RR 2004
3rd European Conference on River Restoration
RIVER RESTORATION 2004
Zagreb, Croatia, 17-21 May 2004

Stream typology- basIs for river restoration process

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ABSTRACT : One of the ways of the achieving of the overall objective of Water Framework Directive, respectively the "good status" of all the European water bodies is represented by the restoration process of rivers and ecosystems directly dependent on aquatic ecosystems, with a strong necessity for the co-ordination of the river restoration measures on river basin level.

A key element in the designing the river restoration programmes is represented by the defining of river typology, which takes into account the natural potential and variability of rivers and which represents the bases for the establishing the river restoration targets.

The paper presents the methodological elements for the defining of stream typology and reference conditions towards the establishing of the targets of the river restoration process.

For defining the stream typology in Romania, the system B has also been applied similar to most European countries (including countries from the Danube river basin district). By applying the system B and by its validation through ecological analysis of macroinvertebrates, a number of 32 types and 43 sub-types differentiated according to the geology has been identified, representing the basis for the defining of reference conditions and of targets for river restoration process.

KEYWORDS: River restoration, Water Framework Directive, stream typology, reference condition, good status, good ecological potential

1. Introduction

For hundreds of years mankind has modified the functions of the rivers towards economical purposes, without taking accordingly into consideration their ecological functions. In most cases the river engineering works have led to the degradation of the river habitats and riparian zones and implicitly to the degradation and antrophisation of the natural ecosystems, behind their support capacity.

In order to protect the aquatic environment, terrestrial ecosystems and wetlands directly depending on aquatic ecosystems against to the increasing and more complex anthropogenic pressures, on 22nd December 2000, the most comprehensive European Directive came into force, under the name of the Water Framework Directive (2000/60/EC).

The Water Framework Directive is the first EU "sustainable development Directive", which states the necessity of the harmonization of social-economical system development with support capacity of aquatic environment , having as overall objective the achieving of the "good status" for all European water bodies within a certain timeframe(15 years).

One of the ways of the achieving the overall objective of Water Framework Directive, is represented by the river restoration process, co-ordinated on river basin level.

During the time, in response to the increasing and more complex human pressures on aquatic and riverane ecosystems and in accordance with the European Water Legislation, the concept of river restoration has evolved, from an initially strong morphological component to the complex river restoration measures as they are defined by the Water Framework Directive.

In the new framework of action in the field of European water management established by the Water Framework Directive, the general objectives of the river restoration process are represented by :

- the achieving of "good status" according to the requirements of the Water Framework Directive;
- the achieving of "goof ecological potential" for the ecosystems (heavily modified and artificial water bodies) which present hydromorphological alterations and alterations of their primary characteristics; this less severe environmental objective has been introduced by the Water Framework Directive in order to reconcile the divergent opinions of the ecologists and civil engineers regarding this category of ecosystems.

2. Requirements of the river restoration process

The objectives of the river restoration process can be reached, as it is mentioned in the Article VI of the WFD, through the following:

- the improvement and the providing of adequate habitats for biodiversity development;
- the improvement of water quality for the reaching of environmental objectives set-up by the European Directives;
- the improvement of hydrological regime.

The designing of river restoration programmes has as basis the defining of stream typology (measures being type-specific targeted) , from which the establishing of reference conditions and the defining of "good status" and "good ecological potential" are derived.

The stream typology takes into account the natural potential and variability on the basis of the natural or near-natural conditions, named reference conditions.

Restoration to some previous natural or near-natural status and the achieving of reference conditions are unlikely and theoretically and practically impossible, having in view the continuous and irreversible evolution of the ecosystems. For this reason the river restoration has to be seen as a control of the evolution towards two status : good status and good ecological potential, which represent the targets of river restoration process (fig.1).

The typological approach provided by the WFD is based on a new and interdisciplinary approach, using data from aquatic ecology, geology, geography and hydrology, which has as aim the development of a common stream type system at European level and the establishing of the environmental objectives and type-specific targets for river restoration.

At the present, the approaches of stream typology at European level are very diverse and shows that the choice of a typology is still an open issues for most EU Member States, Danubian countries as well as for EU Candidate Countries.

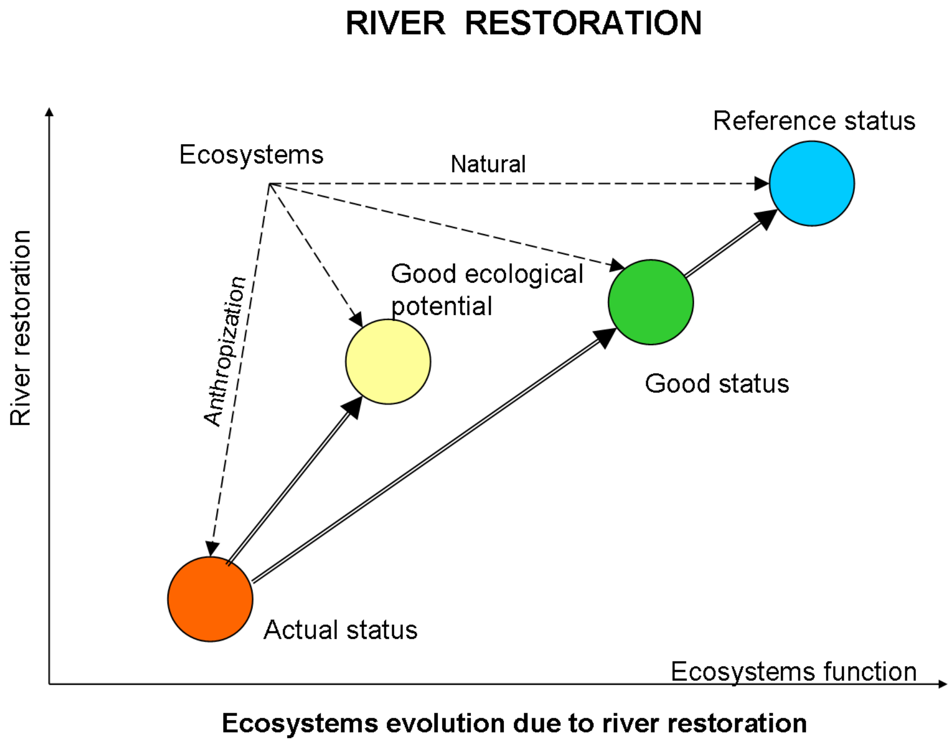

Fig.1 The evolution of ecosystems in relation with river restoration

3. The abiotic stream typology in Romania

The selection of stream typology approaches depends on the purpose of the typology. Having in view that the purpose of stream typology in Romania is represented by both defining abiotic stream types and the reliable determining of reference biological communities, the stream typology is to be defined by the accomplishment of the following steps:

- the "top-down" typological approach /abiotic typology/ cause-effect approach ;
- the "bottom-up"/biotic typology/effects-cause relationship directed by ecological analysis;
- the superposition of these two approaches, in order to obtain a final defining of the types.

In the case of the "top-down" typology, the WFD (Annex II 1.2.) provides two optional approaches for the development of regional river typology: system A and system B [1].

Regarding the optional approaches, at European level, nine countries (Austria*, Belgium, The Netherlands, Germany*, Norway, Sweden, Finland, Romania* and UK out of which * are Danubian countries) have taken the decision to use the System B for rivers [1], each country selecting its optional parameters provided by this system. The comparison of the selected parameters have indicated a relevant similarity among countries [2].

The selection of the system B for abiotic typology also in Romania has been made based on the fact that for a country with high relief variety like Romania, a system which requires more parameters for a more accurate and detailed description is more adequate. The parameters which have been used for the abiotic characterisation are represented by 4 obligatory parameters and 6 optional parameters.

I. Obligatory parameters which lead to the first differentiation, respectively:

- ecoregions (according to Illies, 1978): The Carpathians (10), Hungarian lowlands (11), Pontic province (12), Eastern plains (16);
- size classes (based on catchment area): small: 10-100 km^2 ,medium: >100-1000 km^2 , large: >1000-10000 km^2 ,very large: >10000 km^2
- geology of the catchment: calcareous, siliceous, organic
- altitude classes: high >800 m (mountains), middle: 500-800 m (pied-mont or high plateau area), low: 200-500 m (hilly or plateau area), very low: < 200 m (plain area);

II. Optional parameters which lead to a higher differentiation:

- litological river bed structure, considering the following constituents – blocks (D> 200 mm), boulders (D = 70-200 mm), gravel (D=2-70 mm), sand (D = 0.05-2 mm), silt (D= 0.05-0.005 mm), clay (D<0.005 mm);
- multiannual mean specific flow (q): high: >30 l/s/km^2, average: 3-30 l/s/km^2, minimum: <3 l/s/km^2
- specific yearly minimum monthly flow with 95% probability ($q_{95\%}$): high (>2 l/s.km^2) ,average (0.3-2 l/s/km^2), minimum (<1 l/s.km^2)
- river slope: high >40 ‰, average 10-40 ‰, low <10 ‰,
- annual mean precipitation: abundant > 800 mm, average 500-800 mm, reduced < 500 mm;
- annual mean temperature: high >8^{o}C, average 0-8^{o}C, low < 0^{o}C.

It is mentioned that the specific yearly minimum monthly mean flow with 95% probability was used in order to define the temporary water body types, the stream which have q_{95}% =0 belong to these types .

The analysis of data relevant for stream typology has led to the identification of 32 abiotic types (table 1) and 43 sub-types subject to specific conditions. The differentiation of types into sub-types has been made according to the geology substratum. These abiotic types have been correlated with a biocenotical type/ fish zoning defined by Banarescu (1964) as follows: zone of Salmo trutta fario (trout); zone of Thymallus thymallus (grayling);zone of Chondrostoma nasus (shout);zone of Barbus barbus (barbel); zone of Cyprinus carpio (carp).

4. The biotic stream typology in Romania

The biotic typology is based on the ecological analyses of biotic communities from type-specific reference sites named type-specific biological reference communities of all the quality elements provided by the WFD, respectively: the benthic invertebrates (macrozoobenthos), fish fauna, phytobenthos/macrophytes and phytoplankton. It represents a “bottom-up” approach, an effect-cause relationship through which the pre-defined abiotic types are validated.

At the present, in Romania, similar to most European countries the biological data for the defining of stream types are available only for some quality elements provided by WFD. In this stage only the macroinvertebrates communities have been analysed, taking into account their high relevance for stream status assessment and the available data and existing experience [3].

For the bottom-up validation about 500 data sets of type-specific reference sites (existing monitoring sites and additional sites) have been analysed, containing taxa lists of the macroinvertebrate fauna and data on river morphology, hydrology, physical-chemistry and catchment characteristics of the individual sites. These spatially based 500 data sets represent the reference conditions for the 13 abiotic types, for the remaining types other methods like expert judgement, modelling are going to be applied.

Statistical parameters of saprobic index have been calculated where the number of values were higher than 25.

The values represent the mean values of the Saprobic Index for the stream types/stream sector types from the same ecoregions.

For defining the biotic typology based on macroinvertebrates the following analyses have been carried out:

- **I.** biotic analysis of ecoregion (Ilies, 1978) data set;
- **II.** biotic analysis of the Carpathian ecoregion data set ;
- **III.** biotic analysis of the mountain data set (>800 m)
- **IV.** biotic analysis of pied-mont or high plateau area data set (500-800 m);
- **V.** biotic analysis of hilly or plateau area (200-500 m) data set;
- **VI.** biotic analysis of plain area data set (<200 m);
- **VII.** biotic analysis of gorges data set;

Through the analyzing of the above mentioned data sets, the following have been noticed:

I. • The biotic analyses of ecoregion data sets (Ilies,1978) indicate that the saprobic index vary with the ecoregion. The lowest values are for the Ecoregion 10-The Charpatians and the values are increasing gradualy for the Ecoregions 11-The Hungarian lowlands, 12-The Pontic Province and 16- The Eastern Plain.

- The values of the saprobic index increase with the decrease with altitude.
- The values of Saprobic index differ significantly for the the streams which flow on calcareous, siliceous and organic substrate. Its value increases from 100% for the

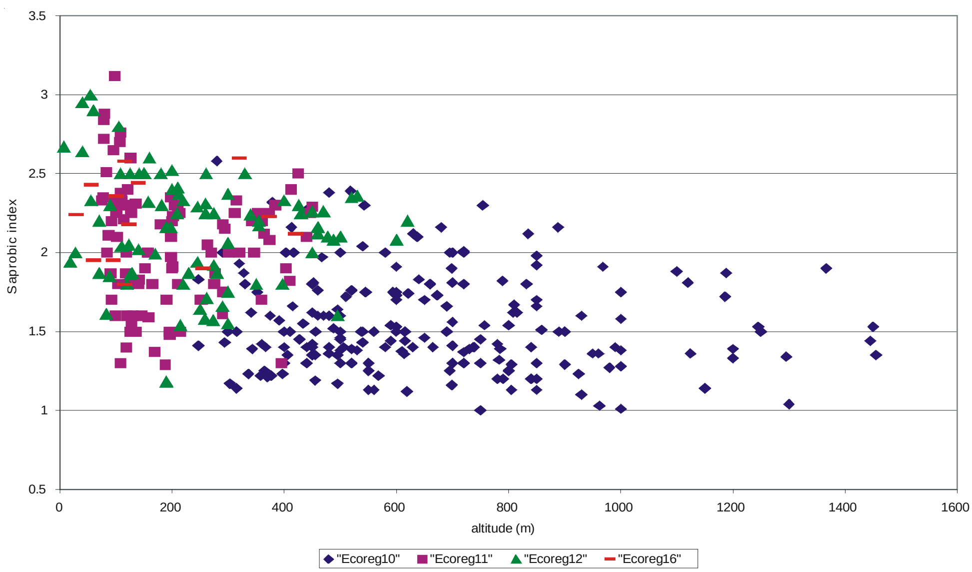

Fig. 2 The variation of the Saprobic Index with the Ecoregions

Table1 The stream typology in Romania

Stream type	Symbol	Factors									
		Catchment size km^2	Geology	Lithological bed structure	Slope ‰	Altitude MdBlack Sea	Precipitation mm/an	Temp. °C	q $l/s/km^2$	$q_{95\%}$ $l/s/km^2$	Fish zonning
Ecoregion 10 – The Carpathians											
Mountain stream	RO01	10-1000	a-siliceous b-calcareous	Blocks, boulders, gravel	40-200	>800	700-1400	-2+8	>20	>1	Trout, Grayling
Stream in pied-mont or high plateau area	RO02	10-1000	a-siliceous b- calcareous	Boulders, gravel	20-50	500-800	600-800	7-9	5-20	0,5-2	Slout, Chub, Trout
Stream sector in pied-mont or high platau area	RO03	1000-10000	a-siliceous b- calcareous	Gravel, boulders	3-20	500-800	600-800	7-9	5-20	1-3	Grayling, Slout
Stream sector in hilly or plateau area	RO04	1000-10000	a- siliceous b- calcareous c-organic	Sand, gravel	0.5 - 5	200-500	500-700	8-10	3-15	0.4 -2	Slout, Barbel
Stream sectors in intramountain depression	RO05	10-1000	a-siliceous b-calcareous c-organic	Sand, gravel, boulders	1-3	500-800	600-800	7-9	3-20	0.2-2	Chub, Slout
Stream sector with wetlands in hilly or plateau area	RO06	1000-10000	a-siliceous c-organic	Sand, gravel	1-2	200-500	500-700	8-10	3-15	0.4 -2	Slout, Barbel
Subecoregion 10- Carphatian Intramountain area											
Stream in hilly or plateau area	RO07	10-1000	a-siliceous b-calcareous c-organic	Gravel, sand	5-30	200-500	500-700	8-10	1-5	0.01-0.5	Chub
Stream sector in hilly or plateau area	RO08	1000-10000	a-siliceous b-calcareous	Sand,gravel	3-20	200-500	500-700	8-10	2-10	0.2-1	Barbel
Ecoregion 11- Hungarian Lowlands											
Stream in hilly or plateau area	RO09	10-1000	a-siliceous b-calcareous c- organic	Sand, gravel	5-20	200-500	500-700	8-10	2-8	0.02-0.5	Chub
Stream in plain area	RO10	10-1000	a-siliceous b-calcareous c-organic	Sand, silt	<8	<200	400-500	9-11	<3	<0.3	Chub
Stream sector in plain area	RO11	1000-3000	a-siliceous b-calcareous c-organic	Sand, silt, clay	<1	<200	400-500	9-11	1-3	0.2-0.4	Chub
Stream sector in plain area	RO12	>3000	a-siliceous b-calcareous c-organic	Sand, clay	0.5 - 5	<200	400-500	9-11	2-10	0.05-1	Slout, Barbel
Stream sector with wetlands in plain area	RO13	>3000	a-siliceous b-calcareous c-organic	Sand, silt,	<1	<200	400-500	9-11	2-10	0.1-1	Carp, Barbel
Ecoregion 12- Pontic Province											
Stream in hilly or plateau area	RO14	10-1000	a-siliceous b-calcareous c-organic	Sand, gravel	5-20	200-500	500-700	8-10	2-5	0.2-0.4	Chub
Stream in plain area	RO15	10-2000	a-siliceous b-calcareous c-organic	Sand,silty clay	<8	<200	400-600	9-11	<2	0.2	Chub, Perch

Stream sector in plain area	RO16	1000-5000	a-siliceous b-calcareous c-organic	Sand, silt	0.5 - 5	<200	400-600	9-11	1-3	0.2-0.4	Chub, Perch
Stream sector in plain area	RO17	>5000	a-siliceous b-calcareous c-organic	Sand, silt, clay	<1	<200	400-600	9-11	2-10	0.1-1	Slout Barbel
Stream sector with wetlands in plain area	RO18	>5000	a-silicioasa b-calcaroasa c-organica	Sand, silt, clay	<1	<200	400-600	9-11	2-10	0.1-1	Barbel Carp
The Danube river –Cazane area	RO19	570.900-574.850	calcareous	Sand,gravel, boulders	0.07	100-200	600-800	8-10	9	3	carp
The Danube river - Cazane-Calarasi area	RO20	574.000-698.000	siliceous	Sand, clay, gravel	0.05	5-70	500-600	9-11	8	2	carp*
The Danube -Calarasi-Isaccea	RO21	698.00-780.650	siliceous	Sand, clay	0.04	5	400-500	9-11	7	1.5	carp*
The Danube Delta	RO22	805.300	organic	Sand, silt	<0.01	<5	400-500	>11			carp** Danube scomber
Ecoregion 16 – Eastern Plains											
Stream in hilly or plateau area	RO23	10-1000	a-siliceous b-calcareous c-organic	Sand, gravel	1-10	200-500	500-700	8-10	2-4	0.02-0.2	Chub
Stream in plain area	RO24	10-2000	a-siliceous b-calcareous c-organic	Sand, clay	1-3	<200	400-600	9-11	0.5-1	<0.1	Chub
Stream sector with wetlands in plain area	RO25	1000-5000	a-siliceous b-calcareous c-organic	Sand, silt	<2	<200	400-600	9-11	1-3	0.2-0.4	Chub
Stream sector in plain area	RO26	>5000	a-siliceous b-calcareous c-organic	Sand, silt	0.5	<200	400-600	9-11	2-10	0.1-1	Slout, Barbel
Stream sector with wetlands in plain area	RO27	>5000	a-siliceous b-calcareous c-organic	Sand, silt, clay	0.3	<200	400-600	9-11	2-10	0.1-1	Barbel, carp
Streams qualitatively influenced by natural causes and temporary streams											
Stream influenced from qualitative point of view by natural causes	RO28	10-1000									
Temporary stream in mountain area	RO29	10-1000	siliceous	Blocks, boulders, gravel	20-150	>800	700-1100	-2+8	2-16	0	
Temporary stream in pied-mont or high plateau area	RO30	10-1000	calcareous	Boulders, gravel	25-45	500-800	600-800	7-9	5-17	0	
Temporary stream in plateau area	RO31	10-1000	a-siliceous b-calcareous	Gravel, sand	5-30	200-500	450-550	8-10	1.5-7	0	
Temporary stream in plain area	RO32	10-2000	a-siliceous b-calcareous	Sand, silt	<8	<200	400-500	9-11	<2	0	

Existing species:

* sturgeons, Danube scomber (Alosa pontica), pike (Esox lucius), tench (Tinca tinca), roach (Rutilus rutilus), red eye (Scardinius erythrophthalmus), bream (Abramis brama), perch (Perca fluviatilis) , catfish (Silurus glanis) , Carassius carassius, Sander lucioperca, Aspius aspius

** sturgeons, pike (Esox lucius), roach (Rutilus rutilus), tench (Tinca tinca), red eye (Scardinius erythrophthalmus), bream (Abramis brama), Carassius carassius , catfish (Silurus glanis), perch (Perca fluviatilis), Sander lucioperca, roach (Rutilus rutilus), Aspius aspius streams on calcareous substrate, to about 115% for the streams on siliceous substrate, respectively to about 126% for streams on organic substrate, fact which justify the differentiation of types into subtypes.

II. The values of the Saprobic index from the Ecoregion 10 have indicated a concentration of these for the Transylvanian Plateau, which lead to the defining of a sub-ecoregion between 200-500m for the streams located in the Intramountain Carpathian area, named Sub-Ecoregion 10 (fig.3).

III-VI. The values of saprobic index from mountain area , pied-mont or high plateau area, hilly or plateau area, plain area indicate that there is no significant difference between the small (10-100 km^2) and medium streams (100-1000km^2) in these cases. It can be concluded that the abiotic types RO01 can be merged with RO02, RO03 with RO04, RO05 with RO06, RO07 with RO08. E.g.:Saprobic Index is 1.5 for RO01a and 1.503 for RO02a ;1,9 for RO07a and 2,13 for RO08a (fig.4).

VII. The values of saprobic index for a stream sector which it is formed or crossses gorges (RO12) do not differ significantly from statistical point of view in comparison with the streams which flow on calcareous substrate. Having in view this thing the defining of a separate abiotic type for the stream which are formed or cross gorges is not justified anymore and it is necessary to associate these sector types to corresponding stream types on calcareous substrate.

- Also for the stream sectors which are formed or cross gorges, a reduction of the values of saprobic index has been recorded with an average of 5%, which indicate again that the calcareous substrate determine the reduction of the values of saprobic index.

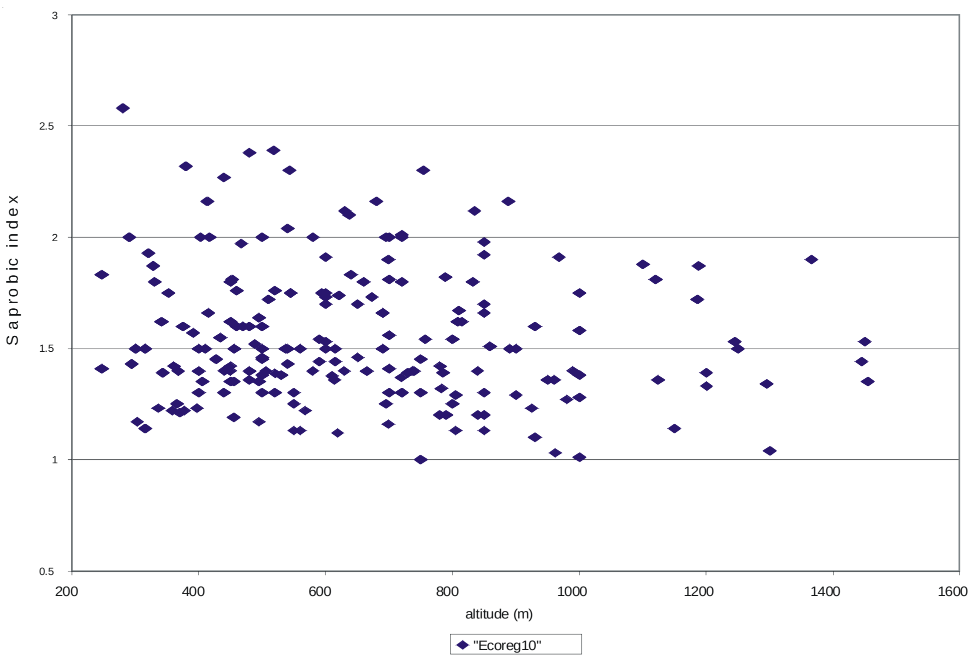

Fig. 3 The variation of the Saprobic Index with the altitude within Ecoregion 10

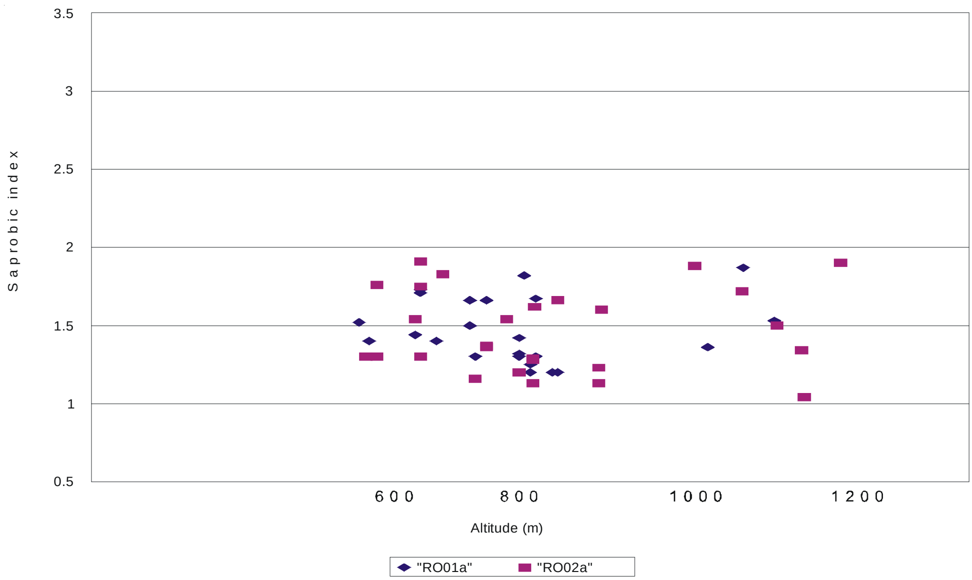

Fig. 4 The variation of the Saprobic Index with the altitude - types RO01a and RO02b

5. The defining of reference conditions in Romania

The selection of reference sites for the defining the values of the reference conditions had as basis the provisions of the Water Framework Directive and the recommendation of the "REFCOND guidance produced by Working group 2.3 – Guidance on establishing reference conditions and ecological status class boundaries for inland surface waters " [4].

The reference sites should reflect very low pressure, with only very minor modification of physico-chemistry, hydromorphology and biology and without the effects of major industrialization, urbanization and intensification of agriculture.

Having in view the fact that the reference sites can reflect a state in the present or in the past ,the methods used in the defining of reference conditions were spatial based (providing a network containing a sufficient number of high status to provide a sufficient level of confidence of the values of reference conditions), historically based, modeling based (or a combination of these) and expert judgement based.

In Romania, similar to most European countries, the work on reference conditions has recently been started.

It was noticed that for Romanian streams, similar to other streams from the Danube river basin, and to other European river basins only very few reference sites which fulfill all reference conditions criteria are available, especially in the lowland areas or at large rivers. Therefore, the description of reference conditions in these cases, apart from the methods above-mentioned, these have to be based upon the criteria for the *best available sites*.

The defining of Reference Conditions in Romania will be achieved in two stages:

- The preliminary defining of Reference Conditions based on the biological elements for which the data are provided by the current monitoring programme, taking into account the multimetric approach (saprobic index, number of taxa or number of family, EPT- taxa, individuals, diversity index, etc);

- The defining of Reference Conditions based on new data for biological, hydro-morphological and physico-chemical quality elements, provided by the monitoring and assessment systems fully compliant with requirements of the Water Framework Directive.

Conclusions

- The river restoration represent a key element for the achieving of "good status" of water bodies;
- River restoration targets have as basis the defining of stream types and establishing of reference conditions;
- The stream typology in Romania is based on the abiotic and biotic approaches;
- For the abiotic approach the system B has been used, similar to most European countries, a number of 32 types and 43 subtypes being defined; out of these 32 types, there are special types which represent temporary stream types and streams qualitatively influenced by natural causes for which special environmental objectives have to be defined;
- For the biotic typology the ecological analyses of spatially derived macroinvertebrates communities have been used for most cases; for the types which cannot be identified in the present the expert judgment and modeling will be applied;
- The biotic (macroinvertebrates) data analysis indicated a defining of a sub-ecoregion within Ecoregion 10;
- The biotic typology based on the ecological analyses of macroinvertebrates communities indicate that several types have been, new other types have been, one type has been not kept anymore and other types have been validated;
- The biotic stream typology will be completed in the next stages, by the ecological analysis of all the other quality elements provided by the WFD, respectively phytoplankton, phytobenthos/macroflora and fish fauna, based on multimetric approach;
- The reference conditions will be derived from the biological, hydromorphological and physico-chemical quality elements.

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