape, e.g. quantile regression ANOVA indicates different model coefficients

Following the indication provided in Mims e Olden (2012), quantile regression estimates multiple rates of change (*slopes*) in all parts of the distribution of a response variable, contrary to Ordinary Least Squares regression that, focusing exclusively on changes in the mean response, can lead to underestimation, overestimation, or a failure to detect changes in heterogeneous distributions.
In their study Mims and Olden, characterized relationships between several hydrologic metrics and proportional life history composition in fish communities (on the basis of quantile regression analysis) as:

Strong association: Significant relationships across multiple quantiles suggest that a particular flow parameter is an important predictor of that life history.

Weak association: A weak association in which only one or a few quantiles have significant relationships indicates that a flow parameter is important in driving life history composition across part of the distribution but that other factors (biotic or abiotic) likely play an addition role

Limiting relationships: in which only the upper or lower most quantiles are significant. They are different from weak relationships in that can identify flow parameters acting as“ceilings” and/or “floors” (Konrad et al. 2008).

An important note is that the choice of quantiles represents an arbitrary selection both in terms of the number of quantiles and the position of quantiles throughout the distribution. It is likely that the chance of a Type I error increases with the number of quantiles tested.
For our study, we used the guidelines of $n > 5/q$ and $n > 5/(1-q)$, where q indicate the quantile and n represent the number of sites (sampling size) proposed by Rogers (1992) to determine the limits of reliable extreme quantiles.
In our study the dataset utilized included 77 sites, thus we tested quantiles from 0.1 to 0.9
All quantile regression analyses were performed using the QuantReg package (Koenker 2005) in R 2.11.0 (R DevelopmentCore Team 2005).

3. RESULTS AND DISCUSSION

Results of quantile regressions were reported in table 4 and 5 for Pool mesohabitat, whereas in table 6 and 7 for Riffle mesohabitat. For each of the environmental descriptor tested (indicator of stress or habitat features) the different response metric obtained were presented.
In addition, in Appendix A, we reported the detailed technical sheets for each biological metric analysed, describing their pressure-response relationship.
Particularly, each technical sheet is composed by a graphical material (similar to those reported in Figure 1 as example) and a

descriptive material (reported in Table 3 as example).

Regression lines between each environmental descriptor and biological metrics were plotted for quintiles 0.1-0.4 (lower distribution), 0.4-0.7 (central distribution) and 0.7-0.9 (upper distribution).

For lower and central distribution we tested 6 quantiles; for upper distribution we tested 5 quantiles

For each part of the distribution we assigned a color as function of the numbers of quantiles tested and resulted significant in a data range of the distribution (lower, central or upper).

Conforming to how presented in Mims e Olden (2012) each color assigned could be interpreted as a measurements of the strength of relationship between a particular metric and the environmental descriptor tested:

Blue color correspond to Strong association, where 4/5 (for the upper) and 5/6 quantiles were significant

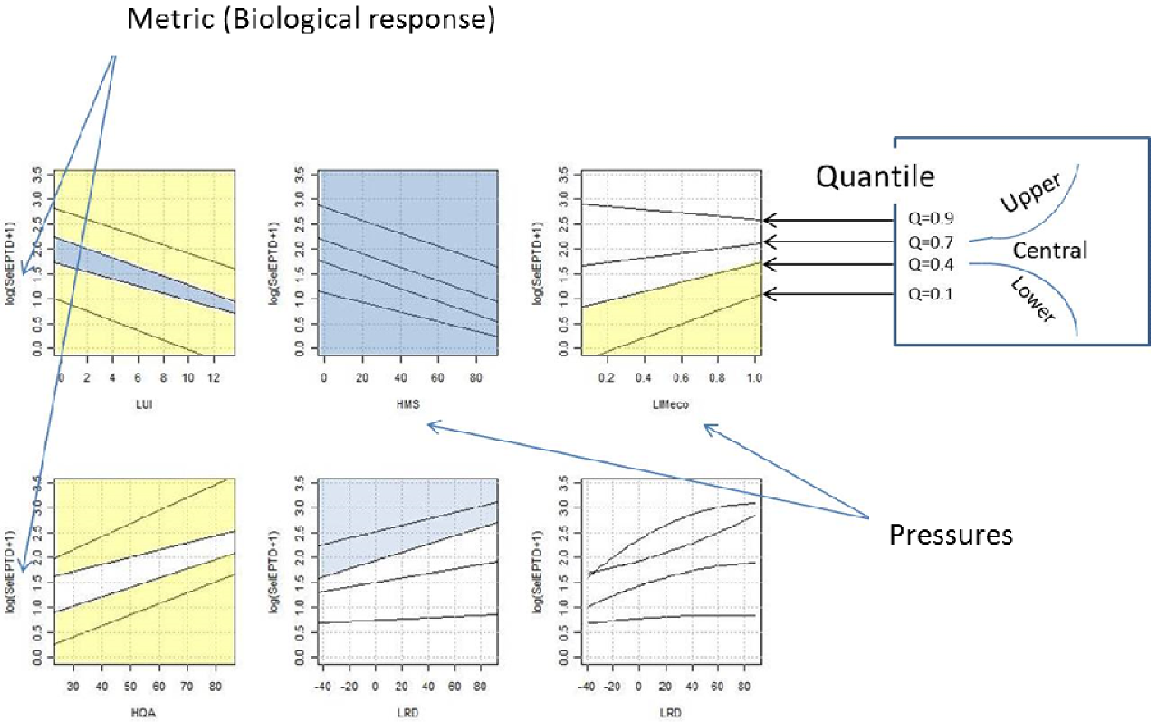
Light blue correspond to Quite Strong (4/6 significant quantiles)

Yellow color correspond to Weak association, where >2/6 and < 4/6 quantiles are significant.

White color correspond to no significant relationship.

In this way it was possible to evaluate directly

- Which descriptor (pressures) resulted strongly associated with the metric analysed (strength of relationship)
- In which part of distribution (L=lower, C=Central, U=Upper, W= whole range) the environmental descriptor resulted a predictor of particular interest.



Color	Strength	n quantiles
	Strong	>4/5 and 5/6
	Quite Strong	4/6
	Wikely	<4/6 and 4/5
	not significant	

Figure 1. Explanatory diagram of the pressure-response models reported in Appendix A

Table 3. An example of descriptive materials reported in each tecnhical sheets reported in Appendix A.

Predictor	lower (6)	central (6)	upper (5)	Total	R	Intensità	Sign
LUI	2	6	2	10	W	Strong	(-)
HMS	5	6	4	15	W	Strong	(-)
LIMeco	3	0	0	3	L	Weak	(+)
HQA	3	1	2	6	LU	Weak	(+)
LRD	0	0	4	4	U	Strong	(+)
LRD1	0	0	2	2	U	Weak	(+)
LRD2	0	0	0	0	ns	ns	ns

In addition, in each sheets we reported in table (see table 3 for an example) the following characteristics:

- the number of significant quantiles in each part of data distribution
- The response type (TR) or rather in what range the response is more strength (W=in

whole range, L= lower range, C = central range, U = upper range).
- the strength of relation, following the color indication reported in graph.
- the response sign (+= increase, -= decrease, ns= not significant)

As seen in Figure 1 and in Table 3 for the LRD descriptor we tested and compared two models: a linear and a polynomial model. We hypothesised that some metrics could respond in a hump-shaped way (Mc Cauley et al., 2009), because major effect of LRD could be noted on both extreme lentic (extreme negative values) and lotic (extreme positive values) character.

3.1 Pressure – Response relationship in Pool mesohabitat

Concerning on results obtained in Pool (Tabb. 4-5) we highlighted the following issues:

ASPT, N_EPT_Fam, STAR_ICMi can be defined as "**generic**" metrics, since they resulted strongly associated with all the descriptors considered. Particularly, since STAR_ICMi is a multimetric index, it is able to synthetize different responses (provided by all the metrics included in its calculation), highlighting a generic response to stress.

Shannon Diversity, LEPab e **DIPab**, resulted mainly influenced by HMS (**habitat modification**), however they resulted associated also to **land use** modification and **water pollution**

1-GOLD resulted specific for **morphological alteration (HMS)**. However**,** it resulted strongly associated also to **LRD** (particularly in lower part of its distribution), highlighting an hump shaped relation (see polynomial model) with a decrease response at extremes condition of lentic-lotic character. In addition, concerning **HMS** descriptor we highlighted strong relation with **log(SelEPTD)** and **DIPB_Siph_G,** that were related also to habitat diversification **(HQA)**.

% shredders is a **trophic metric**, since it is based on the ratio of taxa that consume coarse particulate organic matter (CPOM). As expected we detected a strong association with HQA. Remember that number and types of "retention structures" (e.g. presence of xylal and leaf litter in river bed), where shredders largely live, have to be considered in **HQA** descriptor. Thus, such metric could be utilized as indicator of **habitat diversification**. However it should be considered that for its nature **(trophic metric)** this metric resulted strongly associated also to **water pollution (LIMeco).**
On the other hand**, nFAM,** resulted strongly associated with **HQA,** but it was also influenced by **LRD.**

Sel_OLICHI_SA and **MTS** were exclusively associated with water pollution **(LIMecO)** Particularly, Sel_OLICHI_SA increase with the presence of impact.

nOCH, ***Baetis*/BAETIDAE** were specifically associated with hydrological stress **(LRD).**
Particularly**,** nOCH presented an increase response with the increasing of lentic character, highlighting an increase in abundance of Odonata, Coleoptera and Heteroptera (taxa with preference to standing waters). On the other hand, Baetis/BAETIDAE presented a decrease response with the increasing of lentic character, highlighting an increase of the ratio of Baetis (reophilic taxa) in respect to negative values of LRD (lotic or extreme lotic condition). Therefore, both metrics should be utilized in "surveillance monitoring" to detect problems related to flow intermittency and water abstraction, both considered main matters in Mediterranean streams.
It should be noted that also **LIFE** presented strong association with LRD. However, since this index is based on the whole

macroinvertebrate communities, it is strongly associated also with HMS and HQA. Remember that LIFE (Lotic-invertebrate Index for Flow Evaluation) was developed for detect and highlight relationship among macroinvertebrate taxa and different flow categories (Extence et al., 1999).

3.2 Pressure – Response relationship in Riffle mesohabitat

Concerning the results obtained in Riffle mesohabitat (Tables. 6-7), we highlighted the following issues:

ASPT, N_EPT_Fam, STAR_ICMi confirmed their "**generic**" attitude to be associated with all the descriptors here tested.
Diversely to what obtained in pool, STAR_ICMi presented weak relationship with LRD. Moreover, only in riffle mesohabitat, **NFam** presented "**generic**" response to stress except for LUI.

1-GOLD resulted specific for **morphological alteration (HMS).** However contrarily to what obtained in pool, it presented strong association also with **water pollution (LIMeco).**

MTS, based on Operational Unit of Ephemeroptera, presented strong association with **HMS** and **HQA** (both indicators of **Habitat**). Differences in response types were detected for this metrics between mesohabitat.

Similarly to Pool **% shredders**, presented strong relationship with **HQA** and **LIMeco**.
nOCH, ***Baetis*****/BAETIDAE** confirmed their potentiality in detecting problems related to **hydrological stress (LRD)**.

4. CONCLUSION

In conclusion, our findings indicate that:

- riffle and pool may reflect differently the anthropogenic pressures present. For example, MTS in pool resulted specific for water pollution, whereas, in riffle, was associated with habitat alteration.
- The large part of metrics here tested, including STAR_ICMi, presented a "generic" response to stress
- Specific responses to stress were obtained for 1-GOLD (pool), log(SelEPTD) (pool), DIPB_Siph_G (pool) and MTS (riffle), for **habitat alteration**, Sel_OLICHI_SA (pool) e MTS (pool) for **water pollution**.
- Lentic-lotic character, as fully explained in Buffagni et al. (2009; 2010; INHABIT I3d1.2, 2013), strongly influenced macroinvertebrate communities and consequently also the biological metrics utilized for the evaluation of ecological status. From our results **nOCH** and **Baetis/Baetidae**. resulted specifically associated with **LRD**. Therefore, the use of these metrics should permit to evaluate optimal condition for lentic-lotic character and should be utilized in "surveillance monitoring" to detect problems related to flow intermittency and water abstraction, both considered main matters in Mediterranean streams.

Table 4. Summary of Pressure/Response models for each descriptor of anthropogenic alteration (HMS, LIMeco, LUI) in Pool. Strong associations were highlighted in grey.

Descriptor	Metric code	Strength	Sign	TR
LIMeco	ASPT	Strong in C	(+)	CL
	N_Fam	ns	ns	ns
	N_EPT_Fam	Strong in C	(+)	CL
	log(SelEPTD+1)	ns	ns	ns
	Diversità di Shannon	Strong	(+)	CL
	1-GOLD	Weak	(+)	CL
	STAR_ICMi	Strong	(+)	C
	nOCH	ns	ns	ns
	Baetis_BAE	Strong	(-)	C
	LIFE	ns	ns	ns
	Shredders	Strong	(+)	CL
	LepAb	Weak	(+)	C
	MTS	Strong	(+)	C
	Sel_OLICHI_SA	Strong in C	(-)	WR
	DIPab	Strong	(-)	CU
	DIPB_Siph_G	ns	ns	ns
HMS	ASPT	Strong	(-)	CU
	N_Fam	ns	ns	ns
	N_EPT_Fam	Strong	(-)	WR
	log(SelEPTD+1)	Strong	(-)	WR
	Diversità di Shannon	Strong	(-)	L
	1-GOLD	Strong	(-)	CL
	STAR_ICMi	Strong in CU	(-)	WR
	nOCH	ns	ns	ns
	Baetis_BAE	ns	ns	ns
	LIFE	Strong in C	(-)	CU
	Shredders	ns	ns	ns
	LepAb	Strong in C	(-)	CU
	MTS	ns	Ns	ns
	Sel_OLICHI_SA	Weak	(+)	U
	DIPab	Strong	(+)	U
	DIPB_Siph_G	Strong in CL	Ns	ns
LUI	ASPT	Strong in C	(-)	WR
	N_Fam	ns	Ns	ns
	N_EPT_Fam	Strong	(-)	C
	log(SelEPTD+1)	Strong in L	(-)	WR
	Diversità di Shannon	Weak	(-)	CL
	1-GOLD	Weak	(-)	L
	STAR_ICMi	Strong in C	(-)	CU
	nOCH	ns	Ns	ns
	Baetis_BAE	ns	ns	ns
	LIFE	ns	ns	ns
	Shredders	ns	ns	ns
	LepAb	Strong in C	(-)	CU
	MTS	ns	ns	ns
	Sel_OLICHI_SA	Weak	(+)	U
	DIPab	Ns	Ns	ns
	DIPB_Siph_G	ns	(+)	CU

Table 5. Summary of Pressure/Response models for each descriptor of habitat (HQA and LRD) in Pool. Strong associations were highlighted in grey.

Descriptor	Metric code	Strength	Sign	TR
HQA	ASPT	Strong	(+)	WR
	N_Fam	Strong in L	(+)	CL
	N_EPT_Fam	Strong	(+)	WR
	log(SelEPTD+1)	Strong	(+)	WR
	Shannon Diversity	Strong	(+)	CL
	1-GOLD	Weak	(+)	U
	STAR_ICMi	Strong	(+)	WR
	nOCH	Ns	ns	ns
	Baetis_BAE	Ns	ns	ns
	LIFE	Strong in C	(+)	WR
	Shredders	Strong	(+)	CL
	LepAb	Ns	ns	ns
	MTS	Weak	(+)	U
	Sel_OLICHI_SA	Weak	(-)	CU
	DIPab	Weak	(-)	U
	DIPB_Siph_G	Strong in C	(+)	CU
LRD linear	ASPT	Strong	(-)	CU
	N_Fam	Strong	(-)	CU
	N_EPT_Fam	Strong	(-)	WR
	log(SelEPTD+1)	Ns	ns	ns
	Shannon Diversity	Weak	(-)	L
	1-GOLD	Ns	ns	ns
	STAR_ICMi	Weak	(-)	C
	nOCH	Strong in CL	(+)	WR
	Baetis_BAE	Strong in CL	(-)	WR
	LIFE	Strong	(-)	WR
	Shredders	Strong in U	(-)	CU
	LepAb	Strong	(-)	C
	MTS	Weak	(-)	C
	Sel_OLICHI_SA	Ns	ns	ns
	DIPab	Ns	ns	ns
	DIPB_Siph_G	Ns	ns	ns
LRD polynomial	ASPT	Ns	Ns	ns
	N_Fam	Strong	(-)	U
	N_EPT_Fam	Weak	(-)	L
	log(SelEPTD+1)	Weak	(-)	L
	Shannon Diversity	Strong in L	(-)	LU
	1-GOLD	Strong	(-)	L
	STAR_ICMi	Weak	(-)	CL
	nOCH	Weak	(+)	CL
	Baetis_BAE	Storng in C	(-)	CU
	LIFE	Weak	(-)	U
	Shredders	Ns	Ns	ns
	LepAb	Ns	Ns	ns
	MTS	Ns	Ns	ns
	Sel_OLICHI_SA	Weak	(-)	U
	DIPab	Weak	(-) (+)	LU
	DIPB_Siph_G	Ns	Ns	ns

Table 6. Summary of Pressure/Response models for each descriptor of anthropogenic alteration (HMS, LIMeco, LUI) in Riffle. Strong associations were highlighted in grey.

Descriptor	Metric code	Strength	Sign	TR
LIMeco	ASPT	Strong	(+)	CL
	N_Fam	Strong	(+)	C
	N_EPT_Fam	Strong	(+)	WR
	log(SelEPTD+1)	Weak	(+)	L
	Shannon Diversity	Weak	(+)	U
	1-GOLD	Strong in L	(+)	CL
	STAR_ICMi	Strong in C	(+)	CL
	nOCH	Ns	ns	Ns
	Baetis_BAE	Ns	ns	Ns
	LIFE	Strong	(+)	L
	Shredders	Strong	(+)	C
	LepAb	Ns	ns	ns
	MTS	Ns	ns	ns
	Sel_OLICHI_SA	Strong in C	(-)	CU
	DIPab	Strong in C	(-)	CU
	DIPB_Siph_G	Strong in L	(+)	CL
HMS	ASPT	Strong	(-)	WR
	N_Fam	Strong in CU	(-)	WR
	N_EPT_Fam	Strong in CU	(-)	WR
	log(SelEPTD+1)	Strong	(-)	WR
	Shannon Diversity	Strong in L	(-)	CL
	1-GOLD	Strong	(-)	CL
	STAR_ICMi	Strong	(-)	WR
	nOCH	Ns	ns	ns
	Baetis_BAE	Ns	ns	ns
	LIFE	Strong in U	(-)	CU
	Shredders	Ns	ns	ns
	LepAb	Strong	(-)	C
	MTS	Strong in L	(-)	WR
	Sel_OLICHI_SA	Strong	(+)	U
	DIPab	Strong	(+)	U
	DIPB_Siph_G	Weak	(-)	U
LUI	ASPT	Strong in C	(-)	WR
	N_Fam	Weak	(-)	U
	N_EPT_Fam	Strong in C	(-)	CU
	log(SelEPTD+1)	Strong in C	(-)	WR
	Shannon Diversity	Strong in U	(-)	WR
	1-GOLD	Ns	ns	ns
	STAR_ICMi	Strong in C	(-)	CU
	nOCH	Ns	ns	ns
	Baetis_BAE	Ns	ns	ns
	LIFE	Weak	(-)	U
	Shredders	Weak	(-)	L
	LepAb	Weak	(-)	CU
	MTS	Ns	ns	ns
	Sel_OLICHI_SA	Strong	(+)	U
	DIPab	Weak	(+)	U
	DIPB_Siph_G	Ns	ns	ns

Table 7. Summary of Pressure/Response models for each descriptor of habitat (HQA and LRD) in Riffle. Strong associations were highlighted in grey.

Descriptor	Metric code	Strength	Sign	TR
HQA	ASPT	Strong	(+)	WR
	N_Fam	Strong	(+)	U
	N_EPT_Fam	Strong	(+)	WR
	log(SelEPTD+1)	Weak	(+)	LU
	Shannon Diversity	Strong	(+)	WR
	1-GOLD	Ns	ns	ns
	STAR_ICMi	Strong	(+)	WR
	nOCH	Ns	ns	ns
	Baetis_BAE	Ns	ns	ns
	LIFE	Strong	(+)	LU
	Shredders	Strong	(+)	CL
	LepAb	Ns	ns	ns
	MTS	Strong in CL	(+)	WR
	Sel_OLICHI_SA	Weak	(-)	U
	DIPab	Strong	(-)	CU
	DIPB_Siph_G	Strong	(+)	WR
LRD linear	ASPT	Strong	(-)	CU
	N_Fam	Ns	ns	ns
	N_EPT_Fam	Strong in C	(-)	CU
	log(SelEPTD+1)	Strong	(+)	U
	Shannon Diversity	Ns	ns	ns
	1-GOLD	Strong	(+)	U
	STAR_ICMi	Ns	ns	ns
	nOCH	Strong	(+)	CU
	Baetis_BAE	Strong in L	(-)	CL
	LIFE	Strong in L	(-)	CL
	Shredders	Ns	ns	ns
	LepAb	Ns	ns	ns
	MTS	Ns	ns	ns
	Sel_OLICHI_SA	Ns	ns	ns
	DIPab	Weak	(- +)	LU
	DIPB_Siph_G	Strong	(-)	WR
LRD polynomial	ASPT	Weak	(-)	L
	N_Fam	Weak	(-)	L
	N_EPT_Fam	Ns	ns	ns
	log(SelEPTD+1)	Ns	ns	ns
	Shannon Diversity	Ns	ns	ns
	1-GOLD	Weak	(+ -)	L
	STAR_ICMi	Weak	(+ -)	L
	nOCH	Weak	(+ -)	L
	Baetis_BAE	Weak	(-)	L
	LIFE	Ns	ns	ns
	Shredders	Strong	(+ -)	WR
	LepAb	Ns	ns	ns
	MTS	Weak	(+ -)	L
	Sel_OLICHI_SA	Weak	(+)	U
	DIPab	Ns	ns	ns
	DIPB_Siph_G	Ns	ns	ns

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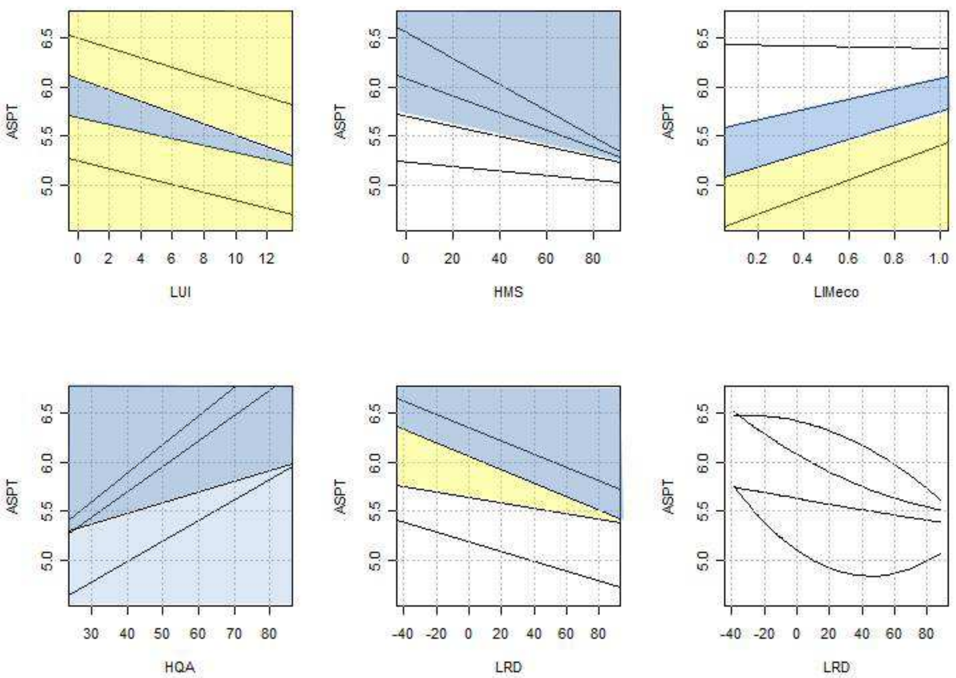
Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	2	6	2	10	W	Strong in C	(-)
HMS	1	6	5	12	CU	Strong	(-)
LIMeco	3	5	0	8	CL	Strong in C	(+)
HQA	4	6	5	15	W	Strong	(+)
LRD (linear)	0	3	4	7	CU	Strong	(-)
LRD (poly1)	2	0	1	3	LU	Weak	(-)
LRD2(poly 2)	1	0	0	1	L	ns	(-)

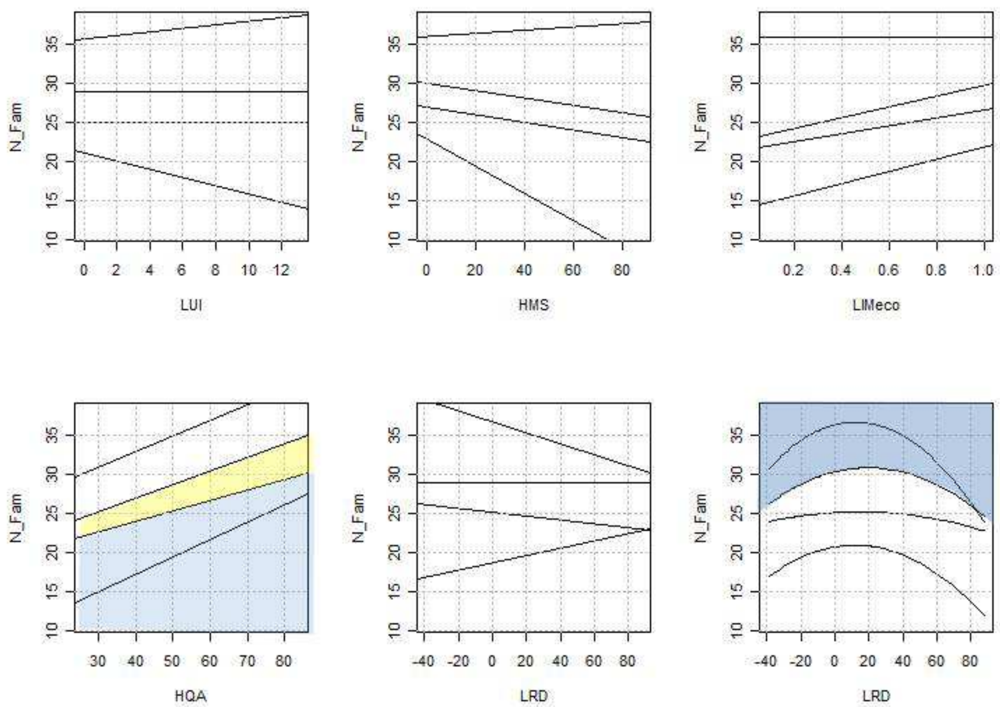
Mesohabitat: POOL
Indice: ASPT



Note: ASPT presented strong relation with all the descriptor here tested, thus it was considered as generic metric. It is based on whole macroinvertebrate community; it was strongly negatively associated with LRD, highlighting a decrease of rheophilic taxa (considered largely as sensible taxa in the calculation of the index) in relation to an increase of lentic character.

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	0	0	0	0	ns	ns	
HMS	1	1	0	2	ns	ns	
LIMeco	0	1	0	1	ns	ns	
HQA	4	2	1	7	CL	Strong in L	(+)
LRD (linear)	0	0	0	0	ns	ns	ns
LRD (poly1)	0	0	0	0	ns	ns	ns
LRD2(poly 2)	0	0	4	4	LU	Strong	(-)

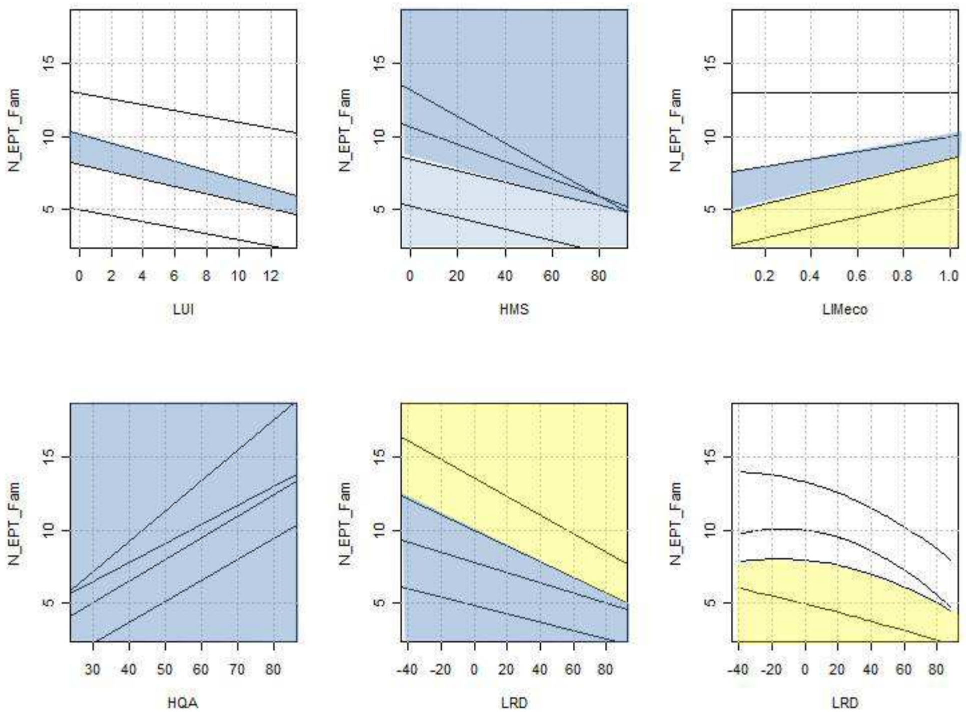
Mesohabitat: POOL
Metrica: N_Fam



Note: N-Fam resulted exclusively associated to habitat features (availability, diversification and lentic lotic character). Particularly, it presented an hump-shaped relationship (in the upper part of the distribution) and highlighting an "optimum" at intermediate condition of LRD

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	1	6	1	8	CR	Strong in C	(-)
HMS	4	6	4	14	WR	Strong	(-)
LIMeco	3	4	0	7	CL	Strong	(+)
HQA	6	6	5	17	WR	Strong	(+)
LRD (linear)	6	6	3	15	WR	Strong in CL	(-)
LRD (poly1)	0	0	1	1	ns	ns	
LRD2(poly 2)	3	0	0	3	LL	Weak	(-)

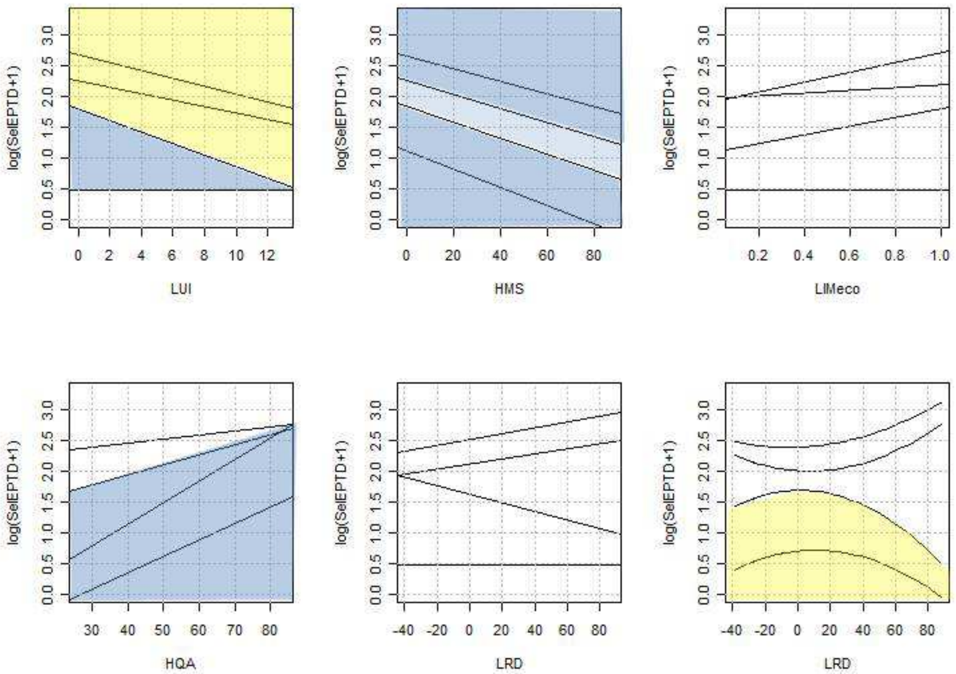
Mesohabitat: POOL
Metrica: EPT



Note: N_EPT_FAM presented strong relation with all the descriptor here tested, thus it was considered as generic metric. It is based on the number of families of Ephemeroptera, Plecoptera and Trichoptera, since large part of EPT is composed by reophilic taxa, it presented negative correlation with LRD

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	4	2	2	8	WR	Weak(Strong in L)	(-)
HMS	6	4	4	14	WR	Strong	(-)
LIMeco	1	0	1	2	ns	ns	
HQA	5	6	0	11	CL	Strong	(+)
LRD (linear)	0	0	0	0	ns	ns	
LRD (poly1)	0	0	0	0	ns	ns	
LRD2(poly 2)	2	0	0	2	LL	weak	(-)

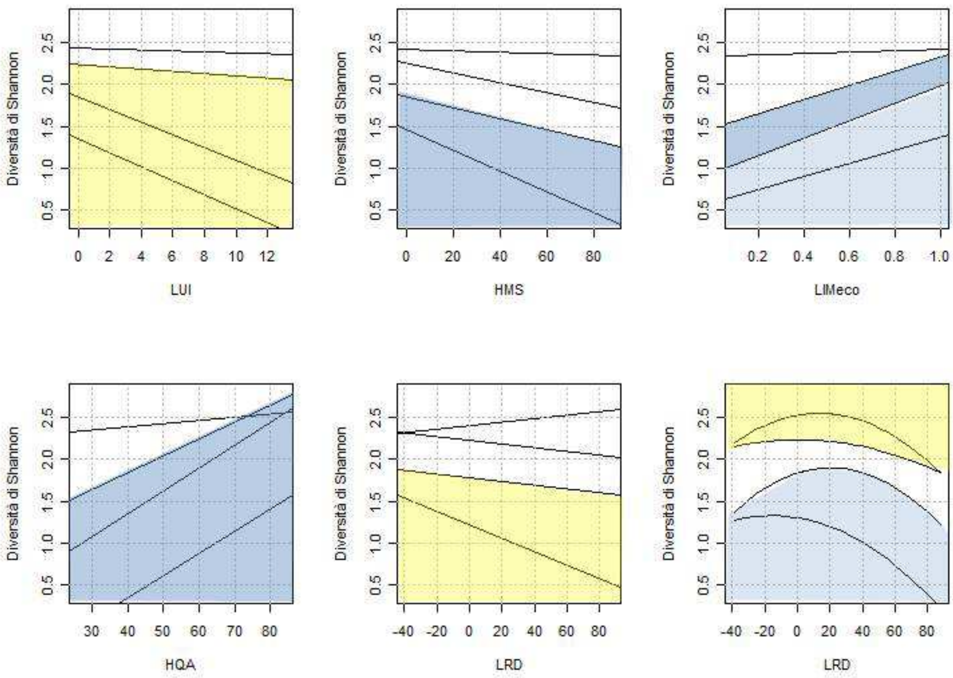
Mesohabitat: POOL
Metrica: EPTD



Note: EPTD resulted strong associated with morphological and habitat alteration.

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	3	2	0	5	CL	Weak	(-)
HMS	5	1	0	6	LL	Strong	(-)
LIMeco	4	5	1	10	CL	Strong	(+)
HQA	6	6	0	12	CL	Strong	(+)
LRD (linear)	2	0	0	2	LL	Weak	(-)
LRD (poly1)	0	0	0	0	ns	ns	ns
LRD2(poly 2)	4	0	2	6	LLU	Strong in L	(-)

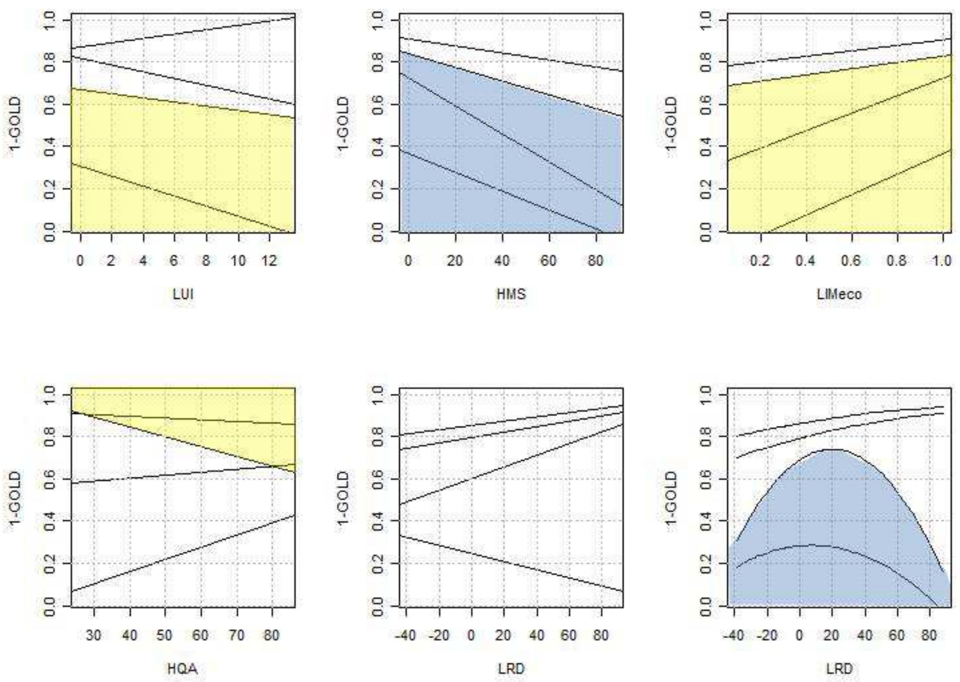
Mesohabitat: POOL
Indice: Shannon



Note: Shannon Diversity presented strong relation with all the descriptor here tested, thus it was considered as generic metric.

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	3	1	0	4	LL	Strong	(-)
HMS	6	5	1	12	CL	Strong	(-)
LIMeco	2	2	0	4	CL	Weak	(+)
HQA	0	0	2	2	LU	Weak	(-)
LRD (linear)	0	0	1	1	ns	ns	ns
LRD (poly1)	0	0	1	1	ns	ns	ns
LRD2(poly 2)	5	0	0	5	LL	Strong	(-)

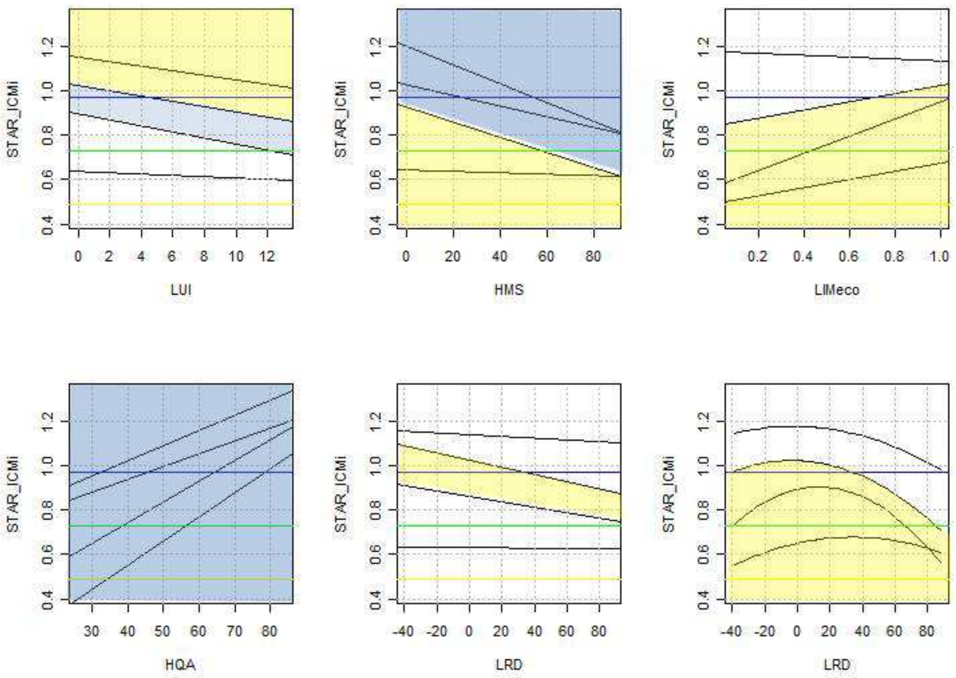
Mesohabitat: POOL
Metrica: 1-GOLD



Note: 1-GOLD resulted particularly associated with hydromorphological alteration, thus it can be considered as a specific metric. However it was associated also to LRD, highlighting an hump-shape relationship (decreasing response at both extremes lentic and lotic)

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	0	4	2	6	CU	Strong in C	(-)
HMS	2	6	5	13	WR	Strong in CU	(-)
LIMeco	3	3	0	6	CL	Weak	(+)
HQA	6	5	5	16	WR	Strong	(+)
LRD (linear)	0	2	0	2	CR	Weak	(-)
LRD (poly1)	0	0	1	1	ns	ns	ns
LRD2(poly 2)	3	3	0	6	CL	Strong	(-)

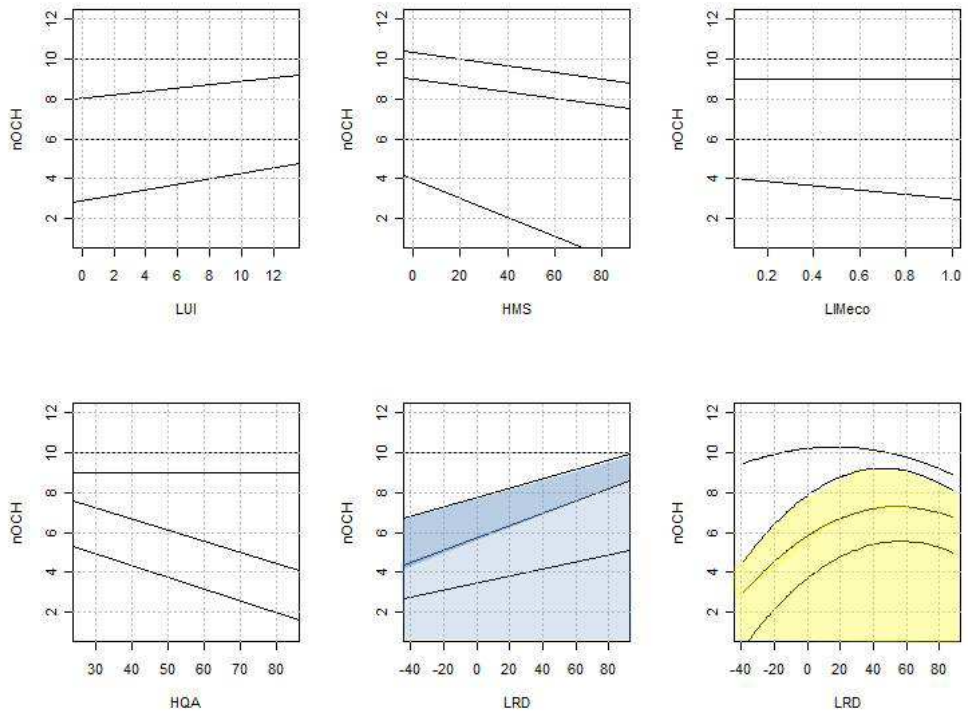
Mesohabitat: POOL
Indice: STAR_ICMi



Note: the multimetric index STAR_ICMi, since it was a synthetic index, presented a generic response to environmental descriptors. Quality thresholds were reported in graph. It should be noted that LRD resulted weakly associated in the lower part of distribution (Good-Moderate Threshold)

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	1	1	0	2	ns	ns	
HMS	0	0	0	0	ns	ns	
LIMeco	0	0	0	0	ns	ns	
HQA	0	0	0	0	ns	ns	
LRD (linear)	4	6	2	12	WR	Strong in CL	(+)
LRD (poly1)	5	6	1	11	CL	Strong	(+)
LRD2(poly 2)	3	2	0	7	CL	Weak	(-)

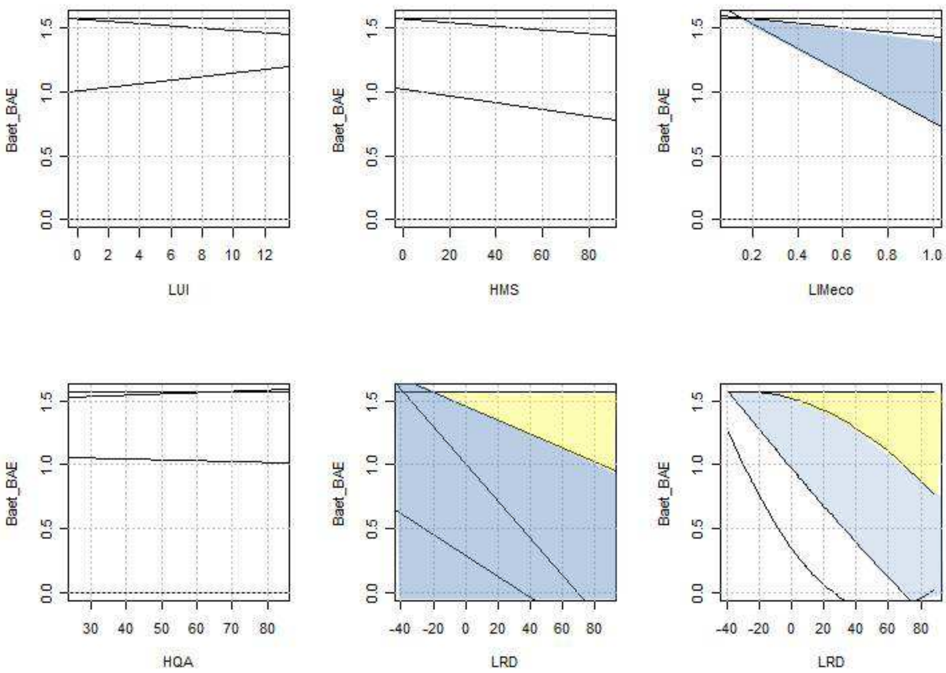
Mesohabitat: POOL
Metrica: OCH



Note: OCH is based on Odonata, Coleoptera and Heteroptera. It’s widely known that OCH are largely composed by taxa with preference for standing waters (strong positively associated with LRD). Thus, it should be utilized in “surveillance monitoring” to detect problems related to flow intermittency and water abstraction, both considered main matters in Mediterranean streams.

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	0	0	0	0	ns	ns	
HMS	0	0	0	0	ns	ns	
LIMeco	0	5	0	5	C	Strong	(-)
HQA	0	0	0	0	ns	ns	
LRD (linear)	6	6	2	14	WR	Strong in CL	(-)
LRD (poly1)	5	5	3	13	WR	Strong	(-)
LRD2(poly 2)	0	4	3	7	CU	Weak	(-)

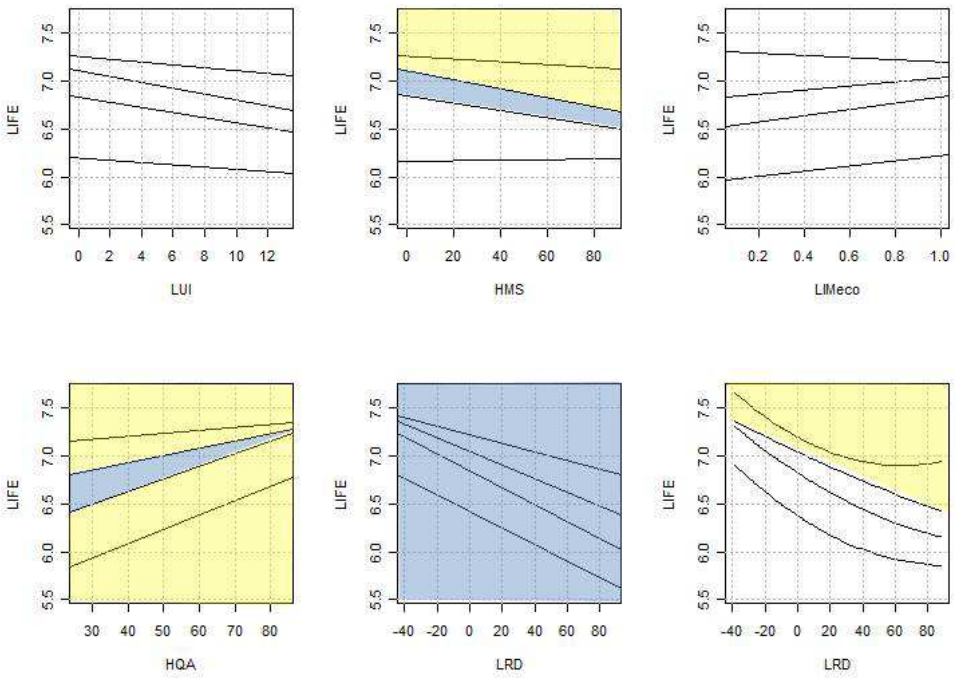
Mesohabitat: POOL
Metrica: Baetis/BAETIDAE



Note: Baetis/BAETIDAE is based on the ratio of *Baetis* (genus) on the total of BAETIDAE (family) .Since genus *Baetis* is composed in large part by reophilic taxa it was negatively associated with LRD. Thus, it should be utilized in "surveillance monitoring" to detect problems related to flow intermittency and water abstraction, both considered main matters in Mediterranean streams.

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	0	0	1	1	ns	ns	
HMS	0	5	2	7	CU	Strong in C	(-)
LIMeco	0	0	0	0	ns	ns	
HQA	2	5	2	9	WR	Strong in C	(+)
LRD (linear)	5	6	4	15	WR	Strong	(-)
LRD (poly1)	6	6	5	17	WR	Strong	(-)
LRD2(poly 2)	0	0	2	2	U	weak	(-)

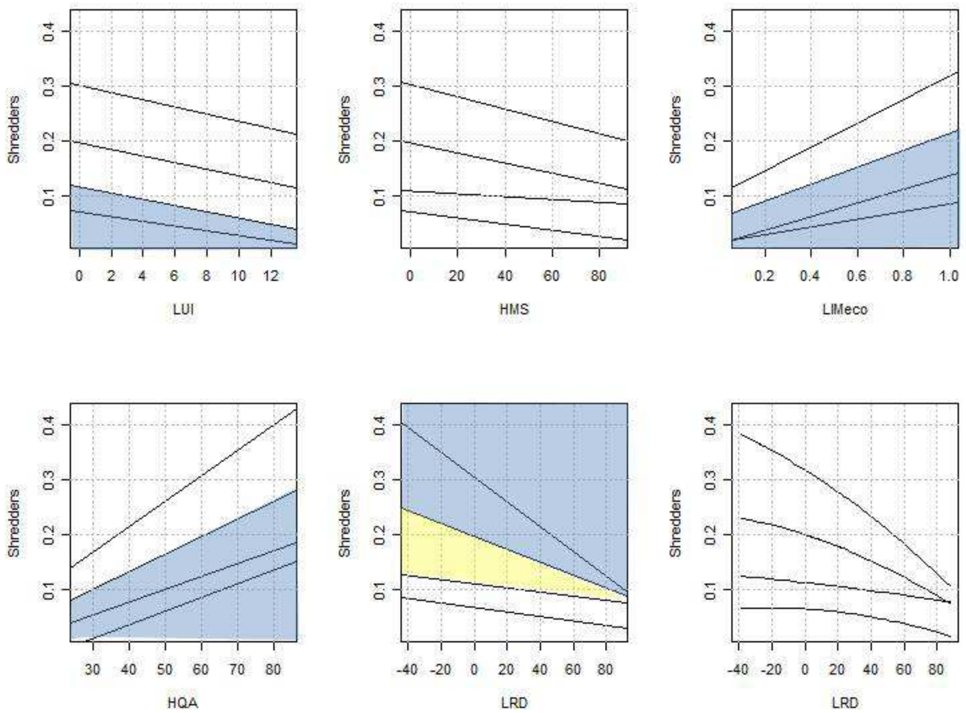
Mesohabitat: POOL
Indice: LIFE



Note: LIFE index (Lotic-invertebrate Index for Flow Evaluation) is based on the whole macroinvertebrate community and it was developed for detect and highlight relationship among macroinvertebrate taxa and different flow categories (Extence et al., 1999). Thus presented strong association with LRD. However, it was strongly associated also with HMS and HQA.

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	6	1	0	7	L	Strong	(-)
HMS	1	0	0	1	ns	ns	
LIMeco	5	6	1	12	CL	Strong	(+)
HQA	6	5	0	11	CL	Strong	(+)
LRD (linear)	1	3	5	9	CU	Strong in U	(-)
LRD (poly1)	0	0	0	0	ns	ns	
LRD2(poly 2)	0	0	0	0	ns	ns	

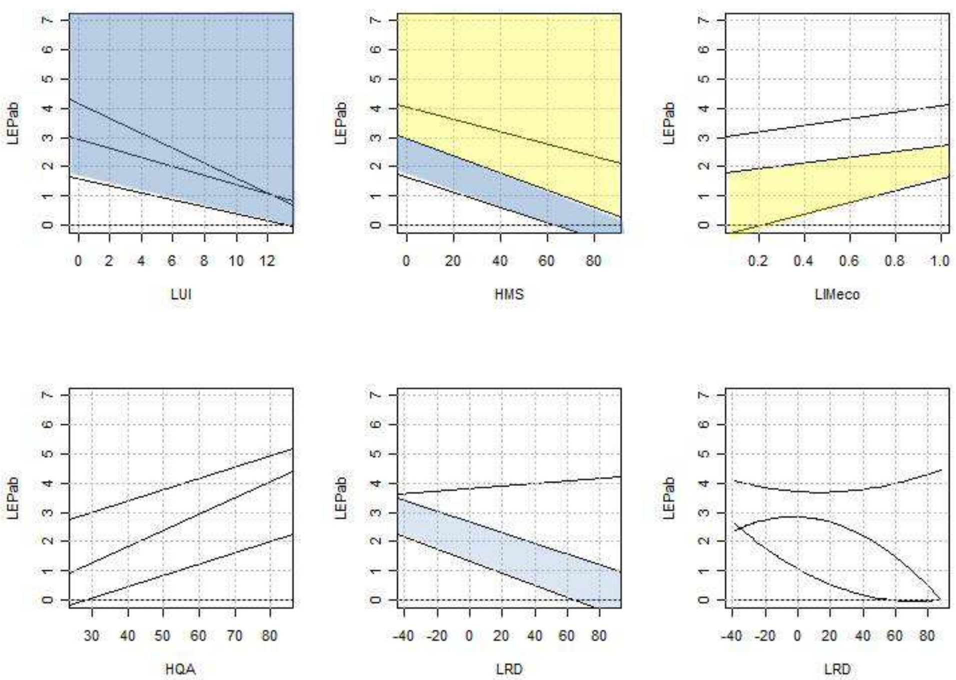
Mesohabitat: POOL
Metrica: %Shredders



Note: % shredders is a trophic metric and it is based on the ratio of taxa that consume coarse particulate organic matter (CPOM). Thus it was strongly associated to the trophic level of water (LIMeco) and to the high presence of “retention structures” (e.g. presence of xylal and leaf litter in river bed). Remember that number and types of “retention structures”, where shredders largely live, have to be considered in HQA descriptor. Thus, such metric could be utilized as indicator of habitat diversification.

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	0	5	5	10	CU	Strong	(-)
HMS	1	6	2	9	CU	Strong in C	(-)
LIMeco	0	2	0	2	C	Weak	(+)
HQA	0	1	1	2	ns	ns	
LRD (linear)	1	4	1	6	C	Strong	(-)
LRD (poly1)	0	1	0	1	ns	ns	
LRD2(poly 2)	0	1	0	1	ns	ns	

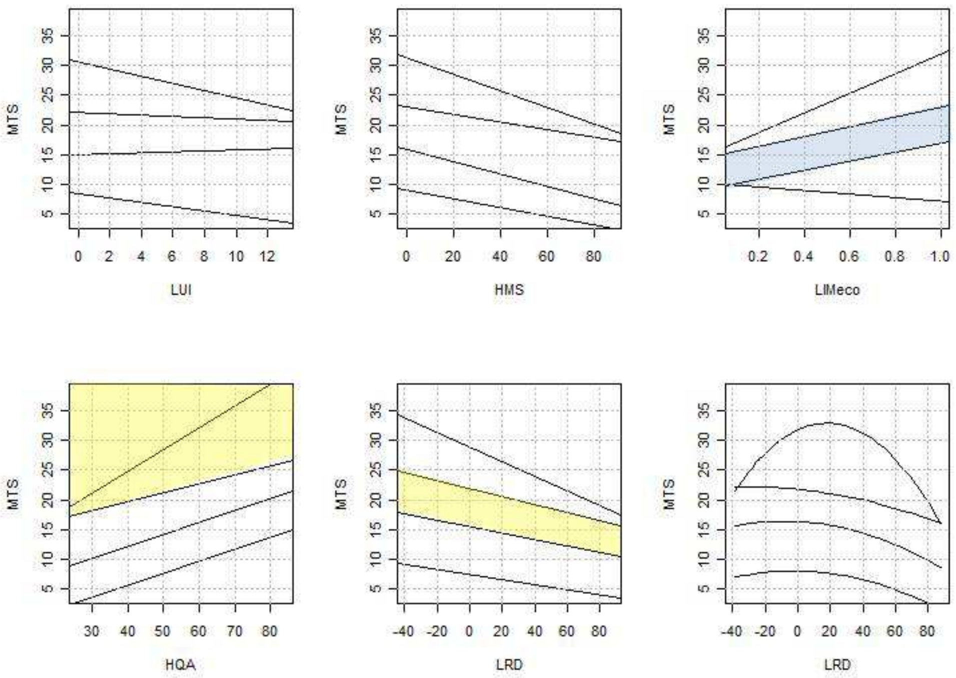
Mesohabitat: POOL
Metrica: LEPTOPHELBIIDAE



Note: LEPab resulted specifically associated with Land Use modification (LUI) and hydromorphological alteration (HMS)

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	0	0	0	0	ns	ns	
HMS	1	1	1	3	ns	ns	
LIMeco	1	4	1	6	C	Strong	(+)
HQA	0	1	2	3	U	Weak	(+)
LRD (linear)	1	2	0	3	C	Weak	(-)
LRD (poly1)	0	0	1	1	ns	ns	
LRD2(poly 2)	0	0	1	1	ns	ns	

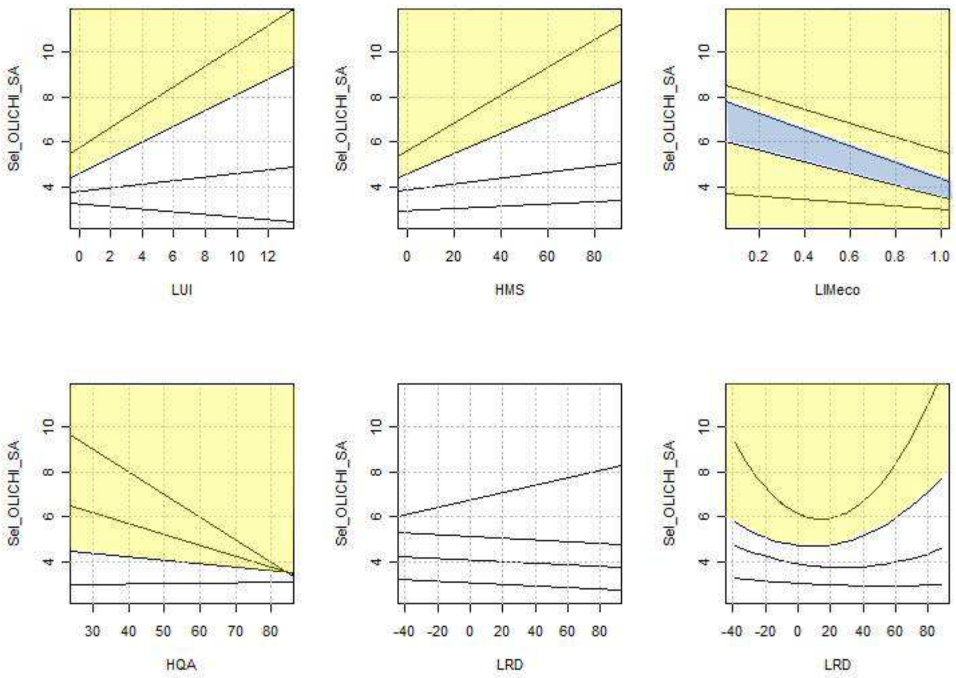
Mesohabitat: POOL
Metrica: MTS



Note: MTS is based on Operational Unit of Ephemeroptera and presented strong association with LIMeco.

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	0	0	3	3	U	Weak	(+)
HMS	0	1	3	4	U	Weak	(+)
LIMeco	3	6	2	11	WR	Strong in C	(-)
HQA	0	2	2	4	CU	Weak	(-)
LRD (linear)	0	0	0	0	ns	ns	
LRD (poly1)	0	0	0	0	ns	ns	
LRD2(poly 2)	0	0	2	2	U	Weak	(+)

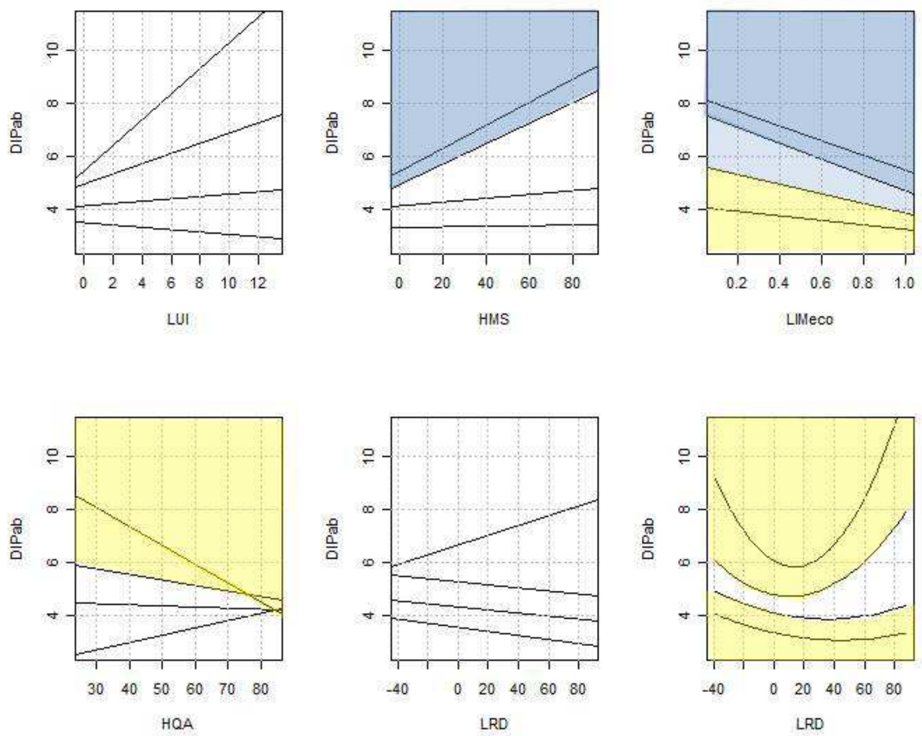
Mesohabitat: POOL
Metrica: OLIGOCHETI + CHIRONOMIDAE



Note: Sel_OLICHI_SA presented an increase response to stress. It's widely known that taxa belonging to Chironomidae and Oligocheta are considered to be tolerant taxa, thus they increase in abundance as stress increase

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	0	0	1	1	ns	ns	
HMS	0	0	5	5	U	Strong	(+)
LIM	2	4	4	10	WR	Strong in CU	(-)
HQA	0	0	2	2	U	Weak	(-)
LRD (linear)	0	0	0	1	ns	ns	
LRD (poly1)	3	0	0	3	L	Weak	(-)
LRD2(poly 2)	2	0	2	4	LU	Weak	(-) (+)

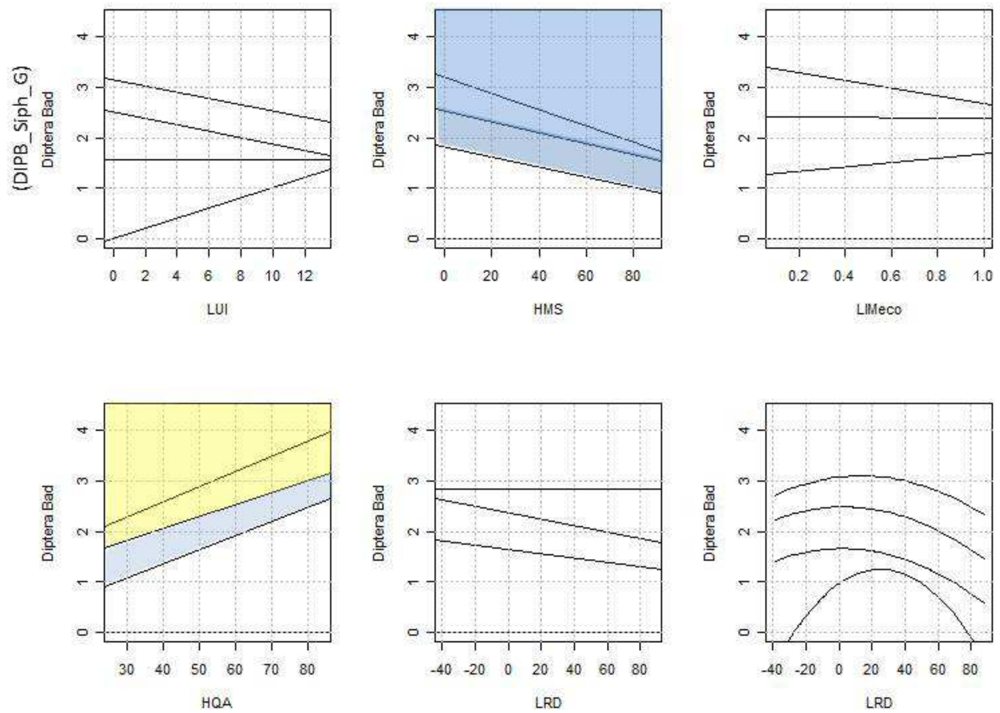
Mesohabitat: POOL
Metrica: Diptera Abundance



Note: DIPab presented an increase response to stress. It's based on abundance of Diptera largely considered to be tolerant taxa, thus they increase in abundance as stress (particularly water pollution, LIMeco) increase

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	0	1	0	1	ns	ns	
HMS	0	6	5	11	CL	Strong	(-)
LIMeco	0	0	0	0	ns	ns	
HQA	1	4	3	7	CU	Weak	(+)
LRD (linear)	0	0	0	0	ns	ns	
LRD (poly1)	0	0	0	0	ns	ns	
LRD2(poly 2)	0	0	0	0	ns	ns	

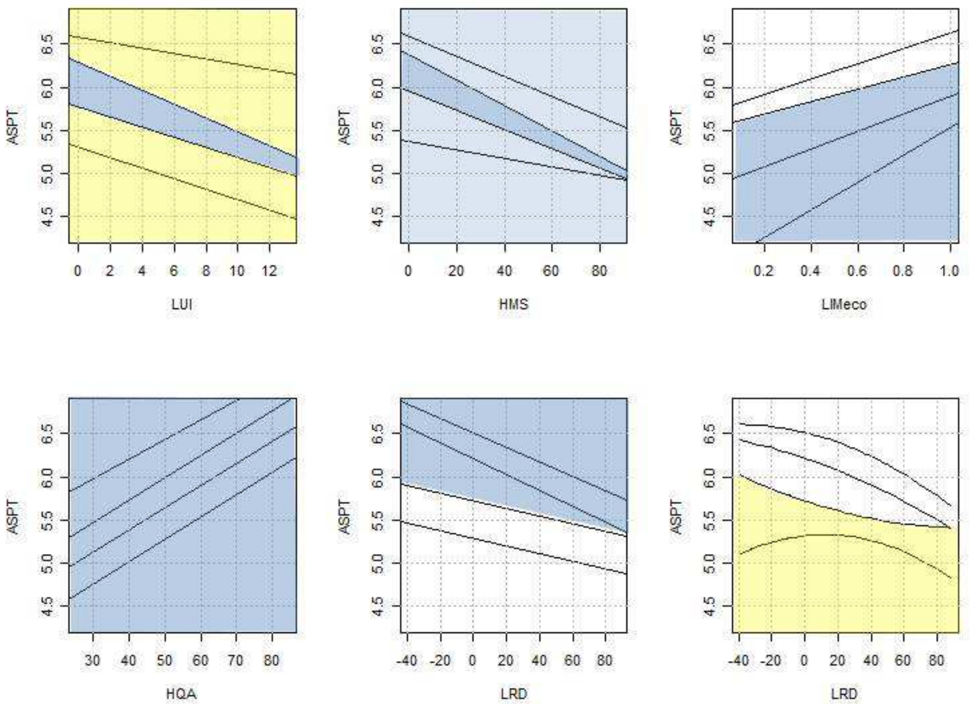
Mesohabitat: POOL
Metrica: Diptera Bad



Note: DIPB_Siph_G seems to be well suited for detecting habitat modification (particularly HQA and HMS)

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	2	6	2	10	WR	Strong in C	(-)
HMS	4	6	4	14	WR	Strong	(-)
LIMeco	5	5	0	10	CL	Strong	(+)
HQA	6	6	4	16	WR	Strong	(+)
LRD (linear)	1	5	5	11	CU	Strong	(-)
LRD (poly1)	5	1	0	6	LL	Strong	(-)
LRD2(poly 2)	3	1	1	5	LL	Weak	(-)

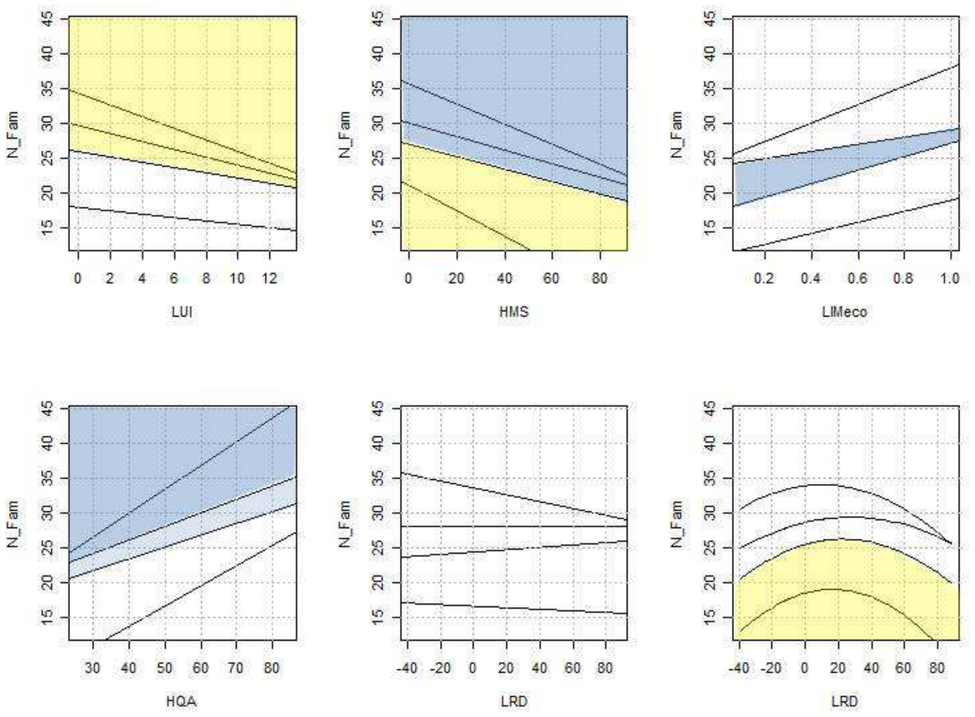
Mesohabitat: RIFFLE
Indice: ASPT



Nota: ASPT presented strong relation with all the descriptor here tested, thus it was considered as generic metric. It is based on whole macroinvertebrate community; it was strongly negatively associated with LRD, highlighting a decrease of rheophilic taxa, considered largely as sensible taxa in the calculation of the index, in relation to an increase of lentic character. No differences with Pool results were detected.

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	1	3	3	7	CU	Weak	(-)
HMS	2	5	5	12	WR	Strong in CU	(-)
LIMeco	1	4	0	5	C	Strong	(+)
HQA	3	4	5	12	WR	Strong in CU	(+)
LRD (linear)	0	0	0	0	ns	ns	ns
LRD (poly1)	0	0	0	0	ns	ns	ns
LRD2(poly 2)	3	1	0	0	LL	Weak	(-)

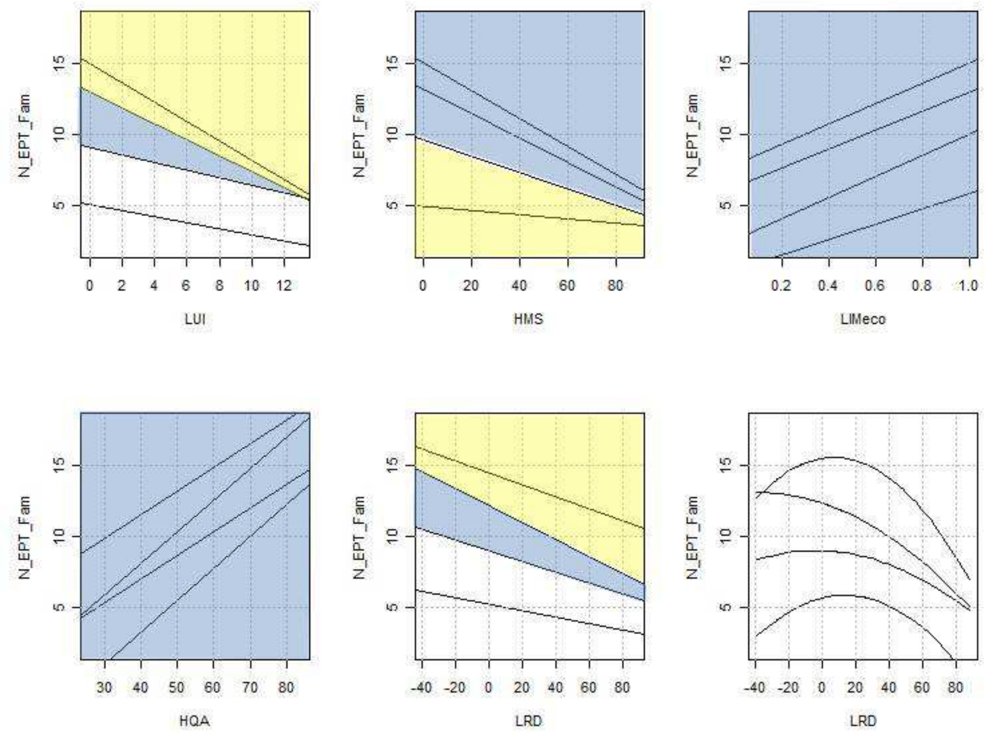
Mesohabitat: RIFFLE
Metrica: N_Fam



Note: Similarly to what obtained in Pool mesohabitat resulted associated with habitat features (availability, diversification and lentic lotic character). Particularly it presented an hump-shaped relationship (in the upper part of the distribution) and presented an “optimum” at intermediate condition of LRD. Contrary to pool we detected strong association also with HMS, HQA e LIMeco.

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	0	6	3	9	CU	Strong in C	(-)
HMS	2	6	5	13	WR	Strong in CU	(-)
LIMeco	5	6	4	15	WR	Strong	(+)
HQA	6	6	5	17	WR	Strong	(+)
LRD (linear)	0	6	2	8	CU	Strong in C	(-)
LRD (poly1)	0	0	1	1	ns	ns	ns
LRD2(poly 2)	0	0	0	0	ns	ns	ns

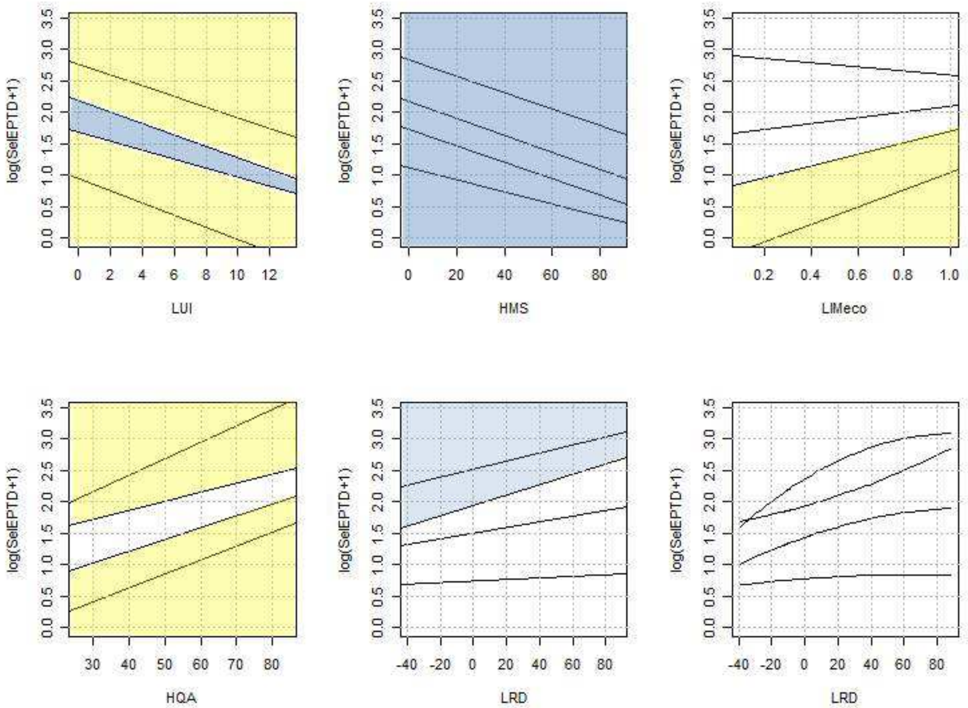
Mesohabitat: RIFFLE
Metrica: EPT



Note: N_EPT_FAM presented strong relation with all the descriptor here tested, thus it was considered as generic metric. It is based on Ephemeroptera, Plecoptera and Trichoptera, since large part of EPT is composed by reophilic taxa, it presented negative correlation with LRD. No differences with Pool results were detected.

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	2	6	2	10	WR	Strong in C	(-)
HMS	5	6	4	15	WR	Strong	(-)
LIMeco	3	0	0	3	LL	Weak	(+)
HQA	3	1	2	6	LLU	Weak	(+)
LRD (linear)	0	0	4	4	LU	Strong	(+)
LRD (poly1)	0	0	2	2	LU	Weak	(+)
LRD2(poly 2)	0	0	0	0	ns	ns	ns

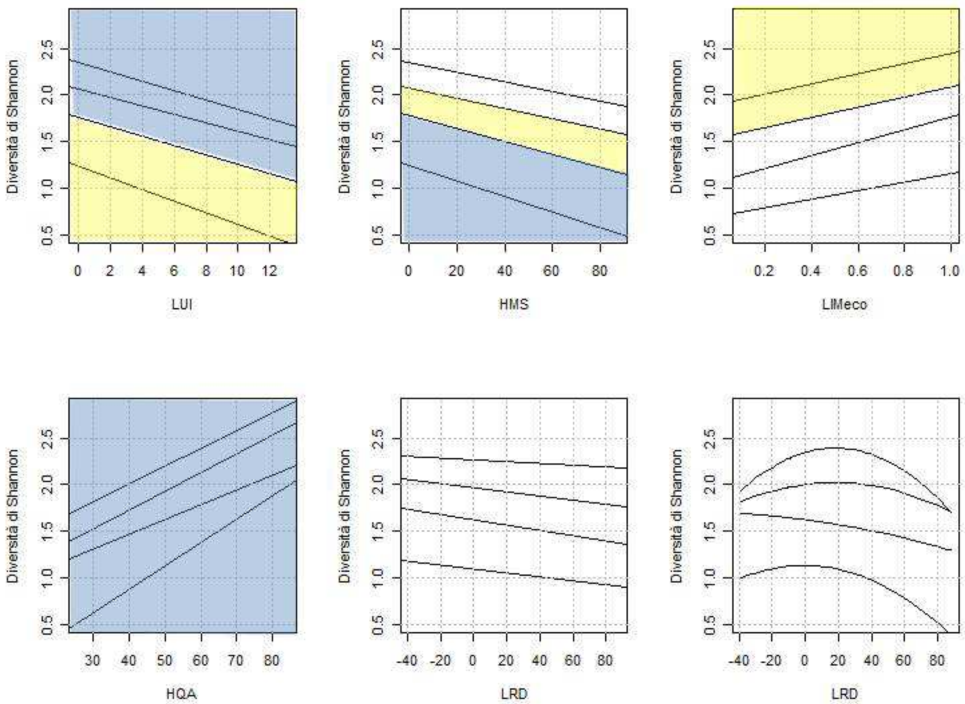
Mesohabitat: RIFFLE
Metrica: EPTD



Note: EPTD resulted strong associated with morphological and habitat alteration. In respect to the results obtained in pool it resulted strongly associated (particularly in the upper part of distribution) with LRD.

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	3	5	4	12	WR	Strong in CU	(-)
HMS	6	2	1	9	CL	Strong in L	(-)
LIMeco	0	1	2	3	CU	Weak	(+)
HQA	6	6	5	17	WR	Strong	(+)
LRD (linear)	0	0	0	0	ns	ns	ns
LRD (poly1)	0	0	0	0	ns	ns	ns
LRD2(poly 2)	0	0	0	0	ns	ns	ns

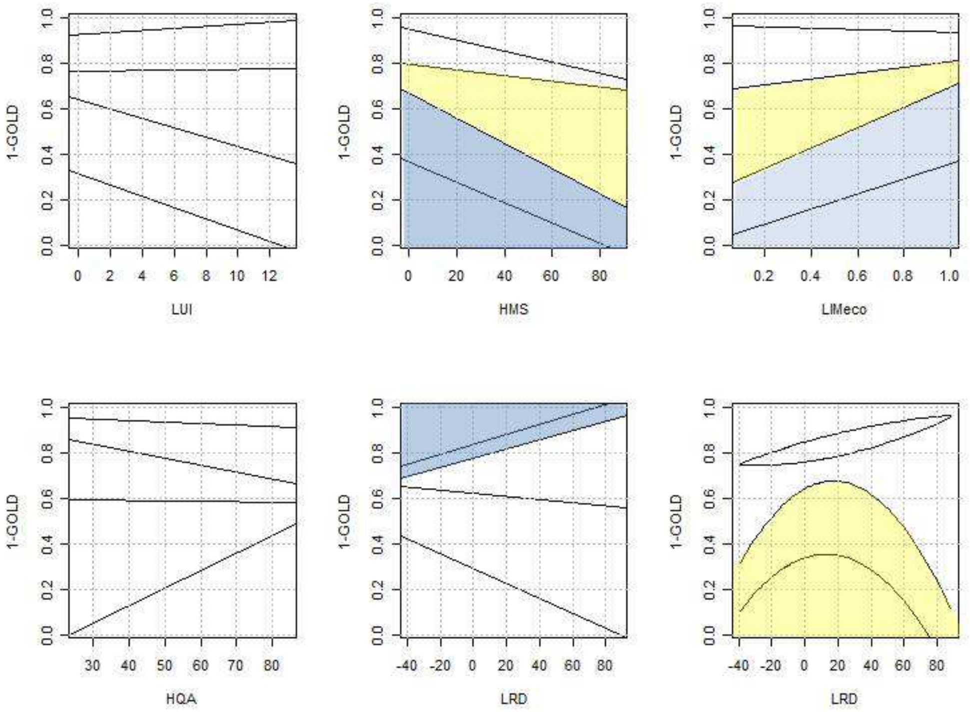
Mesohabitat: RIFFLE
Indice: Shannon



Note: Shannon Diversity presented strong relations with all the descriptor here tested, thus it was considered as generic metric. In respect to the results obtained in pool it didn’t resulted associated with LRD.

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	0	0	0	0	ns	ns	
HMS	6	2	0	8	CL	Strong in L	(-)
LIMeco	4	3	0	7	CL	Strong in L	(+)
HQA	1	0	0	1	ns	ns	
LRD (linear)	1	1	5	7	U	Strong	(-)
LRD (poly1)	3	0	1	4	LL	Weak	(-)
LRD2(poly 2)	3	0	0	3	LL	Weak	(-)

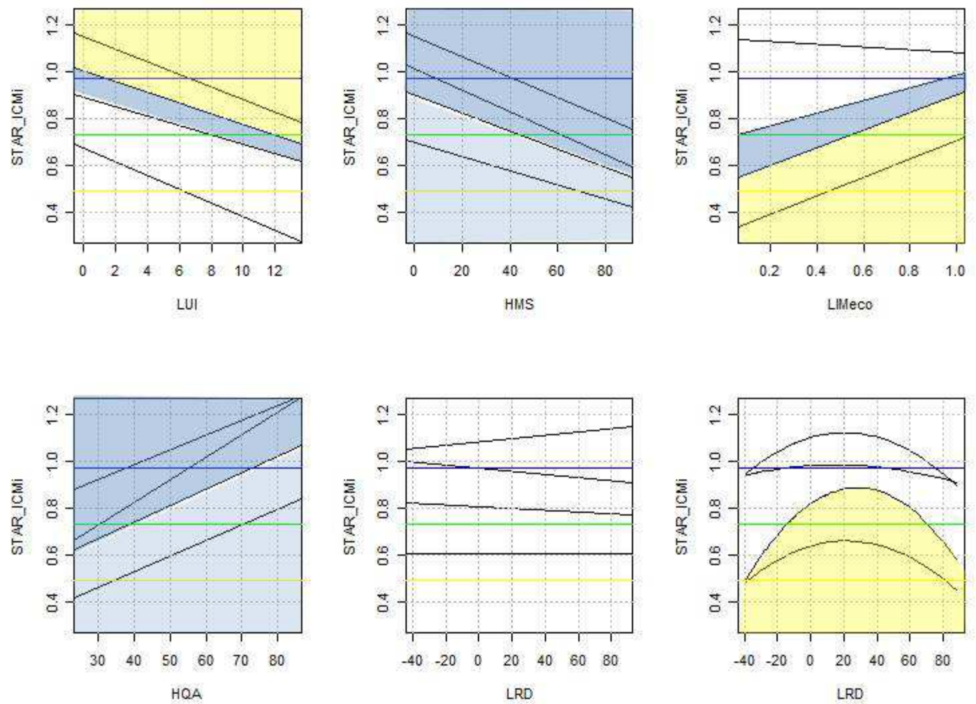
Mesohabitat: RIFFLE
Metrica: 1-GOLD



Note: 1-GOLD resulted particularly associated with hydromorphological alteration and water pollution. However, it was associated also to LRD (particularly in the lower part of distribution), highlighting an hump-shape relationship (decreasing response at both extremes lentic and lotic)

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	1	6	3	10	CU	Strong	(-)
HMS	4	6	4	14	WR	Strong	(-)
LIMeco	2	5	0	7	CL	Strong in C	(+)
HQA	4	6	5	15	WR	Strong	(+)
LRD (linear)	0	0	0	0	ns	ns	ns
LRD (poly1)	0	0	0	0	ns	ns	ns
LRD2(poly 2)	3	1	1	5	LL	Weak	(+ -)

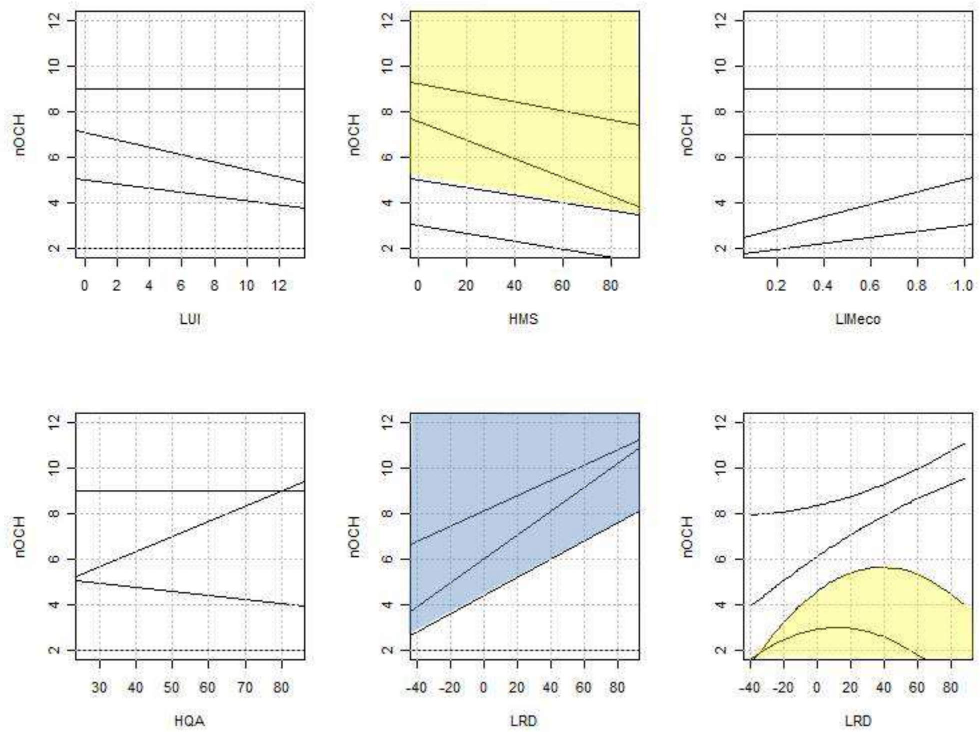
Mesohabitat: RIFFLE
Indice: STAR_ICMi



Note: the multimetric index STAR_ICMi, since it was a synthetic index, presented a generic response to environmental descriptors. Quality thresholds were reported in graph. It should be noted that LRD resulted weakly associated in the lower part of distribution (Good-Moderate Threshold). No differences with Pool results were detected

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	0	1	0	1	ns	ns	
HMS	0	3	3	6	CU	Weak	(-)
LIMeco	1	0	0	1	ns	ns	
HQA	0	0	0	0	ns	ns	
LRD (linear)	1	6	5	11	CU	Strong	(+)
LRD (poly1)	5	5	0	10	LC	Strong	(+)
LRD2(poly 2)	2	1	0	3	L	Weak	

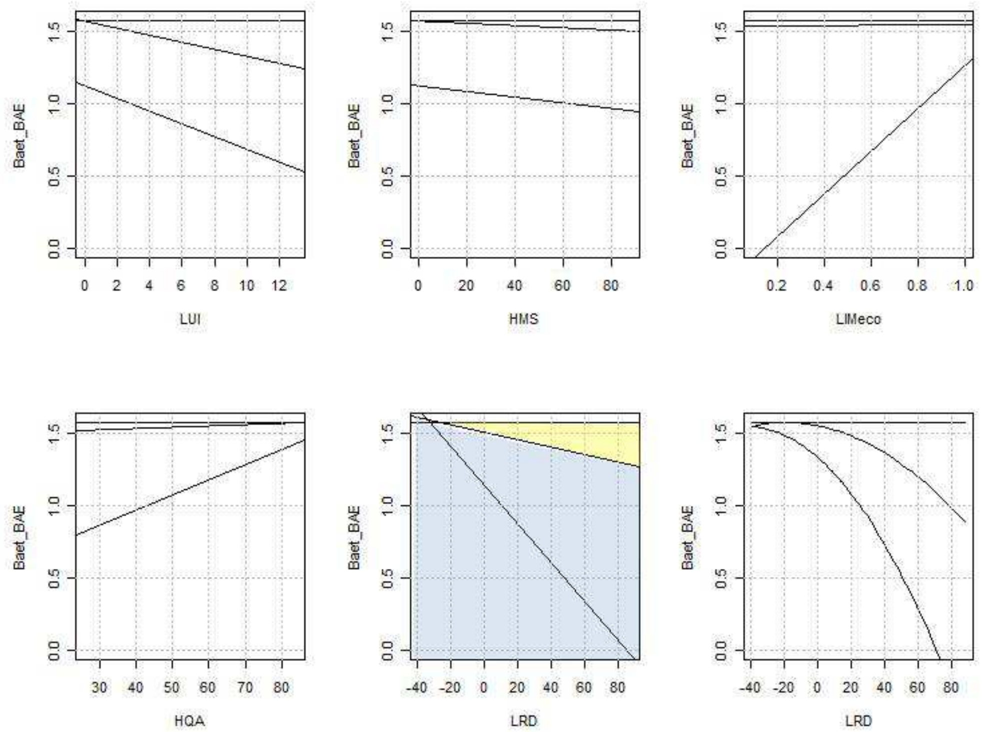
Mesohabitat: RIFFLE
Metrica: OCH



Note: OCH is based on Odonata, Coleoptera and Heteroptera. It's widely known that OCH are largely composed by taxa with preference for standing waters (strong positively associated with LRD). Thus, it should be utilized in "surveillance monitoring" to detect problems related to flow intermittency and water abstraction, both considered main matters in Mediterranean streams. No differences with Pool results were detected

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	0	1	0	0	ns	ns	
HMS	0	0	0	0	ns	ns	
LIMeco	0	0	0	0	ns	ns	
HQA	0	0	0	0	ns	ns	
LRD (linear)	4	2	0	6	CL	Strong in L	(-)
LRD (poly1)	6	4	0	10	CL	Strong	(-)
LRD2(poly 2)	2	0	0	2	L	Weak	(-)

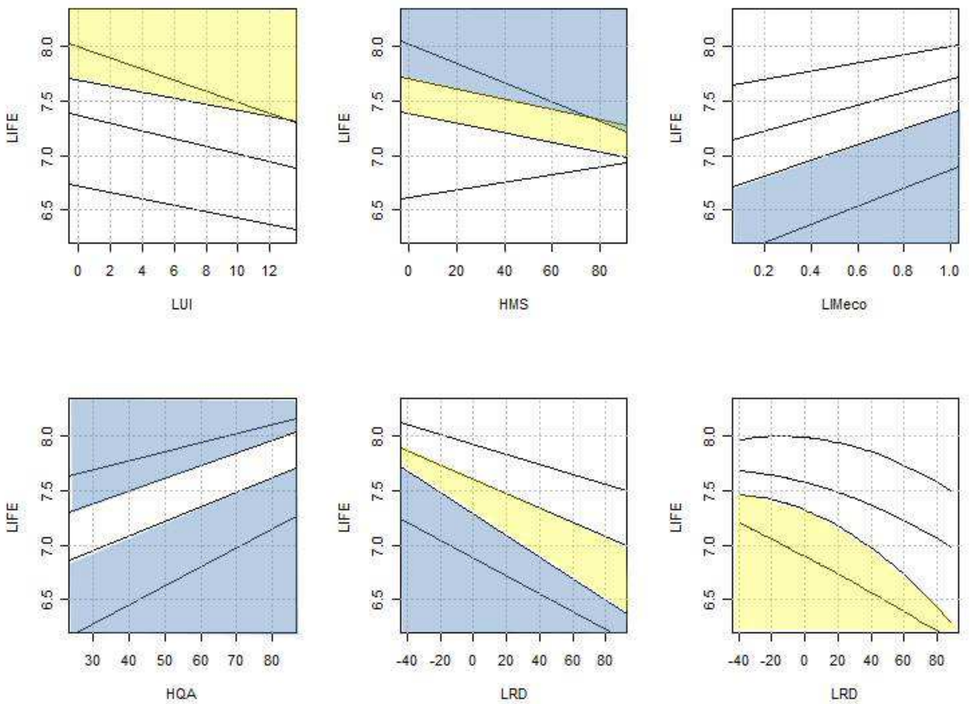
Mesohabitat: RIFFLE
Metrica: Baetis/BAETIDAE



Note: Baetis/BAETIDAE is based on the ratio of *Baetis* (genus) on the total of BAETIDAE (family) .Since genus *Baetis* is composed in large part by reophilic taxa it was strong negatively associated with LRD. Thus, it should be utilized in “surveillance monitoring” to detect problems related to flow intermittency and water abstraction, both considered main matters in Mediterranean streams. No differences with Pool results were detected

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	1	0	2	3	U	Weak	(-)
HMS	0	3	4	7	CU	Strong in U	(-)
LIMeco	5	1	0	6	L	Strong	(+)
HQA	6	1	4	11	CU	Strong	(+)
LRD (linear)	6	3	1	10	CL	Strong in L	(-)
LRD (poly1)	3	0	0	3	L	Weak	(-)
LRD2(poly 2)	0	0	0	0	ns	ns	

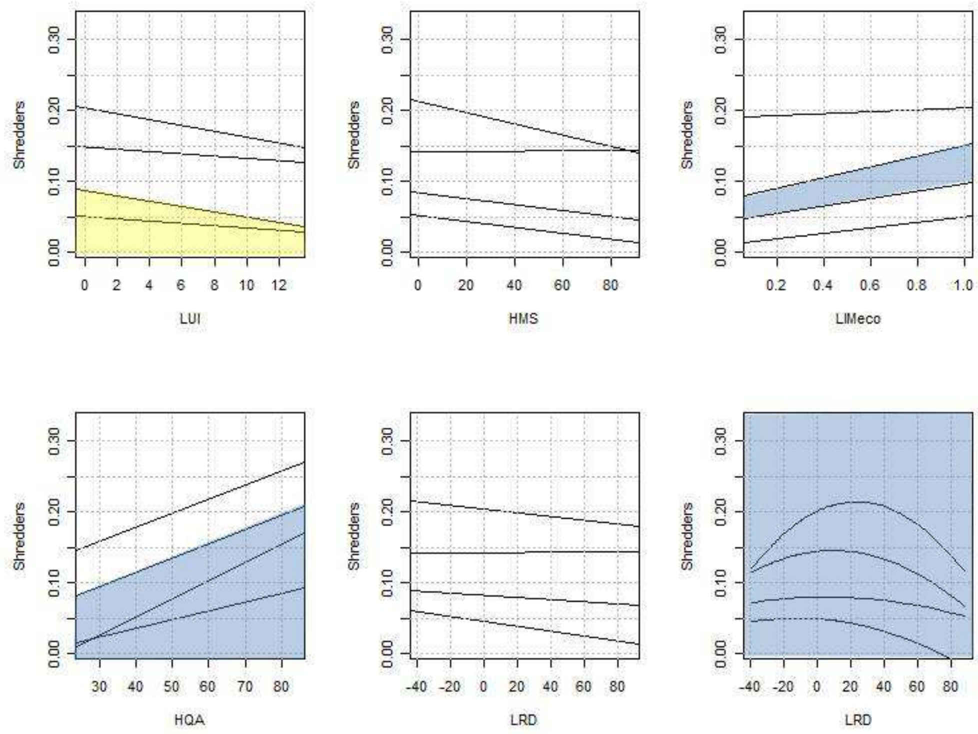
Mesohabitat: RIFFLE
Indice: LIFE



Note: LIFE index (Lotic-invertebrate Index for Flow Evaluation) is based on the whole macroinvertebrate community and it was developed for detect and highlight relationship among macroinvertebrate taxa and different flow categories (Extence et al., 1999). Thus presented strong association with LRD. However, since this index is based on the whole macroinvertebrate communities, it was strongly associated also with HMS and HQA. No differences with Pool results were detected

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	3	1	0	4	L	Weak	(-)
HMS	0	0	0	0	ns	ns	
LIMeco	1	6	0	7	C	Strong	(+)
HQA	5	5	1	11	CL	Strong	(+)
LRD (linear)	0	0	0	0	ns	ns	
LRD (poly1)	0	0	0	0	ns	ns	
LRD2(poly 2)	6	6	5	17	WR	Strong	(+ -)

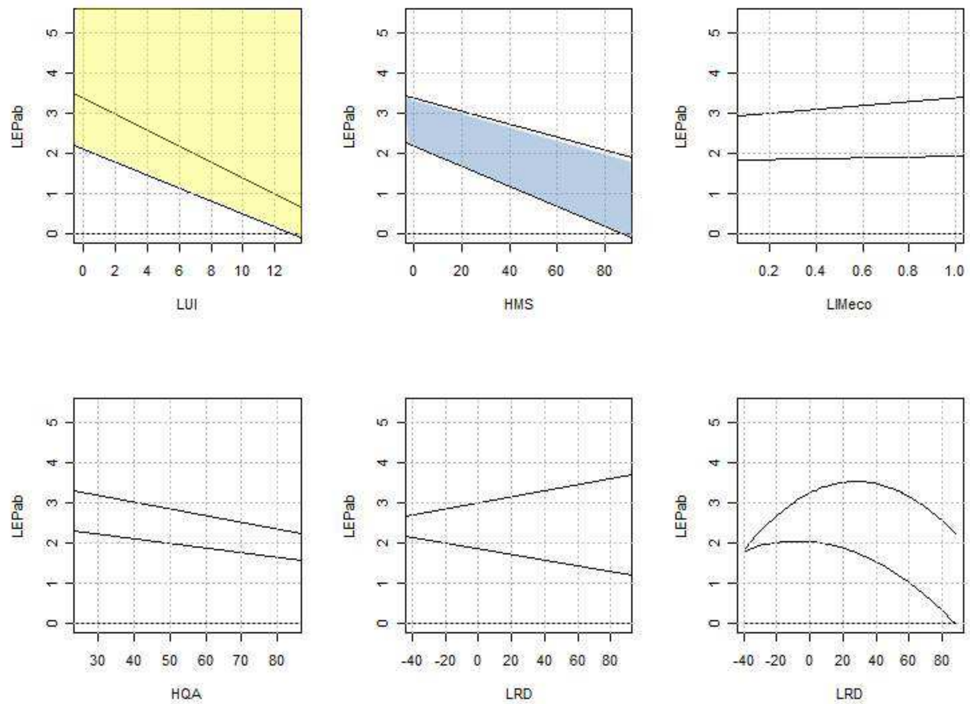
Mesohabitat: RIFFLE
Metrica: %Shredders



Note: % shredders is a trophic metric and it is based on the ratio of taxa that consume coarse particulate organic matter (CPOM). Thus it was strongly associated to the trophic level of water (LIMeco) and to the high presence of “retention structures” (e.g. presence of xylal and leaf litter in river bed). Remember that number and types of “retention structures”, where shredders largely live, have to be considered in HQA descriptor. Thus, such metric could be utilized as indicator of habitat diversification. In respect to what obtained in pool it presented an hump-shape relationship with LRD.

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	0	4	3	7	CU	Strong in C	(-)
HMS	0	5	0	5	C	Strong	(-)
LIMeco	0	0	0	0	ns	ns	
HQA	0	0	0	0	ns	ns	
LRD (linear)	0	0	0	0	ns	ns	
LRD (poly1)	0	0	0	0	ns	ns	
LRD2(poly 2)	0	1	0	1	ns	ns	

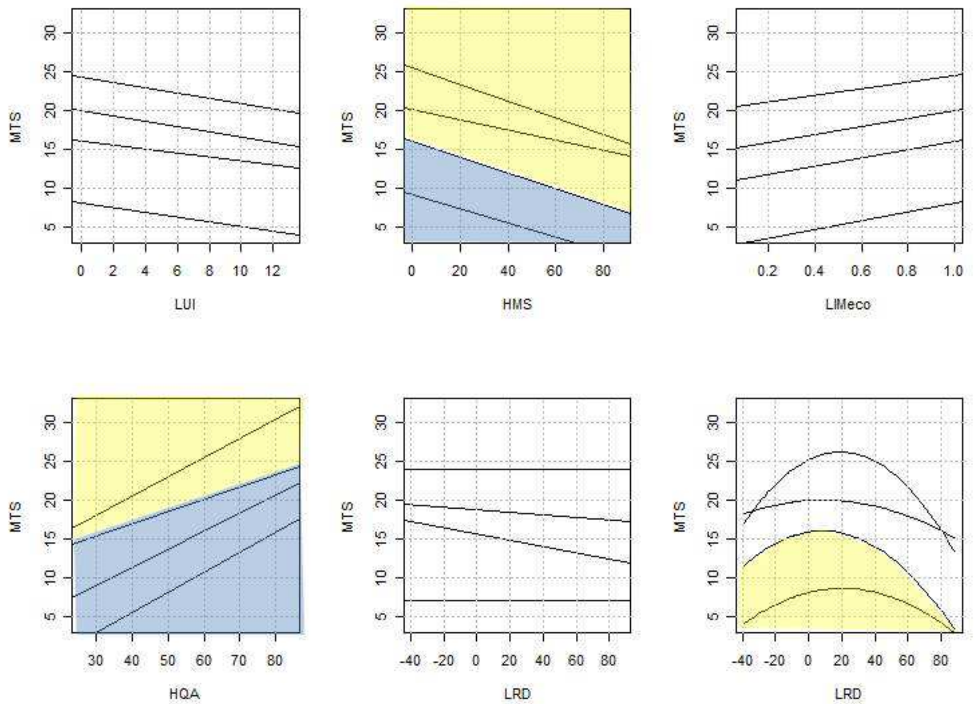
Mesohabitat: RIFFLE
Metrica: LEPTOPHLEBIIDAE



Note: LEPab resulted specifically associated with Land Use modification (LUI) and hydromorphological alteration (HMS)

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	0	0	0	0	ns	ns	
HMS	5	3	3	11	WR	Strong in L	(-)
LIMeco	1	1	1	3	ns	ns	
HQA	6	5	3	14	WR	Strong in CL	(+)
LRD (linear)	0	0	0	0	ns	ns	
LRD (poly1)	0	0	1	1	ns	ns	
LRD2(poly 2)	2	0	1	3	L	Weak	(-)

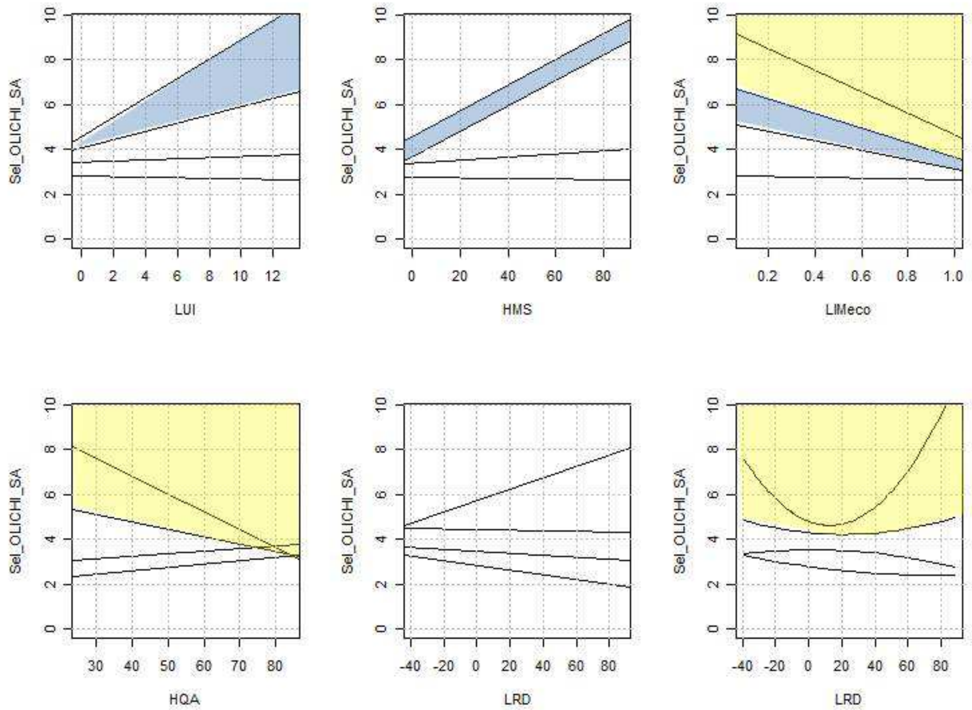
Mesohabitat: RIFFLE
Metrica: MTS



Note: Contrary to Pool results MTS presented a strong association with HMS and HQA, thus it seems to respond better to stress in riffle mesohabitat

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	0	0	4	4	U	Strong	(+)
HMS	0	1	5	6	U	Strong	(+)
LIMeco	1	6	3	10	CU	Strong in C	(-)
HQA	0	0	3	3	U	Weak	(-)
LRD (linear)	0	0	0	0	ns	ns	
LRD (poly1)	0	0	0	0	ns	ns	
LRD2(poly 2)	0	0	2	2	U	Weak	(+)

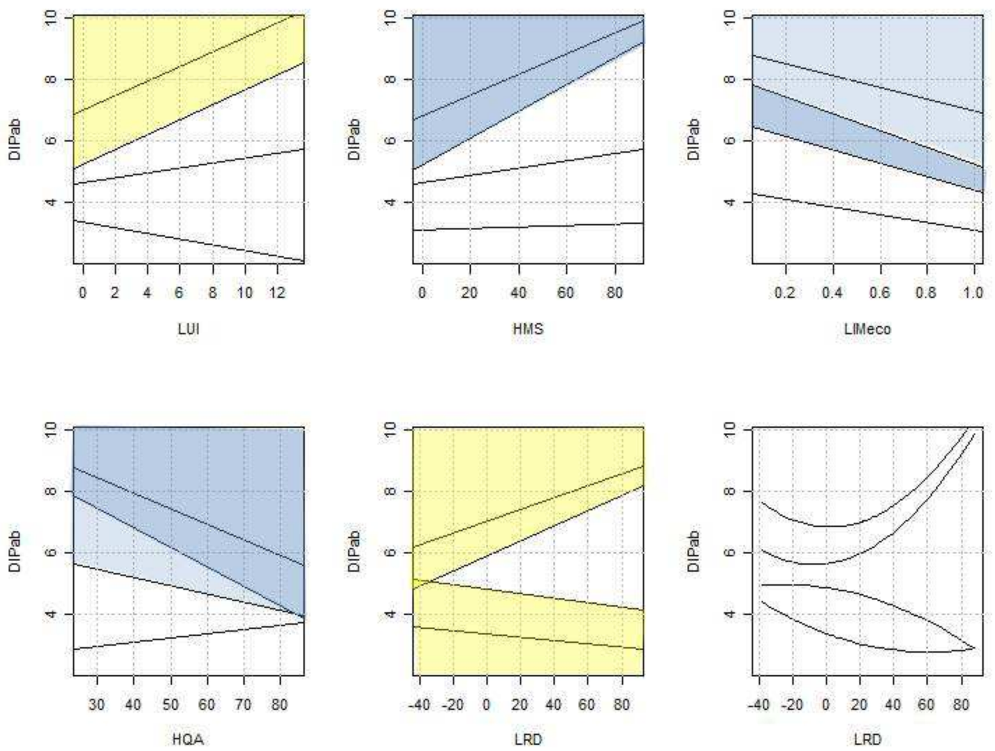
Mesohabitat: RIFFLE
Metrica: OLIGOCHETI + CHIRONOMIDAE



Note: Sel_OLICHI_SA presented an increase response to stress. It's widely known that taxa belonging to Chironomidae and Oligocheta are considered to be tolerant taxa, thus they increase in abundance as stress increase. Comparing to pool it presented better association with LUI.

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	0	1	2	3	U	Weak	(+)
HMS	0	1	5	6	U	Strong	(+)
LIM	0	6	3	9	CU	Strong in C	(-)
HQA	0	4	4	8	CU	Strong	(-)
LRD (linear)	3	0	2	4	LU	Weak	(-) (+)
LRD (poly1)	0	0	0	0	ns	ns	
LRD2(poly 2)	0	0	0	0	ns	ns	

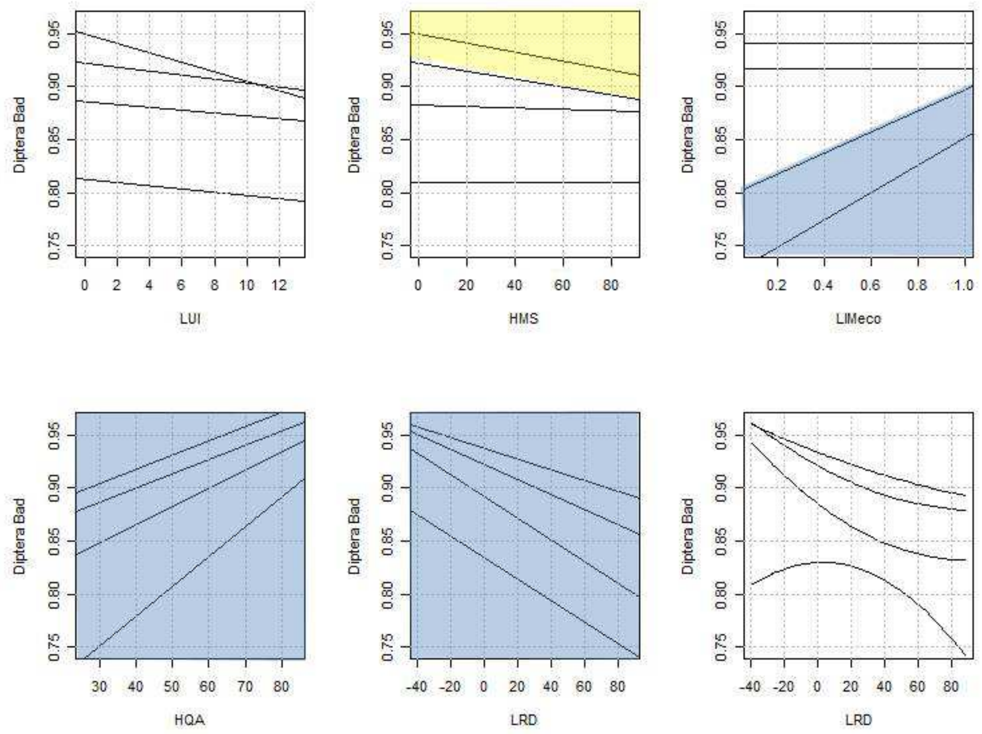
Mesohabitat: RIFFLE
Metrica: Diptera Abundance



Note: DIPab presented an increase response to stress. It's based on abundance of Diptera largely considered to be tolerant taxa, thus they increase in abundance as stress (particularly water pollution, LIMeco) increase. Comparing to pool it presented strong (negative) association also with habitat features (HQA).

Predictor	lower (6)	central (6)	upper (5)	Total	TR	Strength	Sign
LUI	0	0	1	1	ns	ns	
HMS	0	0	2	2	U	weak	(-)
LIMeco	5	2	0	7	CL	Strong in L	(+)
HQA	6	6	5	17	W	Strong	(+)
LRD (linear)	6	6	5	17	W	Strong	(-)
LRD (poly1)	1	6	5	12	cu	Strong	(-)
LRD2(poly 2)	0	0	0	0	ns	ns	

Mesohabitat: RIFFLE
Metrica: Diptera Bad



Note: Comparing to pool results DIPB_Siph_G (Diptera Bad) resulted associated not only to habitat alteration, but also to water pollution (LIMeco) and hydrological character (LRD).

D1D5.6EN – A SYSTEM DYNAMIC MODEL TO ASSESS THE ACCEPTABILITY OF RIVER HABITAT CONSERVATION POLICIES

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1. INTRODUCTION

The conservation of river habitat is one of the main objectives mentioned in the Water Framework Directive. (WFD). The assessment of the water volume that should be released by a reservoir back in the river is of utmost importance. Currently this volume is simply calculated as a percentage of the overall outflow volume, without investigating the actual impact on the quality of the habitat.

In drought conditions, which are quite common in the Mediterranean area, the water volume in the reservoirs is used to meet the needs of the different water users, and particularly the potable one. Thus, during drought, the water volume needed for habitat conservation purposes is often neglected.

Developing and implementing innovative water allocation policies aiming to mitigate the impacts on river habitat quality is a urgent issue to be addressed.

Empirical evidences demonstrates how traditional approaches, based exclusively on imposing limitations to the water use, failed to address complex issues, such as those related to the allocation of a limited resource (Giordano et al., 2013). This is mainly because in this top-down and event-oriented approach of traditional GW management regimes the uncertainty and complexity of water management systems are oversimplified and even neglected (Knűppe and Pahl-Wostl, 2011; Borowoski and Hare, 2007). Oversimplify cause-effect chains in a complex system may lead decision makers to act as if actions and effects are close both in time and space, which is far from being true.

As an effect, decision makers have to cope with the emergence of actions, events and behaviors that they could not anticipate because of their limited understanding of the whole system, and that could strongly influence the effectiveness of their water management policies (Sterman, 2000; Sendzimir et al., 2007).

These unexpected dynamics often lead to policy resistance, that is, the tendency for the intervention to be delayed, diluted, or defeated by the response of the system to the intervention itself. Decisions may also provoke unexpected and often undesirable reactions by the other decision agents interested/involved in water management. Therefore policy resistance originates in the limited understanding of the full range of feedbacks operating in the system, and, particularly, those involving the reactions of other decision agents.

In top-down control water management regimes decisions are generally circumscribed to the local perspectives and interests of the decision agent, and not necessary taken into account the decisions of others agents. The interactions and feedback loops among decision agents operating with intended rational decision rules at individual level could create dysfunctional dynamic for the system as whole (Sterman, 2000).

In order to avoid policy resistance, decision makers need to expand their boundaries of the analysis and to consider the whole system as an ecology of interacting agents whose decisions are not independent from one another. This calls for decision processes that account as much as possible for the interactions that occur among different decision agents (Raiffa et al., 2002).

Starting from these premises, this contribution describes a System Dynamic Modelling (SDM) approach aiming to simulate the evolution of the water system, composed by the Mulargia reservoir, the main decision actors and the water users. The interaction among system components play a crucial role. In this work, the SDM is used to assess the level of conflict due to the implementation of the river habitat conservation policy. As already stated, this policy intends to reduce the amount of water volume used for irrigation purposes, in order to increase the volume used to enhance the habitat quality.

This contribution is organized as following. Section 2 describes the different phases of the implemented methodology. The results of the experimentation are discussed on section 3. Section 4 summarizes the lesson learnt and proposes potential conflict mitigation measures.

2. MATERIALS AND METHODS

This work is based on a multi-step methodology:

1. Problem structuring;
2. Model development;
3. Model validation;
4. Policy analysis using the developed model;
5. Stakeholders feedbacks,

2.1 Problem structuring

The traditional approaches to water management are based on the assumption of perfect rationality of the decision agents. According to these assumptions, decision agents are able to define the problem, to develop the set of alternatives and to define their preferences using the available information. In the real world there is no unique and consensual problem definition. Each decision agents has her/his own problem understanding (Rosenhead and Mingers, 2001).

The way a problem is defined and perceived influences a stakeholder's expectation of future occurrence, and leads stakeholders to adopt different behaviors and to act or react in different ways. In multi-actor decision setting, such as in water resource management, the coexistence of multiple interpretations and meanings given to the management issues is unavoidable. This situation may result in ambiguities with respect to the problem domain, and to the type of behaviors and actions adopted by those involved in the managing process (Brugnach et al. 2011). While certain degree of ambiguity is desirable for fostering diversity and innovation, it can also be the source of discrepancies and conflicts in a group.

Starting from these premises, the elicitation and structuring of the different problem understanding was the core of the applied methodology. The main decision agents involved in water resources management were involved in this phase:

- Regional River Basin Authority;
- Ente Acquedotto della Sardegna (ENAS);
- Potable water supply utility (ABBANOA);
- South Sardinia irrigation consortium (CBSM);
- Farmers associations.

Semi-structured interviews were carried out involving the selected decision-agents. The interviews aimed at collecting the following information:

- What is the normal water allocation process?
- What kind of information is used in this process?
- What are the interactions among the different decision agents?
- How does the allocation process change due to water scarcity during drought period?

The knowledge collected through the interviews was integrated with the information obtained by analyzing the official documents related to the management procedures of Mulargia reservoir. The farmers provided information about their decisions related to the main sources of water for irrigation and the crop selection.

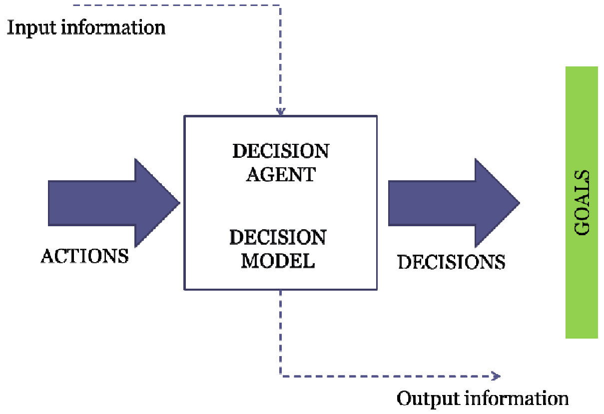

Fig. 1. Scheme of the decision model.

The collected information were structured in Cognitive Map (CM), which allowed to graphically represent the cause-effect chains in the decision-agents' problem understanding.
Figure 2 shows the consortium CM, which clearly describes the main goals, the available actions and the elements influencing the selection of the actions to be implemented. CM are characterized by variables and causal links. The links can be positive or negative. The existence of a positive link between "A" and "B" means that if A increases then B increases. If the links is negative, then an increase in A implies a decrease in B. A weight is also assigned to each link, which represents how strong is the influence of a variable over the others (Giordano et al., 2007).

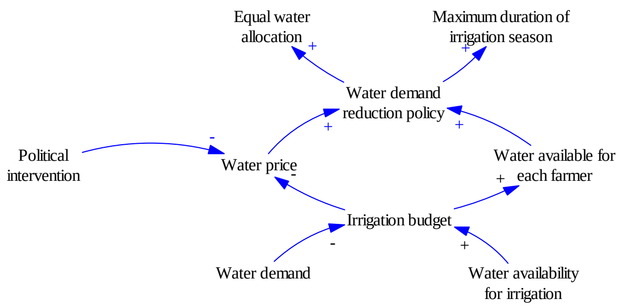

Fig. 2. Consortium CM.

The developed CM were validated by interacting with the involved stakeholders. The validation phase aimed to test the CM capability to represent the decision models of each agent.

The CM analysis allowed to draw some preliminary conclusions about stakeholders' problem perceptions. Farmers' main goal is to keep crop production at a high level, even in case of water scarcity. Their main decision concerns the selection of crops and, thus, the extension of the irrigated areas. Moreover, they could select the most suitable source of water for irrigation, i.e. water from consortium and/or groundwater. According to the results of the knowledge elicitation phase, these decisions are based on the information related to the water availability and to the price of water from consortium. The decisions are taken in the late autumn, when this information are not yet available. Therefore, farmers use their own perception.
The farmers' decision process is strongly influenced by the information delay due to the political intervention to define the water price.
CBSM's main goals are to guarantee the equal distribution of water to farmers for the whole irrigation season, and to fully recover the water management and distribution costs. To achieve these goals two actions are available, i.e. to reduce the water availability, and to increase the water tariff. Those actions are intended to force farmers to keep the water consumption at a sustainable level, without causing a decrease of farmers' contribution to consortium budget. The information supporting these decisions is the level of the water in the reservoir and the expected demand of water for irrigation.
The Regional Authority plays a crucial role. As previously stated, the definition of the water tariff thresholds are the results of a political intervention made by the Regional authority to keep the water price as low as possible, in order to protect the local agriculture, because of its role in preventing the landscape from degradation phenomena. The Regional Authority uses the data related to the water volume stored in the reservoir (ENAS) and the water demand assessment (CBSM). In case of water scarcity, the actions taken by the

Regional Authority aim to lead farmers to reduce water consumption. Due to the information delay, these actions often fail to achieve this objective.

2.2 Model development

The validated CM were used as basis for the development of the SDM, which allowed to simulate the evolution of the system, as result of the complex web of interaction among the elements of the system.

Fig.3 shows the interactions involving the physical elements of the system (the Mulargia reservoir) and the decision agents involved in the water management (regional authority, ENAS; ABBANOA, end users).

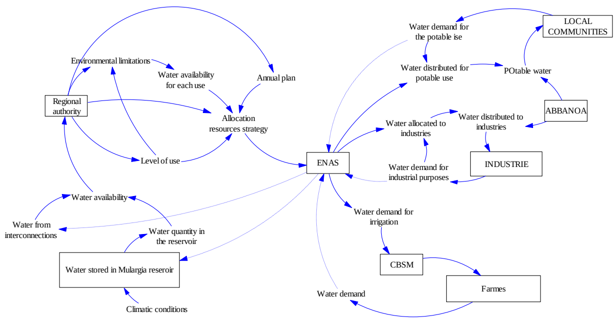

Fig.3. Interactions among the different elements of the system.

In figure 3, the different kinds of expected interaction among the sub-models are represented differently. The thick lines represent the access to information concerning the state of the physical variables of the system. This information allows farmers, regional authority and consortium to take important decision concerning the irrigation management. The thin lines represent the impacts due to decisions taken by other decision agents, e.g. the quantity of water available for irrigation as decided by the consortium.

According to the results of the knowledge elicitation phase, the most important information influencing the interaction among the different users is the water deliverability assessment. This assessment was done by the regional authority comparing the water demands and the water volume in the reservoir. This information is normally used to define the volume of water to be allocated to each use and the water tariffs for irrigation purposes.

The information represents the link among the different decision agents. They usually treats variables outside their perceived environment as exogenous inputs, that is, the given states of the situation. But because in a complex system each element is linked with the others in a network of feedback loops, these inputs are actually not exogenous givens, but are created within the system as result of others' actions, and are strongly influenced by their own behavior (Sterman, 2000).

A stock-and-flow diagram was developed in order to simulate the interactions among decision agents. The specific objects used to represent the system structure are stocks, flows, converters and connector. Stocks have been used to model the variables that characterize the state of the system and generate the information upon which decisions and actions are based. Two kinds of flow have been considered in the model, i.e. the material flow (e.g. the amount of water flowing from the reservoir to the farmers) and information flow (e.g. the information concerning the price of water). The information flows are crucial to determine the evolution of the system. The information from some point in the system could provoke a decision somewhere else in the system (Vennix, 1996). The converter are used to transform input in the form of algebraic relationships. Connectors convey information from one variable to another. The relationship between the structure and the evolution of the system is based on the concept of information, feedback, control and delay (Nandalal and Simonovic, 2003).

The decision models of each decision agent – i.e. the agents' main goals, the decisions and the information used at the basis of the decision process – and the link among the different agents were used as basis for the development of the SDM.

Different type of data have been used to develop the structure and decision rules in the model, namely numerical, written and mental data (Forrester, 1980). Numerical data have been used for the physical variables, that is, the water in the reservoir. The written data refers to the operating procedures in the consortium. Mental data concerns all the information regarding how the decision are taken by decision agents, their understanding of the problem, how exceptions are handled (Sterman, 2000). Mental data have been elicited during the mental models development phase.

The obtained SDM is shown in fig.4.

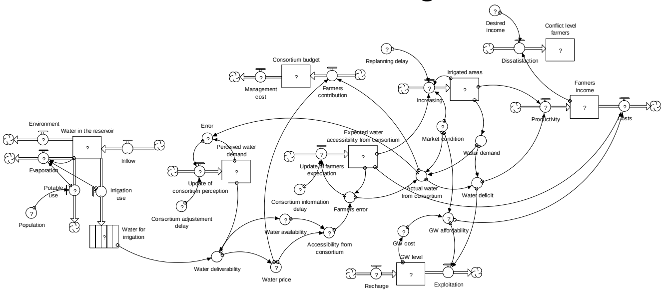

Fig. 4. SDM obtained by integrating the decision agents' mental models.

The central element in the SDM is the Mulargia reservoir, modeled as a stock. The reservoir has an inflow arrow representing the yearly volume of water flowing in the reservoir. The three outflow arrows allow to calculate the volume of water allocated to the two main uses, i.e. the irrigation and the potable use, and the portion of water dispersed in the air through the evaporation. We also added an outflow representing the water volume released in the river bed.

The sub-model "regional authority" aims to evaluate the deliverability of water volume using the water availability and water demand as input information.

The SDM shows the role of the information delays, that is the time needed to decision agents to acquire new information, to update their beliefs and react (Vennix, 1996, Sterman, 2000). These delays have a negative impact on the decision agents' capability to select the most suitable actions. Due to the information delay, decision agents do not have access to reliable information at the beginning of the decision process. Therefore, their decisions are based on beliefs and/or expectations. Once the information becomes available, updating the decision agents' expectations, reflecting and deliberating on the receipt of new information often require considerable time.

In fig.4 the first information delay concerns the assessment of the irrigation demand. This information is not yet available when the deliverability evaluation is carried out. Therefore, a CBSM perception, based on previous year evaluation of water demand, is used in the decision process. This could lead to errors.

The second information delay regards the farmers' decision process. Farmers could take two decisions in order to achieve a satisfying income, i.e. the kind of crop (influencing the extension of the irrigated areas) and the main source of water for irrigation (from consortium and/or from GW). The most important information used by farmers in these decision processes is the amount of water that can be taken from the consortium. This depends on the minimum amount of water distributed by the CBSM, and the water price. CBSM shares this information with farmers at the end of March, whereas most of the farming plans has been defined in the late autumn. Therefore, farmers take these decisions based on their own assumptions, which regards mainly the water price. Once the consortium deliver the information concerning the actual quantity of water available for irrigation and the price, famers could compare this information with their assumptions and become aware of an irrigation deficit. A second information delay mechanism has been introduced in the model. At the end of the updating process, farmers' assumption is close to the actual value of water availability from consortium. Due to the

information delay, farmers cannot change their farming strategy, that is, they cannot reduce the irrigated areas. A further information delay needs to be consider, i.e. the re-plan delay, which strongly depends on the type of crops and it is a function of the timeliness of water availability information.
The level of conflict involving farmers is assessed as distance between the simulated value of the variable "income" and its expected value.

2.3 Model validation

The available data are not enough to use the model for quantitative evaluation. The SDM was used to qualitatively simulate the interactions among the different elements of the system.
Considering that the main goal of the system is to support the debate among the decision agents, the validation phase was carried out by interacting with the stakeholders involved in the knowledge elicitation phase. The validation phase aimed to verify to which extend the SDM was capable to simulate the decision agents' behavior.

3. RESULTS

The SDM was used to simulate two distinct scenarios:

- Business-as-usual scenario: the river habitat protection policy was not been implemented yet;
- Environmental flow protection: this scenario aims to evaluate the impacts of the protection policy.

3.1 "Business-as-usual" scenario

Due to the drought conditions, the water volume in the Mulargia reservoir decreases. The highly interconnected water supply system in the region allows the reduce the Mulargia vulnerability to drought. The needed water volume could be diverted from other reservoirs, increasing the water distribution costs.
The regional policy aiming to share the water costs allows to keep low the irrigation tariffs. The high accessibility of water for irrigation leads farmers to increase the irrigated areas and consequently the water demand. The level of conflict is low at this stage.
In the second year, farmers' expectation about the water availability is high, leading to an increase of the irrigated areas. CBSM is not able to update the information about the actual water demand and to change its decisions accordingly. This results in an overuse of the water volume in the reservoir and to an increase of the water management costs due to the transfer of water volume.
CBSM increases the water tariffs at the beginning of the next irrigation season. Due to the information delay, these changes are communicated to farmers when they have already taken their own decisions which cannot be changed (information delay). At the end of the irrigation seasons, the irrigation costs are higher than expected, resulting in an increase of the conflict level.
Farmers update their perception of water availability and, in order to keep the production to a high level, decide to use GW for irrigation.
Due to the overuse of the GW, the exploitation costs increase, resulting in a decrease of the irrigated areas. Figure 5 shows the level of conflict in BAU scenario.

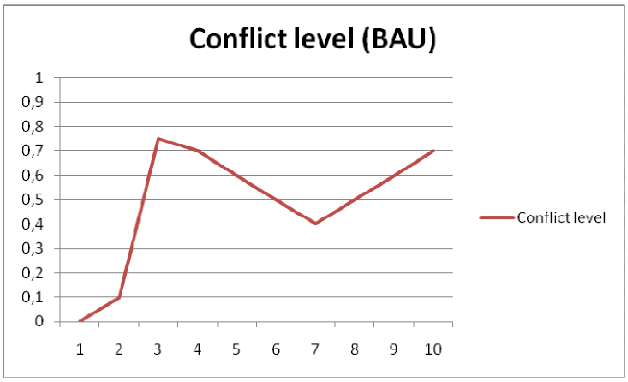

Fig 5: Level of conflict in BAU scenario

The farmers' capabilities to adapt to the changing conditions allow to reduce the level of conflict by increasing the use of GW for irrigation. This results in a impoverishment of GW quality and, consequently, in a reduction of water availability. The level of conflict rises due to this reduction.

3.2 Environmental flow protection

SDM was used to simulate the impacts due to the implementation of the environmental flow protection policy. The this aim, the outflow “environmental flow is increased in the SDM. The water olume available for irrigation decreases and the level of conflict increases.
In order to keep the irrigation costs at a sustainable level, farmers increase the GW use, until they decide to reduce the irrigated areas due to the impoverishment of GW quality.
Figure 6 shows the evolution of the conflict level due to the implementation of the environmental flow protection policy.

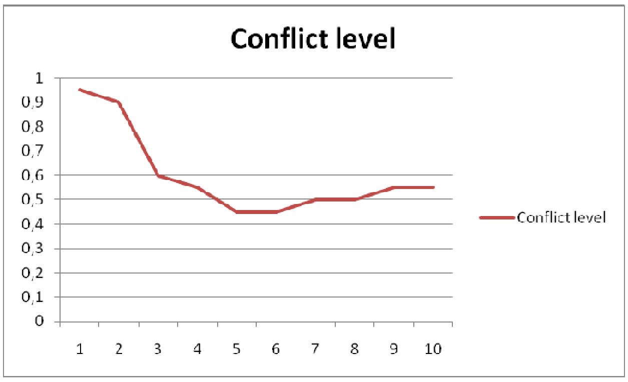

Fig 6: Level of conflict in environmental flow protection scenario

4. DISCUSSIONS AND CONCLUSIONS

The analysis of the obtained results allowed to identify the main reasons of the existing conflicts involving water managers and users. Moreover, the SDM allowed to highlight both the strengths and weakness of the water distribution system. Among the former, the high interconnection degree of the system allowed to keep water tariff at a low level and to guarantee the water distribution even during drought. This reduced the conflict level in the early stage of the simulation.
The transfer of water volume from on part of the network to another implied an increase of water management costs, which were shared among the whole regional population, as results of a political decision.
SDM allowed to highlight the role of information delay in increasing the level of conflict. Farmers seemed capable to adapt to the changing conditions. But they needed to be provided with reliable and timely information about water availability. Increasing the timeliness of information have been demonstrated as crucial to influence farmers’ decisions about the kind of crops and the water demand. This would result in a reduction of the level of conflict.
Improving the monitoring of the water demand by the CBSM would allow to enhance the definition of the water allocation plan, avoiding to underestimate the water consumption.
The implementation of these measures would support local authorities to reduce the level of conflict and, thus, to facilitate the implementation of the environmental flow protection policy.

Acknowledgements

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D1D5.7EN – LOCAL HYDROMORPHOLOGY, HABITAT AND MANAGEMENT PLANS: GENERAL FRAMEWORK OF INHABIT MAIN RESULTS - RIVERS

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1. INTRODUCTION

In the general framework of Water Framework Directive implementation (WFD , EC 2000 /60) it is crucial to consider that alteration of river habitats and their characteristics play a key role in river ecosystems (Maddok , 1999, Garcia et al. , 2012). Monitoring the effects of habitat changes has recently received increasing interest (Friberg et al., 2009; Dunbar et al., 2010). More in general, it is important to identify the environmental gradients and anthropogenic pressures that insist on river systems in order to adopt appropriate quality indicators and to plan effective measures to restore the ecological quality (Hughes et al., 2010). The first step to consider when defining the correct settings of the monitoring systems should include the quantification of natural variability, related to the so-called reference sites. Elements of the spatial scale paly also an important role. The functional link between habitat diversity and biodiversity is observed at hierarchical spatial scales. Each scale shows peculiar biological, hydromorphological and habitat characteristics (Garcia et al. , 2012). In river restoration projects interventions aimed at the diversification of habitats are often carried out in order to improve ecological status. The effectiveness and success of restoration projects is often measured in terms of increase in taxa richness, for it is widely recognized the principle of "biodiversity - habitat heterogeneity" (e.g. Beisel et al. , 2000). In any case, the measure of the adequacy of restoration measures is often affected by the fact that stressors on ecosystems have not been properly identified (Garcia et al. , 2012). In addition, there is a clear need to quantify the relationship between habitat and biota at the local scale in order to understand what physical attributes affect the population dynamics at larger spatial scales.

Moreover, the expression of quality class, also following WFD indications, should be accompanied by a level of uncertainty. Often, the quantification of this uncertainty does not properly take into account the natural variability, related to habitat features, that can affect river ecosystems.

Therefore, with reference to the process of effective implementation of the WFD, EC 2000/60), INHABIT project (LIFE08 ENV/IT/000413) put the emphasis on habitat as a key element for understanding aquatic systems functioning and ecological status. INHABIT project, as part of the LIFE program as 'environmental policy and governance' project, aims to provide some answers to the issues briefly discussed above. In the present contribution the main project results, regarding the rivers are summarized in a nutshell,

2. STUDY AREAS AND CONSIEDERED SCALES E AREE DI STUDIO E LE SCALE DI LAVORO

2.1 Study areas

Project activities have been carried out in Sardinia and Piedmont (Italy), as case study, respectively of alpine/lowland and Mediterranean areas. River stretches/water bodies have been selected according to the following criteria:

- a number of 'Reference' sites (sensu WFD, i.e. sites showing high degree of naturalness) were included (at least 2 per river type);
- selected stretches present wide-ranging habitat conditions and/or peculiar morphological alterations;
- a wide gradient of hydromorphological alteration and lentic-lotic character was covered, ranging from slightly to heavily impaired water bodies; on purpose, studied water bodies were not affected by significant water pollution;
- in order to focus on differences observed in terms of habitat, excluding other possible disturbances, 'couples' of sampling stations have been selected, where possible. The two stations of the couple are positioned at close distance on the same river reach and show obvious differences in habitat features, with the same water quality.

In both the regions, for most the considered water bodies, invertebrate data are available from both pool and riffle mesohabitats, where the recognition of these mesohabitats was expected, otherwise, two samples from 'generic' habitat are available. Invertebrates are sampled through a "multihabitat proportional" technique (CNR-IRSA, 2007), compliant to WFD 2000/60/EC and national legislation (DM 260/2010) requirements. In particular, the adopted sampling strategy, considered the single sampling units to be kept separate.

In other words, for each investigated site, 10 or 20 separate sampling units are available . Analyses on such separate samples can provide important information on the interpretation of factors most affecting biotic communities . The organisms collected were identified to family level, with the exception of some taxa, identified to a greater level of detail. Data from diatoms community are also available for most of the sites. In each river stretch CARAVAGGIO method (Buffagni et al., 2013) for the characterization of habitat and hydromorphological features at a 500m scale has been applied. Through the application of CARAVAGGIO method it was possible to derive descriptors HMS, HQA, LUI and LRD. The details of these descriptors can be found in Buffagni et al. (2010). Simultaneously with the biological sampling a sample of water was collected for the physico-chemical characterization. For each river stretch value and class of LIMeco (DM 260/2010) index is available, in addition to the concentration values of basic chemical and physical variables .

In Piedmont two different river types were investigated (small lowland rivers , small rivers and alpine 6 HER , HER 1), for a total of 18 river stretches. In Sardinia a total of 48 river stretches were investigated, mostly typically temporary. In small streams in Piedmont of the Alpine area river stretches investigated are characterized by a not very marked habitat gradient, and only few sites were affected by strong habitat degradation. Having paired stations whose habitats are unaffected (or at least not significantly compromised) with impaired sites, is the key to a clear understanding community composition. In lowland area, the gradient is a bit more pronounced and a greater number of river stretches with degraded habitat were

observed, while excluding strong alterations related to water quality.
In Sardinia, keeping the general approach considering an high variety of habitat conditions, stations were chosen in order to cover a wide hydraulic gradient, in terms of relative presence of lentic and lotic areas, considering the relevance of the lentic - lotic character in structuring biotic communities. In Sardinia a first field campaign has been performed in May 2011. On the basis of the results obtained in the first field campaign, in particular after the analysis of the observed habitat gradient, a second field survey has been performed in March 2013. In this second campaign, water bodies were selected in order to represent conditions of strong lentic and lotic character. In some of the additional water bodies, disturbance caused by drought on the macroinvertebrates community re-colonization has been investigated.

2.2 Spatial scales and results interpretation

The study of biotic communities, habitats and rivers in general can embrace different spatial scales that can be hierarchically ordered (Maddok , 1999). The different spatial scales can range from microhabitat (e.g. areas with a specific substrate, depth and current velocity), mesohabitats (homogeneous areas , derived from the combination of different microhabitats), river reach , and river system. Each of these components has a different sensitivity , as well as a different recovery time and require clearly different restoration options. Within INHABIT context, analyzed spatial scales were: 1) microhabitat (single invertebrates sampling unit, characterized by flow type, substrate type, current velocity and depth) ; 2) mesohabitat (aggregation of the different sampling units), 3) river reach (500m characterized by the application of CARAVAGGIO method), 4) sub-basin and basin. In particular, for up-scaling large-scale hydro-morphological aspects have been considered, including the processes affecting catchment erosion and land uses, using GIS approach. The detailed results of this activity are included in Deliverable I3d2.
Apart from the substantial differences in the longitudinal distribution of benthic invertebrates, it is also possible to detect differences at a smaller spatial scale. The distribution of benthic invertebrates may be different from bank to bank, depending on the availability of different habitats (e.g. CPOM , submerged roots), flow type, etc. Some studies have shown for invertebrates a shift of niche according to changes in body size (Buffagni et al. , 1996). Invertebrates show often clear preferences in terms of flow and substrate: a change induced in these factors can then lead to a change in the presence of certain taxa. The characterization of autoecological preferences, i.e. the interaction environment / individual, is of particular importance for a better understanding of the links between physical habitat and biota. Also, this is a valuable support to the evaluation of ecological integrity, allowing the implementation of specific strategies for river ecosystems recovery and conservation. The information collected at different spatial scales have been developed in relation to biotic communities, also in order to identify which variables can better represent the observed differences among river stretches in terms of biotic communities.

3. GENERAL FRAME OF RESULTS

The results obtained in the project are summarized in 4 tables (tab. 1-4), each dedicated to a group of topics, described in 4 different sections. Each table summarizes in the different columns the objectives of the project. The type of result is briefly shown for each of the objectives, together with the innovative aspects and the type of selected descriptors, as well as the general utility of the results and their applicability. The contents of the tables are described in detail in the project deliverables (explicitly mentioned in the tables) and should provide an indication of the key points of the project.

3.1 Habitat

Detail project aims related to habitat (Table 1) have been:

- survey and description of river habitats;
- quantification of natural variability;
- quantification of alteration of river habitats;
- habitat classification.

Characterization of habitats, as already described, was carried out by means of CARAVAGGIO method. An important result of INHABIT project has certainly been the preparation of the application manual for the method. CARAVAGGIO, created in 2005 as an improved version of English RHS English, never had a proper application manual. Being focused on habitat, INHABIT project has been an ideal opportunity to finalize some aspects related to the method application and, eventually, to deliver the manual. An important activity of the project INHABIT in the development of the CARAVAGGIO method was the definition and verification of class boundaries for the descriptors defining IQH (Habitat Quality Index, in DM 260/2010). These values allow to perform a classification of the investigated river reach, considering the different aspects of the habitat. The tables containing the class limits were initially presented in deliverable Pd3 . The activity of the finalization of the method CARAVAGGIO has also been accompanied by the development of the 'Experimental' CARAsoft , based on the original RHS software, which can be used for CARAVAGGIO data input and processing. This software will be available on INHABIT project website. Due to the lack of testing, the software could present some problems of compatibility with some OSs. The use of CARAsoft will also allow the calculation of the habitat descriptors HMS, HQA and LUI, used for habitat classification in accordance with Ministerial Decree 260/2010 and subsequent updates. During project activities data from the characterization of habitats, with particular reference to CARAVAGGIO descriptors, were analysed in order to define habitat / biota relationships. Analyses have confirmed the importance of the lentic - lotic character (as quantified by LRD descriptor), especially in the Mediterranean area, and models have derived to improve classification accuracy. About this, it has been possible to describe how lentic-lotic character has to be considered for site-specific refinements of expected reference conditions (Del. I3d1). In fact, when lentic-lotic conditions are not ideal for benthic communities, there is high probability of performing systematic errors in the classification of ecological status. The simultaneous evaluation of both biological and habitat elements can limit this problem, allowing more accurate classifications.

3.2 Fine tuning of MacrOper system

Useful data for the refinement of MacrOper classification system (Table 2) were achieved. Procedural elements necessary to the refinement of MacrOper application were acquired and included in the calculation software MacrOper.ICM. The software was distributed during INHABIT project workshops and meetings and made available on the project website(http://www.life-inhabit.it/cnr-irsa-activities/it/download/software/macropericmsoft).

Data collected have also been used to calibrate and validate (deliverable D1d1) classification system and propose updates to the Ministerial Decree 260/2010 .

INHABIT experience, led by the results obtained in MIRAGE project, allowed the collection of information useful for better definition of the adequacy of the sample considered for classification, in terms of 'aquatic state'. Lastly, through habitat characterization, it was possible to select biological metrics enabling the quantification of specific forms of impact, potentially useful for investigative and surveillance monitoring (e.g. abundance of Leptophlebiidae).

Tab. 1 –INHABIT results explicitly related to habitat theme.

General aim		Survey and description of river habitats	Quantification of natural variability	Quantification of river habitats alteration		River habitat classification
Area of interest		Habitat	Habitat / legislation support	Habitat	Habitat	Habitat / legislation support
Methodological approach / method		CARAVAGGIO	CARAVAGGIO / polinomial regressions	CARAVAGGIO / polinomial regressions	CARAVAGGIO / polinomial regressions	CARAVAGGIO
Main results	Selected descriptors	various	LRD, HQA	LRD	HQA, HMS, LUI	HQA, HMS, LUI
	Synthesis	Definition of field procedures	Accurate reference conditions: type and site specific. Inclusion of information on lentic-lotic character in tyhe estimation of expected values	Quantification of effects of water abstraction on biocoenoses	Quantification of effects of habitat alteration on biocoenoses	Definition of habitat classification assessment system
	Innovative tools	Manual of CARAVAGGIO method	LRD curves vs biological metrics; creation of an APP for Android supporting the identification of lentic-lotic character	LRD curves vs biological metrics	Criteria for the application of individual indices and type of information; support to the selection of possible measures (examples for selected water bodies)	Table containing class boundaries for habitat descriptors; CARAsoft update
	Use	Everywhere	Mediterranean Italy, Cyprus	Models defined for mediterranean rivers; following extra settings, all South European rivers	South european rivers	South european rivers
Notes and potential impacts		Italian and English version	Accuracy correction can determine higher percentages of good/high status classification (>15% and >30% in the two areas) in water bodies not affected by significant water abstraction; possible update of DM 260/2010	Improvement of measures efficacy	The application of suggested criteria can support the selection of measures for river habitat restoration, allowing the verification of efficacy of measures	Possibility of river habitat classification
Reference INHABIT Del.		Pd3, D1d5	I3d1, I3d2	I1d4, D1d5	I1d1, I1d4	Pd3, I1d1, I1d4

Tab. 2 – INHABIT results related to MacrOper system fine-tuning.

General aim		**Fine tuning of MacrOper system**				
Area of interest		Inverebrates / legislation support	Inverebrates / legislation support	Inverebrates / legislation support	Inverebrates	Inverebrates / legislation support
Methodological approach / method		Procedures		CIS approach	various	Muntivariate analysis and data mining
Main results	**Selected descriptors**	various		Official classification metrics	*aquatic state* (MIRAGE project), lentic-lotic character, warning biological metrics	Several biological mertrics
	Synthesis	Refinement of some elements (calculation, area of application) useful to ecological status classification according to macroinvertebrates	Software update including elements at previous point	System setting through definition of new biological reference values	Refinement of sampling approach in Mediterranean area	Some metrics have been defined for surveillance and investigative monitoring
	Innovative tools	Habitat characterization	MacrOper.ICM software Version 1.0.4	New reference values	Possibility of evaluating if observed habitat conditions are adequate to interebrate sampling for ecological status classification	New biological metrics; creation of an APP for Android supporting the identification of Ephemeroptera OU
	Use	Italy/South Europe	Italy	Piedmont and Sardinia	South European rivers	Italy/South Europe
Notes and potential impacts		Better definition of ecological status and adequate application of MacrOper system	Software used by all Italian environment agencies, other public bodies (research institutes, parks etc.) and privates (professionals, students etc.)	EQR calculation and more accurate calculation of ecological status; D.M. 260/2010 update	If suggestions will be used, together with biological metrics, it will be possible to avoid unadequate sampling periods and increase classification accuracy	Better understanding of the effects of different types of alteration and evaluation of the efficacy of measures
Reference INHABIT Del.		D1d5,I3d1, I3d2	D1d5	D1d5, I3d2	D1d5	D1d5

3.3 Self-depuration capacity, possible measures, up-scaling and Directives interaction

Table 3 presents the results related to the following issues:

- Reference sites validation.
- River functioning evaluation – potential for self-depuration.
- Possible effects on river habitats related to erosion in catchment, solid transportation and longitudinal continuity.
- Up-scaling to catchment level of local aspects (reach).
- Comparison for integration of morphological studies carried out at different spatial scales.
- Hypotheses on possible measures in terms of habitat features.
- New elements for integration between HABITAT Directive and WFD.

The project INHABIT performed validation and selection of reference river sites proposed for official use for national classification.

INHABIT activities related to the analyses of functionality of river ecosystems represent one of the first attempts in Italy to carry out experiments of nutrients addition. These experiments have allowed to define how and what habitat characteristics play an important role in nutrient removal.

Regarding the characteristics of habitats that can most affect aquatic biocoenoses, analyses were carried out in order to extend to a larger spatial scales the obtained results. In particular, information related to erosion and deposit were considered and used in order to identify key areas and critical areas within river catchments for the preservation of natural river processes. The same dynamics can also be considered for the evaluation of bank quality in the investigated water bodies. In addition, relationship between the presence of artificial structures and the interruption of longitudinal connectivity, with the related local habitat alteration, has been examined.
A comparison between the evaluations of morphological and habitat conditions, performed at different spatial scales has been considered, in order to verify possible connections and potential for integration in management measures.

With reference to the CARAVAGGIO descriptors (HMS , HQA and LUI) some hypotheses were put forward about the implementation of measures for habitat improvement.

Lastly, some key points of INHABIT project were considered in relation to in Key Habitats Directive (HD) , in order to propose integration between the WFD and HD , as further specified in Chapter 5 .

3.4 Biological data interpretation, cause-effect hypotheses and verification of measures efficacy

Table 4 reports results on:

- Description of gradients of variation defined by macrobenthic communities.
- Biological validation of WFD types.
- Biological data interpretation.
- Assessment of water quality for the interpretation of biological data.
- Definition of the potential of metrics in synthesizing observed gradients of alteration.
- Quantification of the biological response to different types of habitat alteration.

The points listed here, could be summarized in a conceptual scheme that will synthesize the entire process.

Variation gradients of benthic communities have been investigated using multivariate analysis techniques, both in term of taxa and derived metrics (INHABIT D1d5.2en, 2013). These analyses have allowed the identification of the most important factors in structuring the aquatic biocoenoses (deliverable D1d5) and the pre-selection of the most effective biological metrics in representing environmental gradients and anthropogenic pressures. In the evaluation of the variability of benthic communities, analyses of biological validation of river types have been carried out. Such analyses have confirmed the general validity of the typological system, although further insights are needed for the Mediterranean area (Grass et al., 2012).
Quantile regression analyses were carried out (INHABIT D1d5.3, 2013) in order to define relationship between biological metrics (selected by multivariate analysis). These regressions have allowed to define which biological metrics can better identify specific anthropogenic pressures and can therefore be used as tools to measure the effectiveness of restoration measures. In this context, in order to properly assess the baseline conditions, functional to an appropriate measures definition, habitat descriptors can be used to analyse observed conditions and to define expected effects (Figures 1-4). Figures 1 and 2 represent in a pentagon shape the quantification of different environmental factors and habitat in two river stretches: a reference site (Rio Flumineddu) and an heavily impacted site (Canale Monte Depuratore) . The greater the length of the segment that defines a 'tip' of the pentagon, the more the environmental factor is not altered. The result is that the Flumineddu (Fig. 1) may present a not optimal biological community only due to the not ideal hydraulic conditions (excessively lotic conditions). Conversely, it is expected that a site as the Canale MD (Fig. 2) present impaired biological communities for no environmental factor is close to 1.

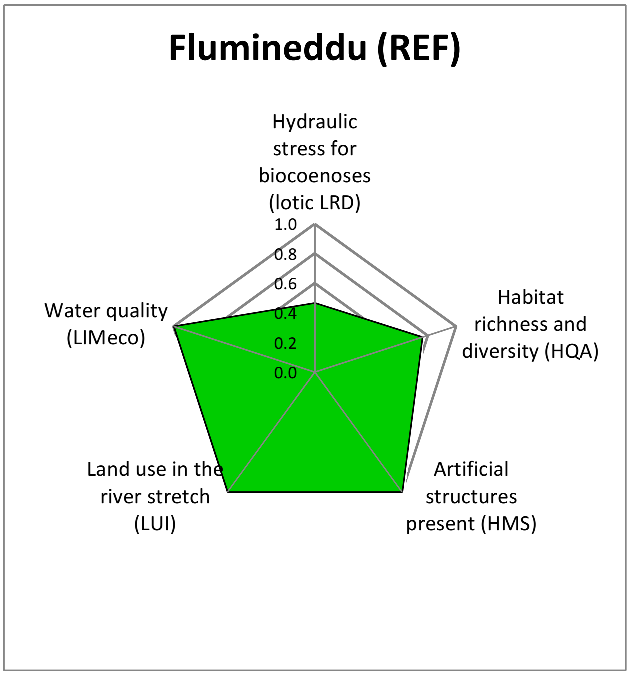

Fig. 1 – Quantification of habitat features in reference site Flumineddu (Sardinia). Green area represents quality status as defined by benthic invertebrates.

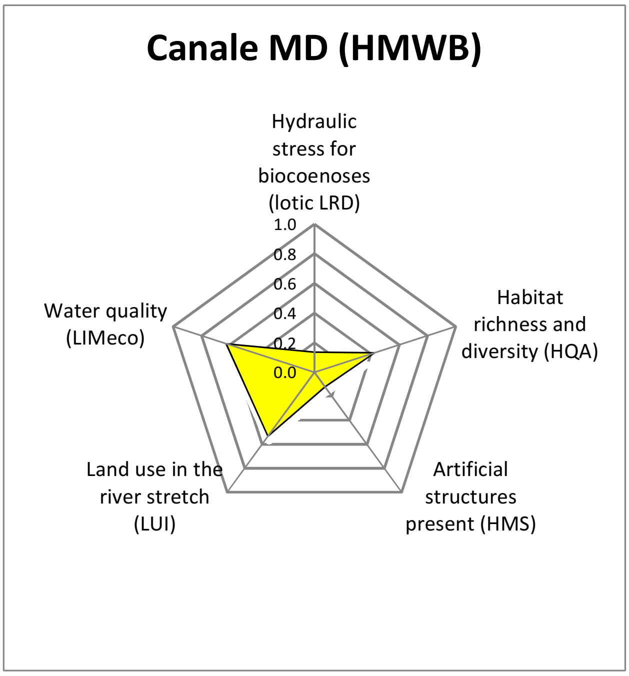

Fig. 2 – Quantification of habitat features in HMWB Canale MD (Sardinia). Yellow area represents quality status as defined by benthic invertebrates.

The same graph type can be used to show the distance from value '1' of the biological metrics, and to verify which metrics are more sensitive to alteration. The placement of the biological metrics correspond to the habitat features that the metrics themselves are mainly able to detect.

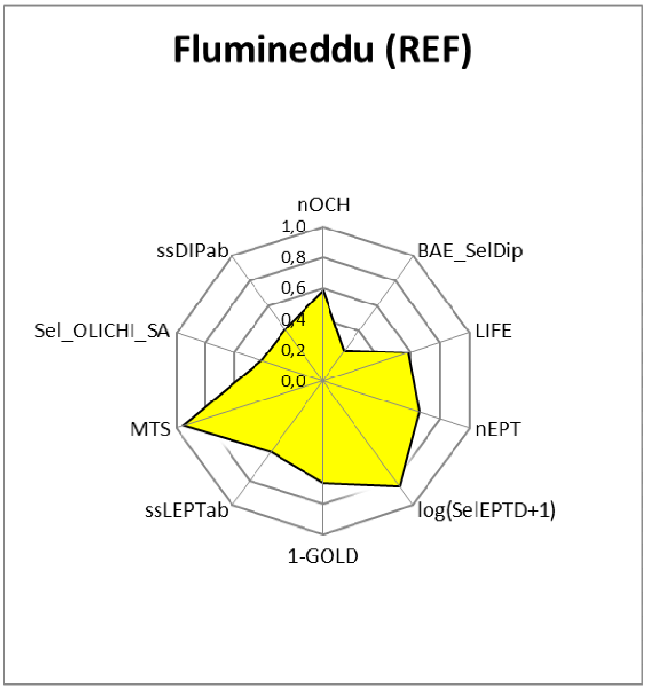

Fig. 3 – Quantification of biological metrics (benthos) in Flumineddu reference site (Sardinia).

As expected from results showed in Figure 1, in Flumineddu (Figure 3) metrics shifting from the optimum condition (1) are sensitive to the hydraulic characteristics (lentic-lotic character). In Channel MD (fig. 4) all the metrics are compromised, as a result of the alteration of all environmental factors.

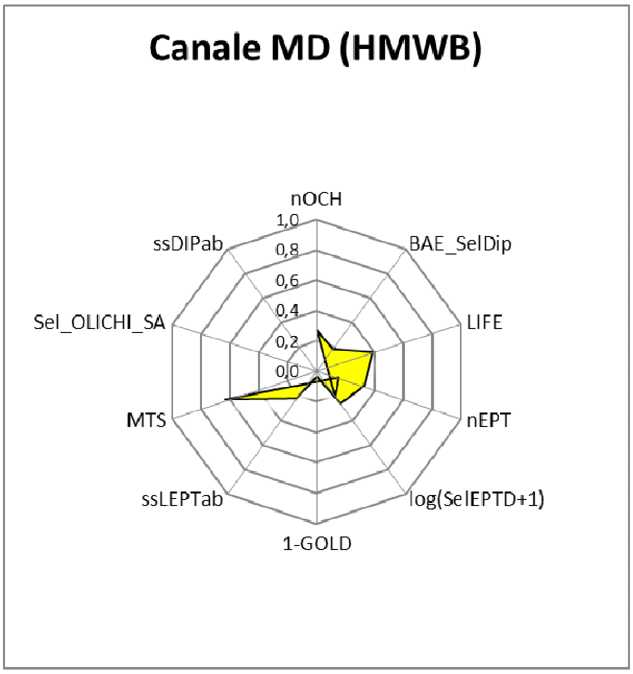

Fig. 4 – Quantification of biological metrics (benthos) in HMWB Canale MD (Sardinia).

As completion of the project and based on the obtained results, briefly summarized in the tables, a conceptual framework to be used to support planning of restoration measures of ecological quality will be developed.

Tab. 3 – INHABIT results related to fluvial functioning and up-scaling.

General aim		**Reference sites validation**	**Evaluation of fluvial functioning and self depuration capacity**	**Study of possible effects of erosion in the basin, sediment transport and longitudinal continuity on river habitats**	**Up-scaling to basin scale of more loca aspects (reach)**	**Hypotheses of possible measures in terms of habitat characteristics**	**Provision of new elemens for WFD and HABITA Directive integration**
Area of interest		Legislation support	Habitat	Large scale hydromorphologicla aspects, uses and habitats	Large scale hydromorphologicla aspects, uses and habitats	Habitat	Legislation support
Methodological approach / method		Official procedure D.M. 56/2009	Nutrient addition experiments (N/P)	GIS	GIS	CARAVAGGIO	Integration INHABIT reults and literature information
Main results	**Selected descriptors**	various	Quantification of transient storage zones; uptake length; uptake velocity	various	various	various	Some key invertebrates species
	Synthesis	Application procedure for selection and validation of reference sites	Capacity of nutrient removal explicable in terms of habitat characteristics (e.g. transient storage areas, width/depth ratio, wetted channel width)	The understanding of the relationship between the presence of man-made structures and local habitat alteration has allowed the estimation of such alterations in the considered basins	Up-scaling of information relating to erosion and deposit for the evaluation of the quality of bank in studied water bodies	Information on components that most influence habitat	Habitat characteristics (LRD) of some taxa and areas of preferential presence were matched with the optimum for good ecological status
	Innovative tools	Combination of different tools for pressure quantification	removal curves for natural and resectioned channels, for NH4 and PO4	GIS model output	GIS model output	IQH calculation	Integrative approach
	Use	Piedmont and Sardina	South European rivers	Sardinia	Sardinia	South European rivers	Potentially everywhere (examples form Sardinia)
Notes and potential impacts		More accurate classification of ecological status	First data from temporary rivers	Better understanding of processes and relations among spatial scales (rive rreach and basin)	Better understanding of processes and relations among spatial scales (rive rreach and basin)	Improved ability to set effective measures	Mitigation of potential conflicts between the two Directives; harmonization between good status achievement and biodiversity protection
Reference INHABIT Del.		I1d1, I1d4	I2d2, I2d3, I3d3	I3d2, D1d5	I3d2	I3d2	D1d5

Tab. 4 – INHABIT results related to biological data interpretation and possible measures for restoring ecological quality.

General aim		Description of variation gradients as defined by benthic community	Biological validation of WFD typoology and need for further investigation	Biological data interpretation	Water quality assessment for biological data interpretation	Definition of potential of metrics in summarizing biological observed alteration gradients	Quantify the biological response to different types of habitat alteration	Development of a framework for the identification of the main causes of the observed effects on biotic communities, of possible measures and effectiveness verification
Area of interest		All	Legislation support	Invertebrates and habitat	Water	All	Habitat, biocoenoses and measures	All
Methodological approach / method		Multivariate statistical analyses (PCA)	Multivariate statistical analyses (TWINSPAN e DCA)	CARAVAGGIO	Chemico-physical analyses	Multivariate statistical analyses (RDA)	Quantile regression	Procedural elements and connections between different elements
Main results	**Selected descriptors**	pressures and type variables	LRD, HER, dist. from source, alt	LRD, HQA, HMS, LUI other	LIMeco	STAR_ICMi metrics (+ other metrics); CARAVAGGIO descriptors; LIMeco	STAR_ICMi, STAR_ICMi metrics, other selected metrics	Various
	Synthesis	LRD first factor of variability in Med area, also when alteration are present	Importance of LRD in Med area in particular, confirmation of HER significance	Joint use of different habitat descriptors and biologicla metrics (in groups)	Good relation STAR_ICMi LIMeco; difficulty in separating water quality and hbaitat quality effects	LRD is separated from other habitat elements; difficulty in distinguish among various component fcators of anthropic alteration	Description and quantification of biological respnse (benthos) to habitat alteration	Integration of the obtained elements into an overall framework
	Innovative tools	Simultaneous evaluation of different aspects	Site specific close examinatio needed in Med area	Possible overlap of habitat and biological information	Simultaneous analysis of differen abiotic factors representative of quality	Metrics pre selection	Models andtype of response of biological metrics for different types of habitat alteration	Conceptual schemes
	Use	All river types	All river types	South European rivers	South European rivers	South European rivers	Diagnosis of the main sources of alteration of benthic community; verification of measures effectiveness	South European rivers
Notes and potential impacts		Better interpretation of biological response	Improvement of classification accuracy when type refinement is considered	Better interpretation of biological response to alteration and definition of possible measures	Better interpretation of biological response to alteration and definition of possible measures	Definition of tools to evaluate measures efficacy	Verification of the measures effectiveness. Development of metrics for surveillance and investigative monitoring	Assessment of the main causes of the observed effects on biotic communities, of possible measures and evaluation of their effectiveness, optimization of monitoring plans and measures planning
Reference INHABIT Del.		I1d4, D1d5	I1d4	I1d4, D1d5	I1d4, D1d5	D1d5	D1d5	D1d5

4. EVALUATION OF RIVER HABITATS: WASTE OF MONEY OR REAL NEED?

WFD has introduced new concepts and new ways to address issues related to aquatic environment. However, regarding habitat in particular, and environmental protection in general, Habitats Directive (HD 92/43/EEC) cannot be overlooked. Habitat Directive refers explicitly to the concept of habitat, although in a different way than intended by WFD. WFD requires the assessment of ecological status to be based also on habitats characteristics, although such characteristics are not clearly defined if not in terms of: morphological conditions, longitudinal and lateral continuity and hydrological regime.

In general, the significance of habitat in structuring biotic communities is widely recognized by the scientific community. The results obtained by INHABIT project bring further evidence for this, providing, in addition, useful tools for a better understanding of the river ecosystem. Experimental evidences of INHABIT project confirm, as well, how biological interpretation of the results may be complicated by the interaction of several environmental factors. The interaction between various environmental factors can cause conditions where low habitat diversification are counterbalanced by markedly lotic conditions, or where a not optimal lentic - lotic character are offset by the possible diversification of habitats (see INHABIT D1d5.5, 2013). Similarly (Fig. 5), lotic values (i.e. negative LRD values) can compensate for conditions of relative water pollution (LIM eco). Conversely, when the hydraulic conditions are lentic (positive values of LRD, i.e. dominance of lentic features compared to lotic habitats) the effects of pollution become evident.

All this leads to the conclusion that the survey and description of the habitats is a crucial step for the understanding of biological communities structure and function under "undisturbed" conditions and their responses to changes due to human activities.

Combined effect of a positive lentic-lotic character (LRD)/lotic environment and poor water quality (LIMeco)

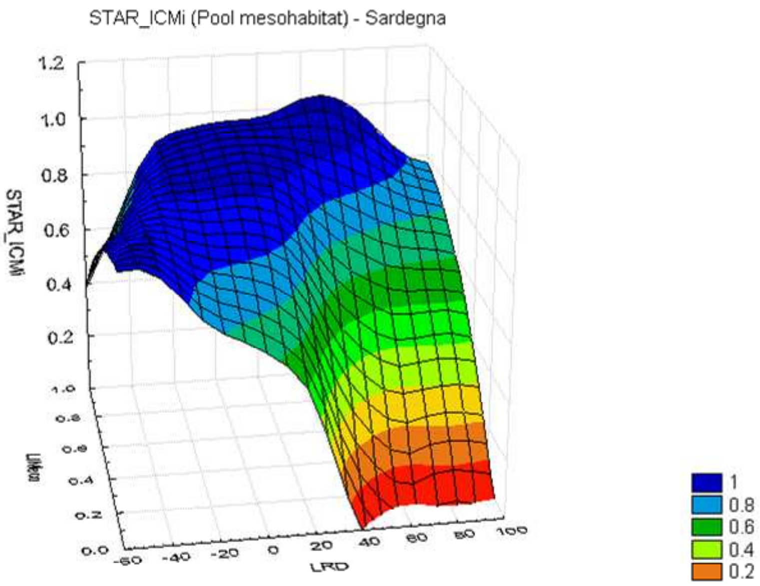

Fig. 5 – Interaction between lentic-lotic character and water quality: effects on STAR_ICMi index.

5. TOWARDS THE INTEGRATION BETWEEN HABITAT DIRECTIVE AND WFD?

Although WFD and HD have been promulgated with different timing, their different objectives cannot be considered as separate. Aims of the two directives should converge, on the basis of the many - and important - points of contact.
In particular, with regard to aquatic invertebrates, even for widely distributed Habitat Directive species, current autoecological knowledge is often not sufficient to define an effective management for the protection of the species. Moreover, even when such knowledge is adequately detailed, this is often not sufficiently organized to ensure a practical use of the information, partly compromising the complex management needs.
Also, it is important to emphasize for Southern Europe the high rate of endemic, rare and endangered species, for example among aquatic insects, poorly represented in the annexes of the HABITAT Directive. This status preclude specific conservation measures or dedicated monitoring for such species. For example, no species of mayflies (Insecta Ephemeroptera) among the ones reported for Mediterranean basin is here present; consequently, the whole order is not subject to any protection action, despite its relevance for aquatic biodiversity, the purposes of the WFD and the known presence of endemic endangered species. This is probably partly due to gaps in basic research. In very few cases the species not included in the annexes of HD are included in the regional Red Lists. Regarding this, it should be noted that orders of insects that includes high percentage of endemic species, such as Plecoptera (28.5 % of endemic species in Italy) and Ephemeroptera (21.3 %) (Stoch, 2000), used as bio-indicators in WFD quality assessment systems, could be considered in specific programs of biodiversity protection or for their possible inclusion in the annexes of the Habitats Directive. In fact, for these taxa only very fragmentary chorological data are available and their autecology (in particular in terms of habitat preferences, at different scales) is, in almost all cases, unknown.
In these cases, each advance in autoecological knowledge will support water bodies management that can - in addition to considering the achievement of good environmental status by 2015 and the protection of HD species and habitats - promote the conservation of these endemic and/or rare species so important for the biodiversity of the Mediterranean region, although not subject to a specific protection. Despite the presence of two major EU environmental directives (WFD and HD), significant gaps in the protection of aquatic insects persist, mostly related to the lack of knowledge of their autoecological preferences, especially in the Mediterranean area. These gaps are also likely to have determined the limited presence of aquatic insects in the HD Annexes.
The data collected during INHABIT project, having considered all the individual sampling units as separate, may contribute to the implementation of such autoecological knowledge.
Moreover, the achievement of the WFD objectives falls only apparently beyond the taxonomical, distributional and ecological issues of many biological groups - with the result that these aspects are neglected - although it is precisely the variability related to such issues that determines the difficulties in interpreting quality results.

Moreover, not always the achievement of WFD quality objectives is a sufficient condition to protect biodiversity or endemic species at risk of extinction, as shown in Figure 6. The figure represents how particular values STAR_ICMi vary with the variation of lentic lotic character (black curve), in unaltered rivers in Sardinia. It also depicts the variation in abundance of two

Sardinian endemic species (*Agapetus cyrnesis* and *Isoperla insularis*), in relation to LRD changes. It is noted that STAR_ICMi index presents the optimal values when LRD is between -20 and +40, for a correct assessment of the ecological status such LRD interval should be considered to avoid underestimation of quality assessment. However, such LRD interval is compatible with the presence of the species *A. cyrnesis* (Trichoptera), but not with the presence of *I. insularis* (Plecoptera), for which values of the LRD around -10 or above would be critical and could cause disappearance of the species. These considerations, although needing further refinements, support the need to integrate evaluation related to HD and to WFD implementation, through habitat information, also considering INHABIT results.

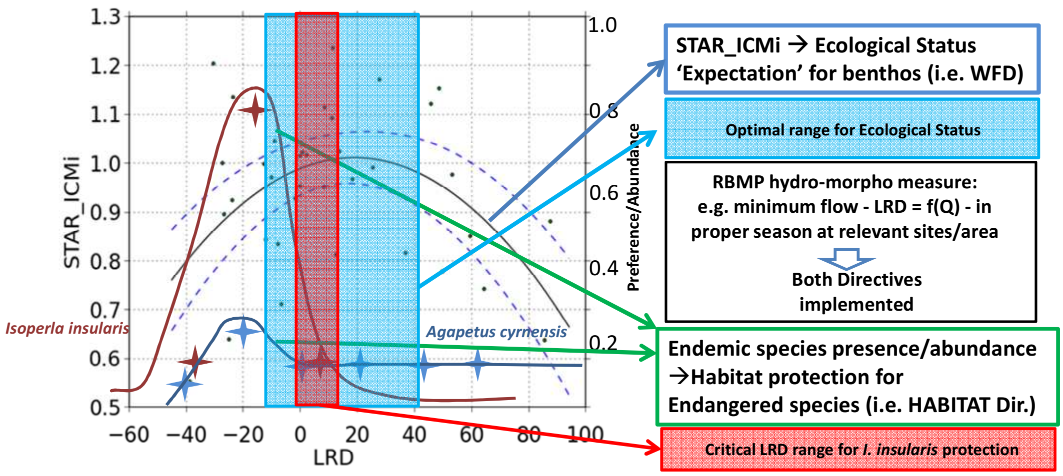

Fig. 6 – Comparison between optimal LRD values for the evaluation of ecological status (STAR_ICMi, black line), for *Agapetus cyrnesis* (blue line) and for *Isoperla insularis* (violet line) in unimpaired rivers in Sardinia.

6. CONCLUSIONS

This paper is meant to present a summary of INHABIT project achievements, also providing a guide to the various issues, related to rivers, the project has dealt with. In particular, we believe that the evidence obtained in the project, for what rivers are concerns, can provide useful elements addressing some important issues related to :
- better definition of river types;
- better definition of reference conditions;
- improvement in the knowledge of habitat related aspects;
- use of habitats information for the assessment of ecological status;
- better understanding of the factors affecting macrobenthic communities;
- definition of ecological status classification (invertebrates) precision and accuracy;
- acquisition of elements useful for evaluating the effectiveness of the measures.

INHABIT has also collected habitat related information that may, at a later stage, be used for:
- setting environmental assessments of impacts related to the creation of mini-hydroelectric plants. Recent years have seen an increasing amount of requests for mini-hydroelectric plants construction, although no proper tools are available at present to evaluate their effects on stream ecosystems;
- supporting the quantification of ecologically acceptable flows (ecological flows), using descriptors such as LRD and the relationship between lentic - lotic character and biotic communities (see INHABIT Deliverable I3d1);
- supporting the Environmental Impact Assessment (EIA, SEA) in relation to the requests for installation of derivation. Some weakness at technical level are present at the moment for hydromorphological and habitat assessment. At national level (Italy), no univocal guidelines are available on the methodology to be used to assess certain types of impact. Some regions refer to PHABSIM (Milhous et al., 1984), considered as a complicated and single-species targeted method; other regions use the IDRAIM (Rinaldi et al., 2011) that can in some cases lack of sensitivity, being applied at a larger scale. In this regard, INHABIT achievements may support the evaluation of the impacts on habitats (through application of CARAVAGGIO method) and on a wide array of specific biological metrics, making available specific tools for the EIA/SEA and for surveillance monitoring.

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