COMMISSION OF THE EUROPEAN COMMUNITIES

environment and quality of life

PROPOSAL FOR A BIOTYPOLOGICAL CLASSIFICATION OF WATERCOURSES IN THE EUROPEAN COMMUNITIES

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PROPOSAL FOR A BIOTYPOLOGICAL CLASSIFICATION OF WATERCOURSES IN THE EUROPEAN COMMUNITIES*)

by

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ABSTRACT

During the EEC Symposium on "Principles and methods for determining ecological criteria on hydrobiocenoses" (Luxemburg 1975) it appeared that "...the study of the various ecological types with which watercourses in the Member States of the Commission of the European Communities are associated, corresponding to biocenoses with similar ecological requirements is a matter of some urgency..... A biotypological classification of watercourses in the Community is a preliminary requisite to any generally adopted scientific assessment of the ecological consequences of pollution on hydrobiocenoses and the determination of ecological criteria..." (AMAVIS and SMEETS, 1976).

A proposal for such a biotypological classification has been worked out by the author of this document with the help of experts of the Member States.

The classification is based on the selection of a restricted number of physico-chemical parameters (width, slope, water hardness, structure of substratum and temperature regime) with a minimum number of subdivisions (3 to 4). The combination of these parameters with their respective subdivisions leads to a theoretical classification system of 432 macrohabitat classes characterizing portions of watercourses.

A minimum number of plant and animal group have been selected from all the groups of organisms which can be found in running waters to characterize biocenotypes.

This theoretical macrohabitat classification system should be followed by an extensive hydrobiological sampling program in as many portions of watercourses as possible in different hydrographic basins of countries in the Community.

Since the aim of this biotypological classification is to serve as a reference system for future water quality surveys, the hydrobiological samplings shall be restricted to unpolluted portions of watercourses.

The latter procedure should finally lead to the establishment of (a relatively small number of) major macrohabitats and to the selection of "taxonomic units" which can be utilized for the definitive hydrobiocenotypes characteristic for ecological types in watercourses of the Community.

ACKNOWLEDGEMENTS

The proposal forwarded hereunder would not have been possible without the assistance of many experts of several European countries.

This biotypological classification slowly took shape during countless hours of discussion on a personal basis as well as during round-table meetings.

The author of this document, whose only merit has been to gather and rework ideas and criticisms into a system which should be applicable at the brood level of the hydrographic basins in the Community, hereby acknowledges with thanks the kind collaboration of the following persons especially:

AMAVIS, R.	*(E.E.C.)*
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SCHMIDZ, W.	*(Fed. Rep. Germany)*
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TABLE OF CONTENTS

1. INTRODUCTION

In November 1975, a Colloquium was organized in Luxemburg by the Health Protection Directorate of the Directorate-General for Social Affairs of the Commission of the European Communities, together with the Environment and Consumer Protection Service and the Environmental Research Division of the Directorate General for Research, Science and Education.

The theme of the Symposium which was attended by approximately 80 experts of member countries of the Community was : "Principles and methods for determining ecological criteria on hydrobiocenoses".

The main objective of this European Scientific Colloquium the results of which were published by AMAVIS and SMEETS in a 530 pages volume was ...

"to define a scientific basis for assessing the results of pollution on hydrobiocenoses (aquatic fauna and flora) and the biological methods to be used in assessing the extent of such pollution".

Indeed, as formulated pertinently by the rapporteurs TENDRON and RAVERA :

"The principles of Community environmental policy demand that ecological requirements be taken into consideration in the determination of quality objectives, with a view to satisfying the demands of the protection of human health against pollution and nuisances, saveguarding the natural environment, especially flora and fauna, preserving natural

resources, and preserving, restoring and improving the quality of human life".

From several papers presented, as well as from the vivid floor discussions among the numerous experts present, it appeared that in order to be able to assess the effect of pollutants on aquatic ecosystems and to define criteria and standards for the protection of our watercourses, more knowledge should be gained on the typical biocenoses populating lotic biotopes.

Indeed, as pointed out clearly by VERNEAUX during the Symposium :

"the global elements of the ecosystem : water substrate (drainage basin, water table, bed, banks) and the trophic structure, are functionnaly indissociable, any change in one having an effect on the whole system. The biological structure and water quality are interdependent : they are both determined and determining, each being dependent on the quality of the other".

VERNEAUX further emphasized that :

"part of watercourses may be related to ecological types characterized by qualitatively and quantitatively different populations, from diatoms to fish and the ecological objectives and criteria must be determined in relation to the ecological type of which the part of the watercourse in question belongs".

As a result, the first of the conclusions formulated at the end of this most fruitful international Colloquium, with regard to the nature and conduct of action to be carried out at the

Community level , was that :

"the study of the various ecological types with which watercourses in the Member States of the Commission of the European Communities are associated, corresponding to biocenoses with similar ecological requirements, is a matter of some urgency. These types are characterized by their specific composition, the relative frequency of the taxa and their trophic levels".

A biotypological classification of watercourses in the Community is a preliminary requisite to any generally adopted scientific assessment of the ecological consequences of pollution on hydrobiocenoses and the determination of ecological criteria (exposure/effect and exposure/reaction relationships).

The present study is an attempt towards a biotypological classification system of lotic waters within the Community. It should be emphasized here that this classification system shall only take "non-polluted" lotic environments in consideration, in order to establish the "zero pollution" state of aquatic ecosystems, as a reference base.

2. CLASSIFICATION SYSTEMS OF WATERCOURSES

Since the end of the last century, many systems of classification which can roughly be qualified as "biotypological" have been worked out and applied, mostly on a local or restricted geographical basis.

It is out of the scope of this work to quote and discuss the value of each of the many systems put forward by various authors.

Excellent reviews on the matter have been written by ILLIES and BOTOSANEANU in 1963 and more recently by HAWKES in 1975.

According to the latter author only two researchers have attempted to produce a scheme of river-zone classification which could be applied throughout the world .

The system of ILLIES (1961) is, in essence, a temperature-flow based classification with two primary divisions : the upstream-rhithron, and the downstream-potamon.

HAWKES (op. cit.) translates the German characterization of ILLIES-zonation as follows :

"(i) Rhithron is defined as that part of the stream from its source down to the lowerpost point where the annual range of monthly mean temperatures does not exceed 20°C. The current velocity is high and the flow volume is small. The substratum may be composed of fixed rock, stones or gravel and fine sand. Only in pools and sheltered areas is mud deposited.

(ii) Potamon is the remaining downstream stretch of river where the annual range of monthly mean temperatures exceeds 20°C, or, in tropical latitudes, with a summer maximum of the monthly mean exceeding 25°C (ILLIES & BOTOSANEAUNU, 1963). The current velocity over the river bed is low and tends to be laminar. The river bed is mainly of sand or mud,

although gravel may also be present. In the deeper pools oxygen may be depleted, light penetration limited and mud deposited".

The organisms of the rhithron are mostly cold stenotherms and associated with running, well aerated waters, those of the potamon are eurytherm or warm-water stenotherms, typical for lentic waters.

The two major zones are furhter subdivided in an epi-meta and hypo-zone ; ILLIES and BOTOSANEANU (1963) add an additional "crenon" zone upstream of the rhithron, to include the springs and headstreams in their system.

An excellent schematic comparison of different river classification systems was worked out by HAWKES (op. cit.) (Table 1).

The second author to propose a universal classification system of lotic habitats is the American scientist PENNAK. PENNAK (1971) bases his system on physical and chemical parameters and rejects biological indicators as criteria to subdivide or categorize flowages.

From the two reviews quoted above, it appears that two different approaches have been utilized for the elaboration of biotypological classification systems :

a) the physicochemical approach with physical (including geomorphological) and chemical criteria,
b) the biological approach, based on autecological or synecological data.

Illies (1961a)	Illies & Botosaneanu (1963)	Müller (1951) Illies (1953) Schmitz (1957) R. Fulda, Germany	Ricker (1934) Ontario streams	Harrison & Elsworth (1958) Great Berg River, S. Africa	Huet (1954) W. European rivers	Thieneman (1925) W. Europe		Carpenter (1928) (G. Britain)
(Eucrenon)*	Zone I	Quellezone	-	Zone I - source	-	Quellen	brooks	Head stream
(Hypocrenon)*	Zone II		Spring creeks	-	-	Quellrinnsale		
Epirhithron	Zone III	Obere Salmonidenregion	Swift trout stream	Zone II-mountain torrent	Zone à Truite	Region der Bachforelle	Highland	Trout beck
Metarhithron	Zone IV	Mittlere Salmonidenregion	Slow trout stream	Zone IIIA-upper foothill				
Hyporhithron	Zone V	Untere Salmonidenregion	Warm rivers	Zone IIIB-lower foothill-hard bottom zone	Zone à Ombre	Region der Asche		Minnow reach
Epipotamon	Zone VI	Bargenregion		Zone IV-lower foot-hill soft bottom	Zone à Barbeau	Barbenregion	Lowlandcourses	Upper reach
Metapotamon	Zone VII	-	-	Zone V-flood plain	Zone à Breme	Brassenregion		Lower reach
Hypopotamon	-	-	-		-	Brackwasser-region		Brackish estuary

* Added later by Illies & Botosaneanu (1963).

Table 1 : Comparison of some classification schemes showing corresponding zones (from HAWKES, 1975).

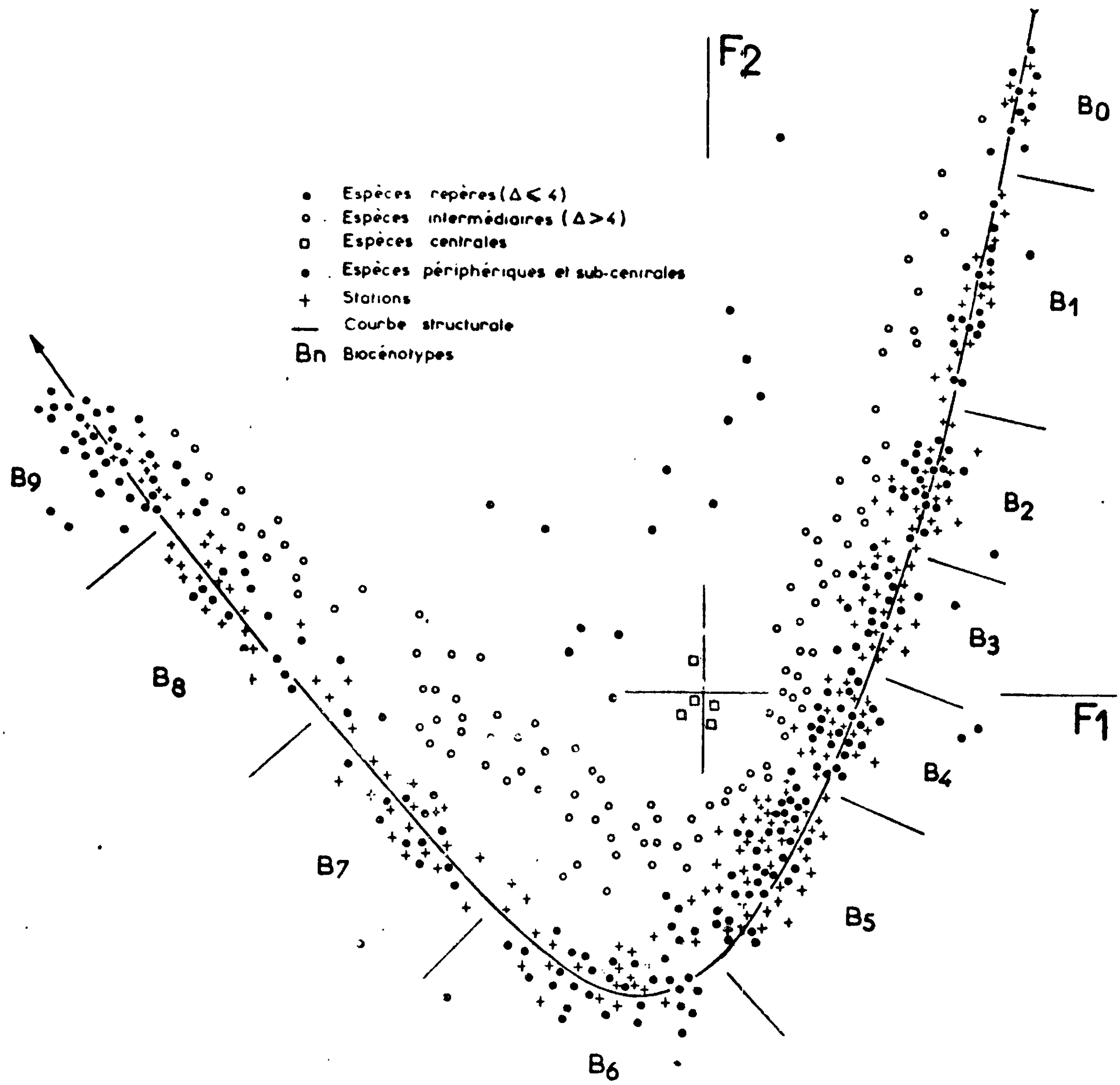
Recently the Frenchman VERNEAUX (1973, 1976a) has worked out a new, modern biotypological approach based on the "biological structure of a theoretical ecosystem".

This structure was developed through statistical analysis of a large number of quantitative zoological data (invertebrates and fishes) obtained by methodic prospection of several French and Swiss river basin.

Through factorial analysis of correspondences 10 theoretical "typological levels" succeeding each other from the source to the mouth of streams can be distinguished (Figure 1). Each level is populated by a characteristic biocenotype. The latter is not necessarily composed of species belonging to the same biocenoses, but by species with closely related ecological characteristics.

Indeed, according to VERNEAUX's system, species can be classified in four ecological types :

a) eury-species ("espèces euryèces") of few typological significance
b) intermediate species, associated to a specific typological level which constitute its "ecological preferendum" but which can also be found in adjacent levels
c) characteristic species ("espèces repères") which are most significant from the typological point of view and have a very stenoïc character
d) species of few typological significance which have either a peripheric position (when few abundant) or a subcentral one when associated to a habitat, a microclimat or a particular ecological factor.



<u>Figure 1</u> : Biotypological structure of the "running water" ecosystem, *sensu* VERNEAUX (from VERNEAUX, 1976 b).

VERNEAUX (1976, 1977a) further demonstrated that his theoretical ecosystem and its biotypological structure could be correlated with the evolution of four fundamental physico-chemical parameters along a watercourse viz : distance to the source,median width of stream bed, slope and temperature.

Fig. 2 shows the correlations of these physiochemical variables with the 10 typological levels along a theoretical watercourse ecosystem (from VERNEAUX and LEYNAUD, 1974).

Despite the endeavors of all those who devoted the best of their efforts to classify watercourses from the ecological point of view and characterize portions of streams through biotypological parameters, it appears that to date :

1) no universal biotypological system has yet been adopted by hydrobiologists, each systems having its defendants and detractors ;
2) the applicability of any particular system depends to a large extent on the use one wants to make of the classification.

It is with the latter statement in mind and thinking particularly of the applicability at the broad level of the Community, that we attempted to work out a system of biotypological classification which could be applied by as large a group of hydrobiologists as possible and with a minimum on equipment or highly specialized taxonomic training.

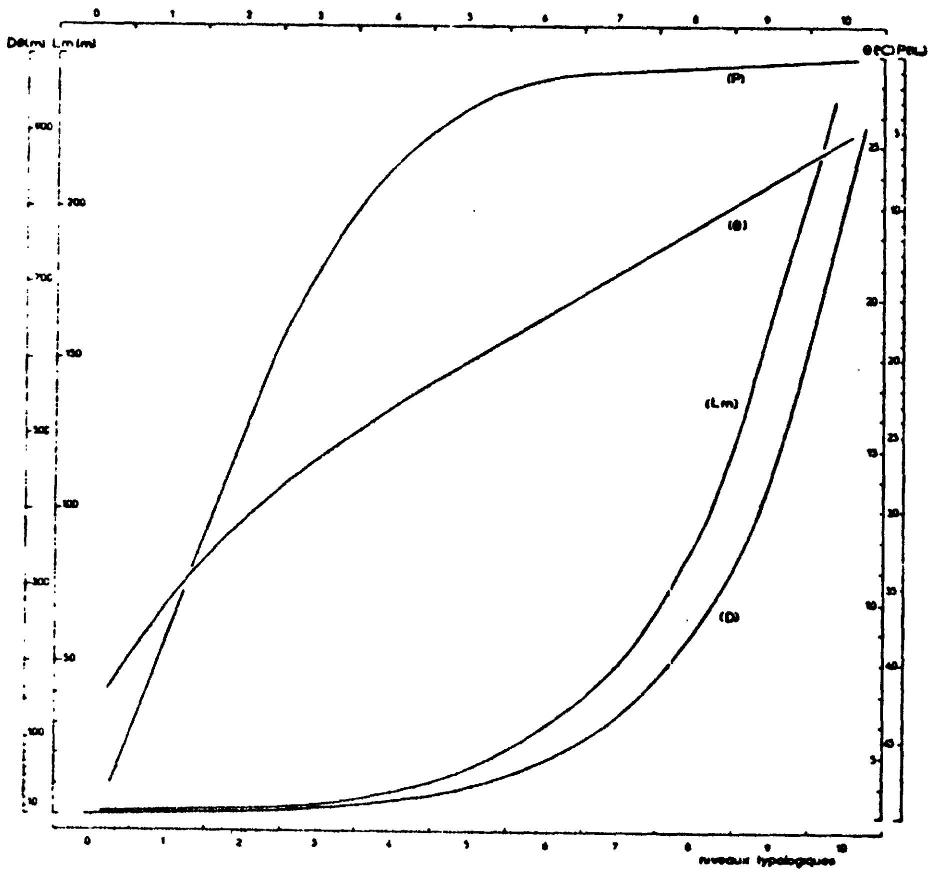


Figure 2 : Variations of 4 fundametal parameters along the biological structure of a theoretical "running water" ecosystem (from VERNEAUX and LEYNAUD, 1974)

D : distance to the source

Lm: median width of water bed

OM: median maximum temperature of the warmest month

Pm: median slope in a stretch of 1 km

The resulting proposal, outlined below, takes the *rationales* of the classification systems described in the literature as much as possible into account, and took shape after numerous discussions with experts in different countries. Each one of the often critic opinions expressed has contributed to this final document.

It leaves no doubt that the biotypological classification presented here can be heavily criticized. Considering, however, that the guidelines formulated could lead to an easy application within the Community, we are hopeful with regard to its implementation.

3. BASIC APPROACH FOR A BIOTYPOLOGICAL CLASSIFICATION APPLICABLE TO WATERCOURSES IN THE COMMUNITY

The best way to establish a biotypological classification of watercourses at the national or international level, would be take biological samples in as many segments or sections as possible, of each watercourse, to list the organisms present, and to try to elaborate a system on the basis of the biological similarities found in identical habitats.

Needless to say that in practice this would be an insurmountable task even for a team of hydrobiologists, because of the number and vastness of the Community's river basins.

An approach based on literature data was proposed during the EEC Colloquium in Luxemburg:

"Ideally, there should be an exhaustive list of species. In fact European species are by and large common to the Community countries and the first job would be to draw up a balance sheet of these species. An existing body or one to be created should centralize regional and national data on flora and fauna". (TENDRON and RAVERA - Synthesis and Conclusions).

A realistic approach to tackle the very complex problem of defining ecological types in watercourses is in our opinion composed of the following six consecutive steps :

1. *ESTABLISHMENT OF A THEORETICAL CLASSIFICATION SYSTEM BASED ON WELL-DEFINED SETS OF PHYSICOCHEMICAL CHARACTERISTICS (MACROHABITATS) REPRESENTATIVE FOR, AND COVERING ALL TYPES OF WATERCOURSES IN THE COMMUNITY.*
2. *SELECTION OF THE MAJOR PLANT AND ANIMAL GROUPS TO BE CONSIDERED FOR THE DIFFERENT BIOCENOTYPES.*
3. *HYDROBIOLOGICAL SAMPLINGS IN WELL-DEFINED STREAM SECTIONS OF AS MANY RIVERS AS POSSIBLE IN THE COMMUNITY WITH DETERMINATION OF THE MACROHABITAT (ABIOTIC) CHARACTERISTICS AND DRAFTING OF THE LISTS OF DOMINANT OR CHARACTERISTIC ORGANISMS BELONGING TO THE TAXONOMIC GROUPS QUOTED ABOVE.*
4. *ALLOCATION OF THE ANALYZED STREAM SECTIONS TO THEIR HABITAT CATEGORY IN THE CLASSIFICATION SYSTEM.*

5. *COMPARISON OF THE BIOTA FOUND IN IDENTICAL MACROHABITATS, ESTABLISHMENT OF THE TAXONOMIC LEVEL OF SIMILARITIES AND DETERMINATION OF THE ASSOCIATIONS MOST REPRESENTATIVE FOR THE DIFFERENT TYPES OF HABITATS.*

6. *ESTABLISHMENT OF THE DEFINITIVE NUMBER OF HABITATS AND BIOCENOTYPES PRESENT IN THE WATERCOURSES OF THE COMMUNITY.*

It was agreed that the present work could only cover the first two steps since the following ones (especially the third) can only be realized in a larger program involving the assistance of many specialists from the different E.E.C. countries.

4. DETERMINATION OF MACROHABITAT TYPES FOR WATERCOURSES IN THE COMMUNITY

Any biotypological classification always departs from the basic principle that :

"... *widely separated streams and rivers having very similar non-biological features will usually have parallel and ecologically similar faunas*" (PENNAK, 1971).

However, the number as well as the nature of the physico-chemical parameters considered necessary to characterize a stretch or segment of a watercourse varies very much from one system to another, ranging from one single factor (OHLE, 1937) to as much as 13 (PENNAK, 1971).

According to the latter author the following physical, chemical and even biological parameters are necessary for the precise characterization of a part of a watercourse :

- width
- flow
- current speed
- substratum
- summer temperature
- winter temperature
- turbidity
- total dissolved inorganic matter
- total dissolved organic matter
- water hardness
- dissolved oxygen
- rooted aquatics
- stream side vegetation

VERNEAUX and TUFFERY (1967) even list 23 physical and morphometric factors to precisely define the environment in which a particular biocenosis thrives.

According to HAWKES (1975), the major
"factors of ecological significance which exhibit a progressive change in value along the lenght of rivers are : current velocity, substratum, flow, temperature, dissolved oxygen, dissolved nutrients, hardness ... and organisms. Many of these are interdependent".

PITWELL in his remarkable review on "Biological monotoring of rivers in the Community" presented at the E.E.C. Colloquium in Luxemburg corroborates this with the following statements :

"Thus water speed is dependent on gradient and cross section of the bed and bed form, whilst bed form is dependent chiefly on water speed...Width is obviously related to exposure to air... For the time being, flow rate (or gradient) and width are certainly essential. Flow rate determines turbulence and bed type, whilst depth determines the rate of oxygen diffusion to the bed. Width is dependent on the volume of water available having due regard to bed shape. Flow rate also has an effect on the rate of oxygenation in that turbulence influences oxygen transfer. Gradient may be substituted for flow rate as they are directly related parameters".

After numerous discussions, and considering especially the implementation of the biotypological classification at the level of all the river basins of the Community, it was finally decided to reduce the number of physicochemical parameters to characterize macrohabitats to five, namely :

- width of channel
- slope
- water hardness
- structure of substratum
- temperature regime

The first two are those considered by PITWELL to be of prime importance, whereas the same author also suggest bottom material to be the next most important variable.

Our selection also matches quite well the conclusions drawn by VERNEAUX (1977a) from a correlation analysis of his 10 point typological structure with 23 physicochemical parameters.

From the study of this author it appears that temperature, water hardness and slope are part of the 3 "synthetic" factors which are statistically most characteristic for the abiotic evolution of watercourses.

VERNEAUX's 3 "synthetic factors" are respectively :

- θMm : maximum mean temperature of the warmest month
- doD : distance to the source (in km) time total hardness
- $\frac{Sm}{Pl^2}$: ratio of average cross section (in m^2) to slope (in °/₀₀) time square of width of water bed (in m^2).

It is clear that a classification based on only five parameters cannot be as refined as one based on say 23. The major objective of the system, however, is not to define an infinite number of "microhabitats" or "mosaics of biotopes" as mentionned in the review of ILLIES and BOTOSANEANU (1963), each populated by "sinusia" of organisms, but to define an (as small as possible) number of major physicochemical categories (macrohabitats) and to correlate them (in a second step) with their major (dominant or chacteristic) biota.

For each of the five environmental factors mentioned above a minimum of subdivisions are proposed to characterize broadly segments of watercourses as "riverine types", in the sense of PITWELL (op. cit.).

Considering the fact that in most cases, these physico-chemical or morphometric chracteristics of the examined segments of the watercourses will have to be determined by biologists, we thought it useful to describe or refer to unsophisticated field methods.

A. WIDTH OF CHANNEL

The importance of this factor shall not only be sought "in se" but mainly in correlation with the next one : the slope of the channel.

Both indeed determine the flow rate of the water mass (cf. statements of PITWELL above) ;it is precisely this rate which is one of the major ecological parameters determining the presence or absence of a particular species.

As far as the width itself is concerned, EINSELE (1960) has shown that even at a constant slope there is a definite increase in current speed with increasing size of the channel width.

With regard to the number of subdivisions which should be considered for this parameter PENNAK (op. cit.) pertinently remarks that :

"...almost any set of width categories is arbitrary and based on personal experience".

Departing from the rough ecological statement of the same author that :

"both very narrow brooks and broad rivers have more restricted bottom faunas, the most complex and dense faunas usually being found in lotic habitats between 5 and 20 meters wide"

it was finally decided to consider three categories of widths

a) less than 2 meter

b) from 2 to 25 meters

c) more than 25 meters

As a generale rule, and especially with regard to the increase in width by run-off, only the width at the typical river condition shall be considered : the so-called "over-bank flow".

The width of small watercourses can easily be measured with a ribbon meter ; for larger rivers or streams a tachymeter will have to be used.

B. SLOPE

This factor in only indirectly related to the presence or absence of aquatic organisms : the important parameters from the biological point of view are indeed the flow rate or the current speed which also determine the oxygen regime (cf. quotation from PITWELL above).

As both flow (volume/time) and current (distance/time), however, are very much dependent of parameters such as depth, roughness of the bed (including nature of the substratum), discharge, surface tension of the water etc. , they are factors which are difficult to measure and categorize. We prefered to consider the slope of the channel section as representative for both factors flow and current, an opinion inspirated by the "regle des pentes" proposed by HUET in 1946 for the classification of fish zones and based on both the factors slope and width of stream channel.

According to LEOPOLD et al. (1961) the mean water velocity in a channel is indeed proportional to the square root of the product of the hydraulic radius and the slope :

$$v = c\sqrt{Rs}$$

where v = mean velocity

c = a constant

R = hydraulic radius (cross-sectional area divided by the length of the wetted perimeter)

s = slope (of the water surface)

In wide shallow water this is almost equivalent to

$$v = c\sqrt{ds}$$

with d = mean depth.

VERNEAUX's (1977a) 3rd synthetic factor : $\frac{Sm}{Pl^2}$ (see above) is another mathemical formulation related to water velocity.

HUET's "slope rule" was worded as follows :

"In a given bio-geographical area, rivers or stretches of rivers of like breath, depth and slope, have nearly identical biological characteristics and very similar fish populations".

By extrapolating HUET's "regle des pentes" (Fig. 3) we propose to consider four slope categories :

7°/oo : steep

3 - 7°/oo : medium steep

1 - 3°/oo : flat

1°/oo : plain

Depending on the site and the equipment available, the hydrobiologist can use any of the following methods to measure the slope of a watercourse segment :

1) charts : on some detailed charts the denivelation from km to km is indicated
2) theodolite : unavailable in most cases
3) any type of leveling device
4) for those who do not possess any specific equipment the following very crude but most simple method may be helpfull.

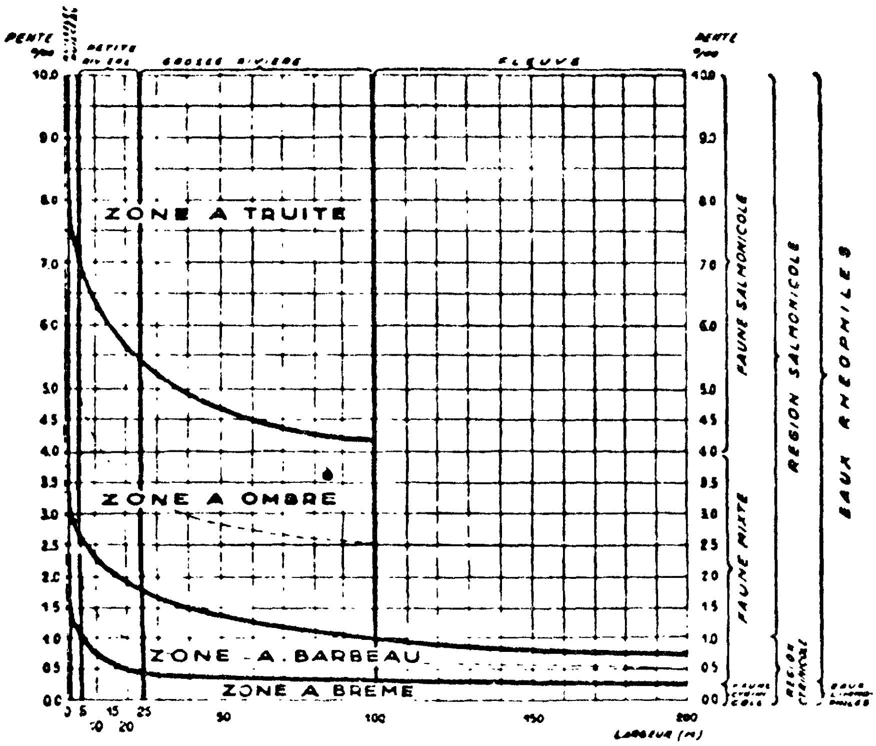


Figure 3 : Relationships between the slope and fish zones (after HUET, 1946).

<u>Determination of the approximate slope of a terrain</u> (and, by extrapolation, the portion of the watercourse under study).

Equipment necessary : a) 25 m (or even better 50 m) transparent plastic tubing (of ± 5 - 10 mm inner diameter)

b) two sticks of 1 m lenght, with sub-divisions of 1 mm

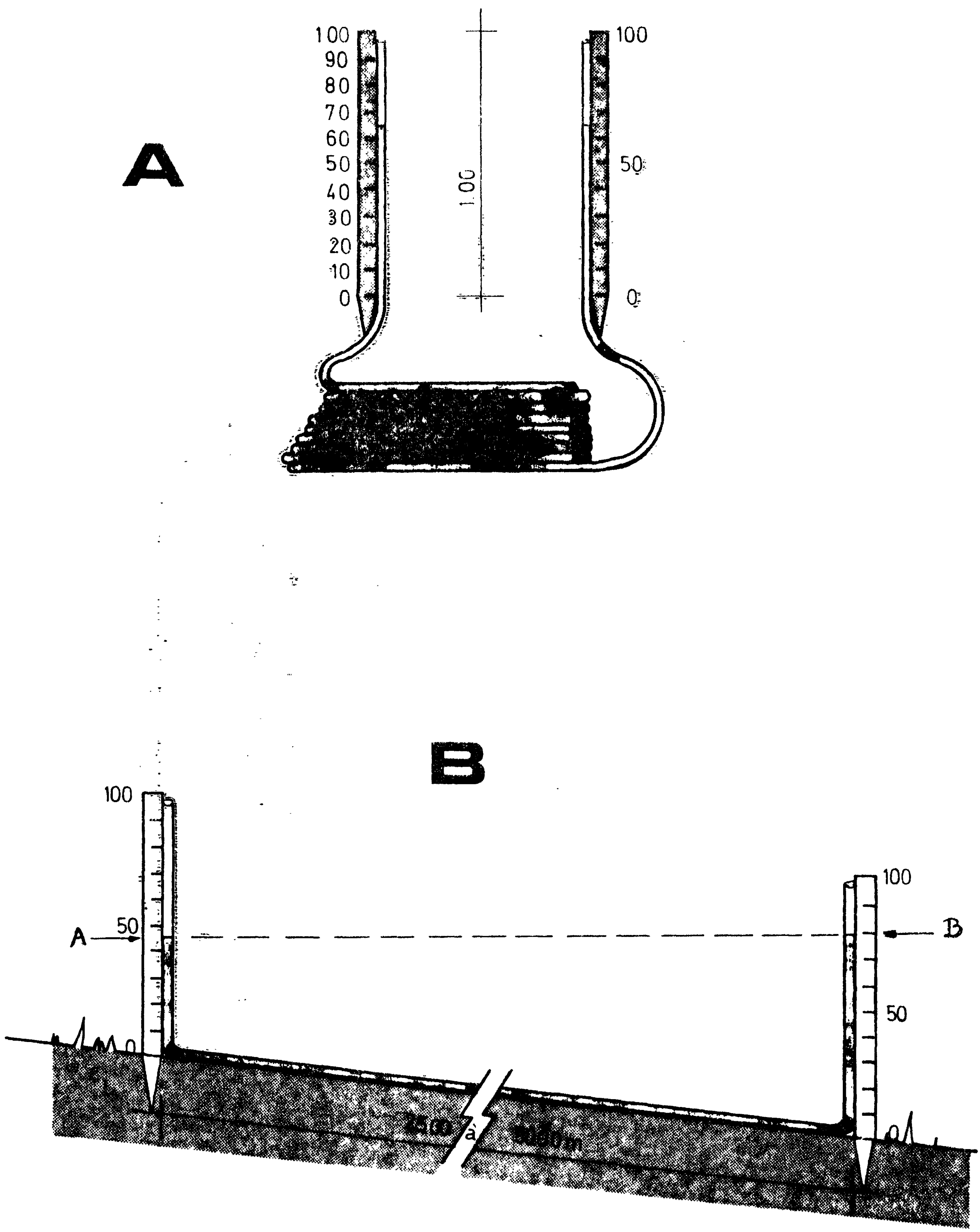
1) The tube shall be lined along and fastened to the stick at each extremity (Figure 4A)
2) At the investigation site, the two sticks are put next to each other with the demarcations at exactly the same height. The tube is filled with water till the water level is beyond the 0.5 meter mark on both sticks (the water level should give exactly the same read out on both sticks).
3) The first stick is put on the ground in a vertical position as close as possible to the bank of the watercourse ; a second investigator goes down along the bank with the second stick untill the entire lenght of the tube is unrolled and stretched. The second stick is then also put vertically on the ground (Figure 4B).
4) Both investigators then carefully read the exact mark of the water level on the stick (A and B)
5) The slope S of the terrain (corresponding roughly to the slope of the watercourse) can be calculated very easily from

   B-A = difference (in cm) between the water level on both sticks

   l = lenght of tube (in cm) between both sticks

   $S\ (°/_{\circ\circ}) = \frac{B-A}{l}$

Figure 4 . Determination of the slope of a terrain



Considering the limited lenght of the tube, it is recommended to repeat the exercise several times at different sites along a 1 km stretch of the watercourse and to average the obtained measurements.

C. WATER HARDNESS

From all the chemical parameters influencing the composition of the aquatic fauna and flora in lotic biotopes the water hardness is probably one of the most representative.

As said before the oxygen content has already been taken into account since it is roughly correlated to current speed and as such to its determinant:the slope.

Water hardness, as mentionned by HAWKES (1976)

"is the only one of the many variables in the chemical content of water, with which different characteristic biological communities can be associated".

Hardness mainly reflects the content in calcium, one of the major ions in freshwater ; it is also closely related to carbonate (or sulfate) and its linkages to bicarbonate, carbon dioxide, alkalinity and pH.

The hardness depends in the first place of the geological nature of the streambed (calcareous or siliceous) of the headwaters.

It is known for a long time that there are definite and rather clear-cut biological differences between hard water biota and soft water biota.

In this regard HAWKES (op cit.) mentions that :
"in hard waters a rich macrophytic-flora develops and the invertebrate fauna is dominated by crustaceans and molluscs. In soft acid waters the macroflora is restricted and the invertebrates are dominated by exopterygote insect nymphs".

The importance of the Calcium content of running waters for a biotypological subdivision based on macrophytes, has been demonstrated in a recent paper by WEBER-OLDECOP (1977) : "Fliessgewässertypologie auf vegetationskundlicher Grundlage".

Although arbitrary, a rough demarcation line seems to be possible at the 1 meq/l and 5 meq/l level to distinguish the soft waters (below 1 méq/l) those of intermediate hardness (from 1 to 5 méq/l) and the very hard waters (above 5 méq/l) typical for example for chalk streams.

The soft waters are further characterized by pH values mostly below 7, whereas the other categories have an alkaline pH.

D. STRUCTURE OF SUBSTRATUM

Generally it can be said that in most river systems the mean particle size decreases in the downstream direction, the size of the substratum material being determined by the water velocity. As such a rough correlation exists between the particle size and the slope.

It is well known that the nature of the benthic biota is very closely correlated with the size of the substrate material, much more even than with the chemical composition of the latter.

HAWKES (1976) mentions that :

"stable stones and rocks as well as fine silt form suitable substrates for different communities whereas the intermediate small gravel and sand provides an inhospitable habit for most organisms".

Considering the temporay presence of many types of substrata in function of the changes in flow and run-off, it has been discussed at lenght to consider a division based on the eroding, respectively despositing character of the substrate, to be further subdivided into stable versus unstable types.

Although this subdivision is in essence very meaningfull, it appears most difficult to define the limits of each subdivision for practical application of the system.

Consequently we preferred to categorize the substrates according to their particle size, as preconized by most authors.

We deliberately restricted the number of subdivisions to three categories of inert substrates :

a) dominant stony : including all types of substrates consisting of particles exceeding 2 cm.

b) dominant sandy : with particle sizes ranging from 2 mm to 200 µm.

c) dominant muddy : particles smaller than 200 µm.

It is clear that in many cases sediments with mixed particle sizes will be present.

PENNAK (op. cit.) emphasizes that :

"essentially every lotic substrate is a mixture of particle types ; usually, however, a section of a stream can be visually characterized in accordance with the dominant item forming the substrate".

In river stretches where two or three types of substrates are found close to each other, the biota of each of them should be determined separately and classidied accordingly in their respective "habitat boxes".

E. TEMPERATURE REGIME

This parameter which is dependent on both altitude and latitute is of primary importance in our classification since the distribution pattern of the organisms is function of their temperature tolerance range.

Let us also remind that this factor controls to a certain extent dissolved oxygen and dissolved nutrients.

According to ILLIES (1961) (see chapter 2) the maximum of 20°C for the monthly mean water temperature seems to be an important physical barrier for the distribution of animal species, an opinion recently confirmed for plant associations by WEBER -OLDECOP (1970-1971).

Most experts considered that a further subdivision was highly desitable to distinguish the typical fauna's and flora's of cold, temperate, warm and hot waters.

As HAWKES (1975) pertinently remarks :

"for an organism to establish a population in a given biotope, the environmental conditions must be such that the organism not only survives, but is not caused to leave, is able to feed and grow and successfully reproduce".

Considering the impossibility of temperature readings at different moments of the year, it was decided to adopt the temperature approach of ILLIES, namely the highest mean temperature of the stream (summer temperature).

Whenever possible a mininum - maximum thermometer (or a thermometrograph) should be left in the water for a certain period to establish the thermal character of the watercourse.

Finally it was decided to distinguish the following four temperature classes :

cold : mean summer temperature always below 12°C

Temperature : mean summer temperature between 12°C and 17°C (occasionnaly up to 20°C)

warm : mean summer temperature between 20°C and 23°C (occasionnaly down to 17°C)

hot : mean summer temperature always exceeding 23°C

5. MAJOR PLANT AND ANIMAL GROUPS TO CONSIDER FOR THE ESTABLISHMENT OF THE BIOCENOTYPES

Every aquatic habitat is by definition succeptible to be colonized by a tremendous variety of species belonging to a wide array of taxonomic groups.

Table 2 which is derived from a training Manual on Water Pollution edited by the Environmental Protection Agency (USA) gives an idea of the number of groups of organisms that can theoretically be encountered in aquatic biotopes.

It is obvious that the qualitative presence of a species in an aquatic biotope depends in the first place on its tolerance range for the environmental (abiotic) factors characteristic for the particular habitat ; the quantitative presence is, besides abiotic influences, also dependent from trophic relationships with the other species.

As a result any biocenosis thriving in a particular habitat is (or can be) composed of a mixture of species the tolerance of which towards the abiotic characteristics of the particular environment can range from <u>eury</u> to <u>steno</u>.

In other words, some of the species present will also be found (or can also thrive) in other habitats whereas others will be restricted to that particular set of environmental conditions.

Table 2

PELATIONSHIPS BETWEEN FREE LIVING AQUATIC ORGANISMS

Energy Flows from Left to Right, General Evolutionary Sequence is Upward

PRODUCERS	CONSUMERS		REDUCERS
Organic Material Produced, Usually by Photosynthesis	Organic Material Ingested or Consumed Digested Internally		Organic Material Reduced by Extracellular Digestion and Intracellular Metabolism to Mineral Condition
ENERGY STORED	ENERGY RELEASED		ENERGY RELEASED
Flowering Plants and Gymnosperms	Arachnids	Mammals	Basidiomycetes
	Insects	Birds	
Club Mosses, Ferns	Crustaceans	Reptiles	
	Segmented Worms	Amphibians	
Liverworts, Mosses	Molluscs	Fishes	Fungi Imperfecti
Multicellular Green Algae	Bryozoa	Primitive Chordates	
	Rotifers		Ascomycetes
	Roundworms	Echinoderms	
Red Algae	Flatworms		
	Coelenterates		Higher Phycomycetes
Brown Algae	Sponges		

DEVELOPMENT OF MULTICELLULAR OR COENOCYTIC STRUCTURE

H I G H E R P R O T I S T A

	Protozoa		
Unicellular Green Algae	Amoeboid	Ciliated	Lower
Diatoms			Phycomycetes
Pigmented Flagellates	Flagellated, (non-pigmented)	Suctoria	(Chytridiales, et. al.)

DEVELOPMENT OF A NUCLEAR MEMBRANE

L O W E R P R O T I S T A

(or: Monera)

Blue Green Algae	Actinomycetes
Phototrophic Bacteria	Spirochaetes
Chemotrophic bacteria	Saprophytic Bacterial Types

(From : Training Manual on Water Pollution, Environmental Protection Agency, U.S.A.)

For this reason VERNEAUX (1976b), in his biotypological system, considers both "ecological preferendum" and the "typological amplitude" of the species.

The former factor refers to the category to which the species belongs in his 10 point system whereas the latter expresses the degree of "stenoïcy".

VERNEAUX (op cit.) came to the conclusion that there are practically no species the typological amplitude of which is lower than 3 successive levels in his biotypological system.

The characteristic species are the most stenoïc and range over 3 ± 1 level ; the intermediate can be spread out over 6 ± 1 level ; the central species are the most eurytopic : 9 ± 1 levels.

Theoretically a given aquatic environment is characterized biologically by all the species composing the hydrobiocenoses, qualitatively as well as quantitatively.

Needlees to say that in practice an extensive listing of all species populating a particular habitat is not applicable for any biotypological classification for reasons of time as well as of determination problems.

From this practical consideration three questions arise :

a) <u>shall our biotypological classification be based on one group of organisms or take different groups into consideration</u> ?

It should be reminded that most of the earlier zonation studies were based on fish as sole characteristic species.

More recently DESCY (1975) proposed an algal typology based on diatom communities.

It was agreed that, in analogy to schemes utilized throughout Europe for water quality surveys, different categories or organisms should be considered for this reference biotypological classification.

b) <u>which organisms are really representative or characteristic for a particular habitat</u> : those that are found in abundance (dominant species) or those of which the distribution is restricted to that specific habitat (steno-species) ?

The latter question is particularly pertinent with regard to pollution since it is well-known that, due to their more narrow tolerance ranges, steno-species will in most cases be wiped out first.

However, the determination of the "steno"-species involves once again the establishment of the complete list of organisms since steno-species can be either quantitatively very well represented or on the contrary occur in only very small numbers.

Considering that the dominant biota quantitatively reflect the overall effect of the aquatic environment and that as such there can be no doubt that they characterize the habitat biologically, it was decided that for the establishment of the biocenotypes, only the predominant species from different groups of organisms should be taken into consideration.

With regard to the concept "dominant" it is not possible to set any precise rule for practical application since, besides avoiding extensive lists, we also want to exclude any mathematically exact quantitative analysis of the biota for a general biotypological classification system.

At the risk of oversimplification we would like to compare the typing of the major biota in each of the specific macro-habitats (biotopes) with a plane flying over a certain region at a certain altitude. The higher the plane flies the rougher the characterization of the terrestrial region (with, however, the possibility of pinpointing the dominant features of the landscape) ; the lower the aircraft flies, the more details can be recognized (which can be translated as more groups considered or more specific determination in each dominant group of organisms).

c) which of the numerous groups of organisms populating running waters shall be selected for the establishment of major biocenotypes ?

With regard to the practical implementation of the biotypological system proposed and especially considering the problems of sampling and analysis, as well as the degree of taxonomic expertise required as such a broad level as the entire Community hydrographic basins , it was decided to limit the analyses to the macrophytic vegetation (including the macroscopic algae) and the macroscopic fauna (size exceeding 0.5 mm), sampled in the lotic facies (thus avoiding the littoral zone).

The following groups of organisms should be considered :

- Aquatic weeds (macroscopic groups only)
- Vascular plants
- Vermes, Turbellaria (Tricladida)
  - Oligachaeta
  - Hirudinea
- Mollusca, Gastropoda
  - Bivalvia
- Crustacea, Isopoda
  - Amphipoda
  - Decapoda
- Insecta, Plecoptera
  - Ephemeroptera
  - Trichoptera
  - Odonata
  - Megaloptera
  - Hemiptera
  - Coleoptera
  - Diptera
- Pisces

The level of determination of the organisms encountered is a matter of taxonomical expertise as well as of availability of good taxonomic keys. Indeed it is a fact that in some countries of the Community certain watercourses have never been analyzed hydrobiologically and the probability that new species will be found is quite high.

As a general rule the organisms should be determined "as far as possible".

HAWKES(personal communication) considered that for the river basins of the U.K. with which he was familiar, the determination in many of the above mentioned groups could be carried out down to the species level ; Coleoptera and Diptera larvae to the genus, Trichoptera larvae to the family or species (depending on the group), bivalves to the genus, Oligochaetes to the family, and macroscopic algae to the genus.

Although the approach outlined above might seem extremely crude, it should be admitted that before any more sophisticated classification system would be applicable in the entire Community, we absolutely need basic biological data to characterize, able it but very roughly, portions of watercourses.

With regard to the period of sampling it is obvious that the hydrobiological analysis shall preferably be carried out during a "normal situation" of the watercourse (no spring run-off or winter samplings).

For the sampling methodology we can refer to the recent WOODIWISS - report of the "EEC Technical Seminar on Biological Water Assessment Methods" held at Nottingham in October 1976.

6. NUMBER OF MACROHABITAT CLASSES AND THEIR SPECIFIC BIOCENOTYPES

Table 3 summarizes the environmental parameters and their subdivisions to be considered.

Despite the drastic limitation of the number of subdivisions for each parameter, the combination of all the subdivisions nevertheless results in : 3 x 4 x 3 x 3 x 4 = 432 theoretical categories of macrohabitats (biotopes) i.e. portions of water-courses with well-defined physicochemical characteristics (at least with regard to the parameters considered (which as mentioned above are, however, interdependent with many others).

It is evident (and fortunate) that a certain number of the combinations will only result in "theoretical" habitats which will not occur in nature.

It is for example hard to imagine that anywhere in the Community a river exists of more than 25 meter width, the summer temperature of which does not exceed 12°C.

Considering the numerous river basins in the EEC, it would however, be presumptuous to try to determine the exact number of existing macrohabitats starting more a theoretical basis.

Since each sampling shall by definition characterize a particular habitat, the exact number of habitats will automatically be known at the end of the vast hydrobiological survey at the Community level (cf. chapter 3) should the present proposal be implemented.

From the practical point of view we propose in the meantime to attribute to each of the 432 theoretical macrohabitats a code, which can be very easily defined as follows :
the five basic parameters are identified by the following symbols :

Width of channel : W

Slope (or gradient) : G

Water hardness : H

Structure of substratum : S

Temperature regime : T

The subdivisions for each abiotic parameter are characterized by a number (from 1 to 3 or to 4, according to the number of subdivisions).

The proposed system is outlined in table 4.

The code number : W2G3H2S2T2 thus refers to a portion of a watercourse from 2 to 25 m width, with a medium steep slope of 1 - 3 °/₀₀, and an intermediate water hardness ; it has a sandy bottom and the temperature regime is that of a temperate climate.

For reasons of simplicity the 432 theoretical macrohabitats shall preferably be characterized by their "box number". For the example given above the box number is thus 23222.

Width of channel	Slope	Water hardness	Structure of substratum	Temperature regime
< 2 m	Steep > 7°/oo	Soft < 1 méq/l	Stony > 2 cm	Cold < 12°C
2 - 25 m	Medium steep : 3-7°/oo	Intermediate : 1 - 5 méq/l	Sandy : 2mm - 200 µm	Temperate : 12 - 17°C
> 25 m	Flat : 1 - 3°/oo	Very hard > 5 méq/l	Muddy < 200 µm	Warm : 20-23°C
	Plain < 1°/oo			Hot : > 23°C

Table 3 : Environmental parameters selected and their subdivisons

Width	W	Slope Gradient	G	Water hardness	H	Substratum	S	Temperature
< 2 m	1	Steep > 7°/oo	1	Soft < 1 méq/l	1	Stony > 2 cm	1	Cold < 12°C
2-25 m	2	Medium steep : 3-7°/oo	2	Intermediate : 1-5 méq/l	2	Sandy : 2 mm-200 µm	2	Temperate : 12-17°C
> 25 m	3	Flat : 1-3°/oo	3	Very hard > 5 méq/l	3	Muddy < 200 µm	3	Warm : 20-23°C
		Plain < 1°/oo	4					Hot > 23°C

<u>Table 4</u> : Code (symbol and number) for the characterization of the different macrohabitats

7. PRACTICAL PROCEDURES

A. ABIOTIC PARAMETERS

For the hydrobiological analysis of the portions of water-courses, we suggest to use the following chart (see table 5).

B. DOMINANT BIOTA

The dominant plants, respectively animals, occuring in a particular watercourse shall be listed in a decreasing sequence of importance.

The taxonomic citation shall be as follows :

Class Order Family Genus Species

When comparing the biota found at different geographical sites for environments with similar physicochemical characteristics (similar macrohabitats) the full taxonomical description should allow to determine the taxonomic rank of similitude in the dominant floristic and faunistic groups.

8. DETERMINATION OF FINAL NUMBER OF MACROHABITATS AND THEIR RESPECTIVE CHARACTERISTIC HYDROBIOCENOZES

The procedure outlined above should permit to extrapolate the "unités systématiques" (in the sense of VERNEAUX and TUFFERY, 1967) on which the definitive biocenotype, characteristic for each macrohabitat, should be based.

For example the comparison of the biota of similar macrohabitats in different hydrographic basins or regions, will reveal

Table 5 : Physical and chemical characteristics of the macrohabitat

Date of analysis : ....
Name of watercourse : ....
Geographical or cartographical coordinates : ....
Width of overbank flow : ....
Water hardness : ....
Structure of substratum : ....
Mean summer temperature : ....
Habitat category : W..G..H..S..T..
Box number :

similitudes in aquatic weeds at the family level, for molluscs at the genus level and for certain categories of organisms maybe even at the species level.

The characterization of the biocenotypes representative for each macrohabitat class, by the mere listing of the dominant biota, even at the order or family level of determination, will, in our opinion already lead to a most useful reference system for the future establishment of water quality criteria.

When the biocenotypes will be compared with each other (each of them standing for one particular macrohabitat) identical biocenotypes will probably show up for different (but probably neighbouring) classes of the theoretical physico-chemical macrohabitat subdivision system proposed above.

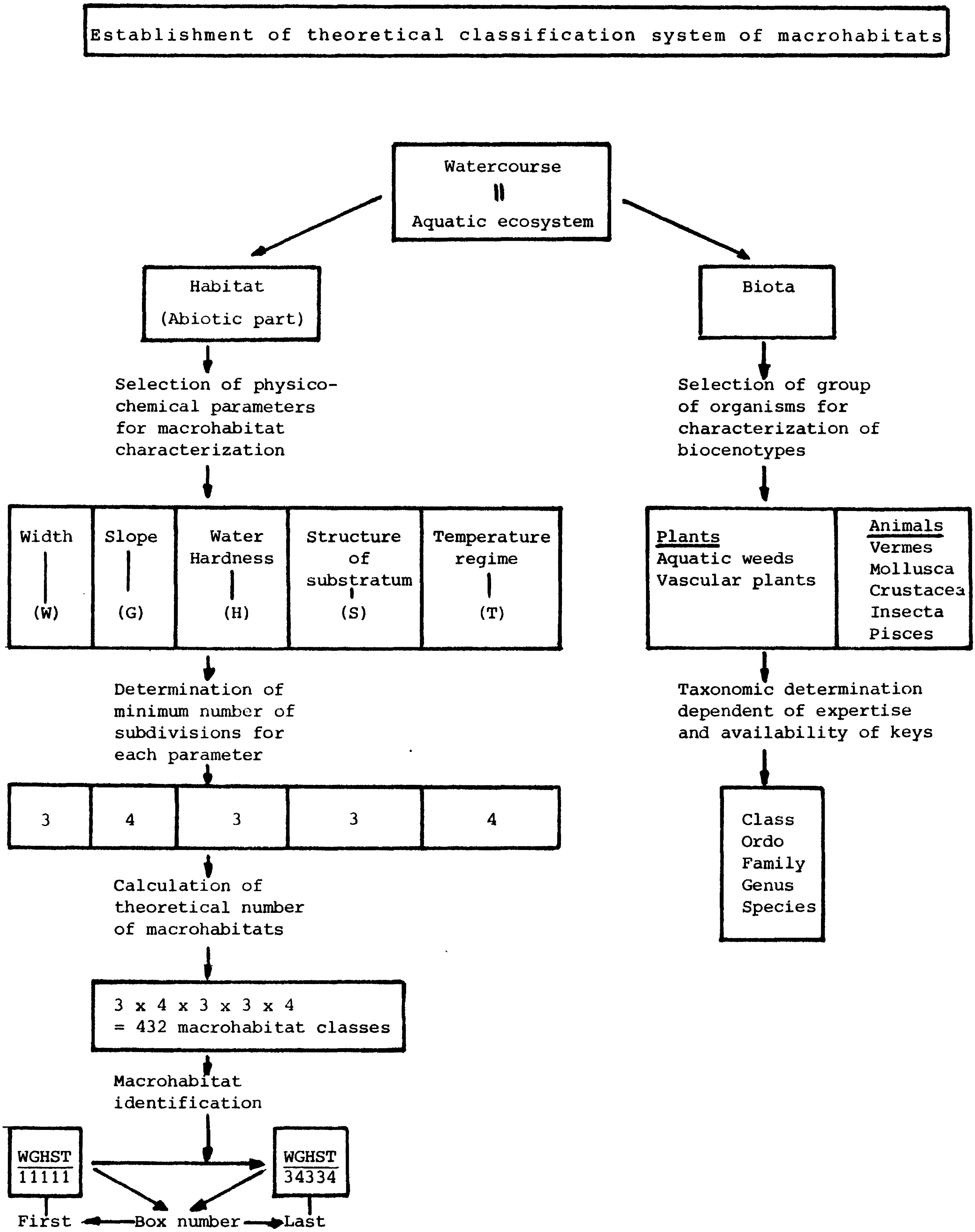
The pooling of the habitat types of the latter will finally lead to a minimum number of categories of major hydrobiocenonses (in the sense of biocenotypes) characterizing ecological types in watercourses.

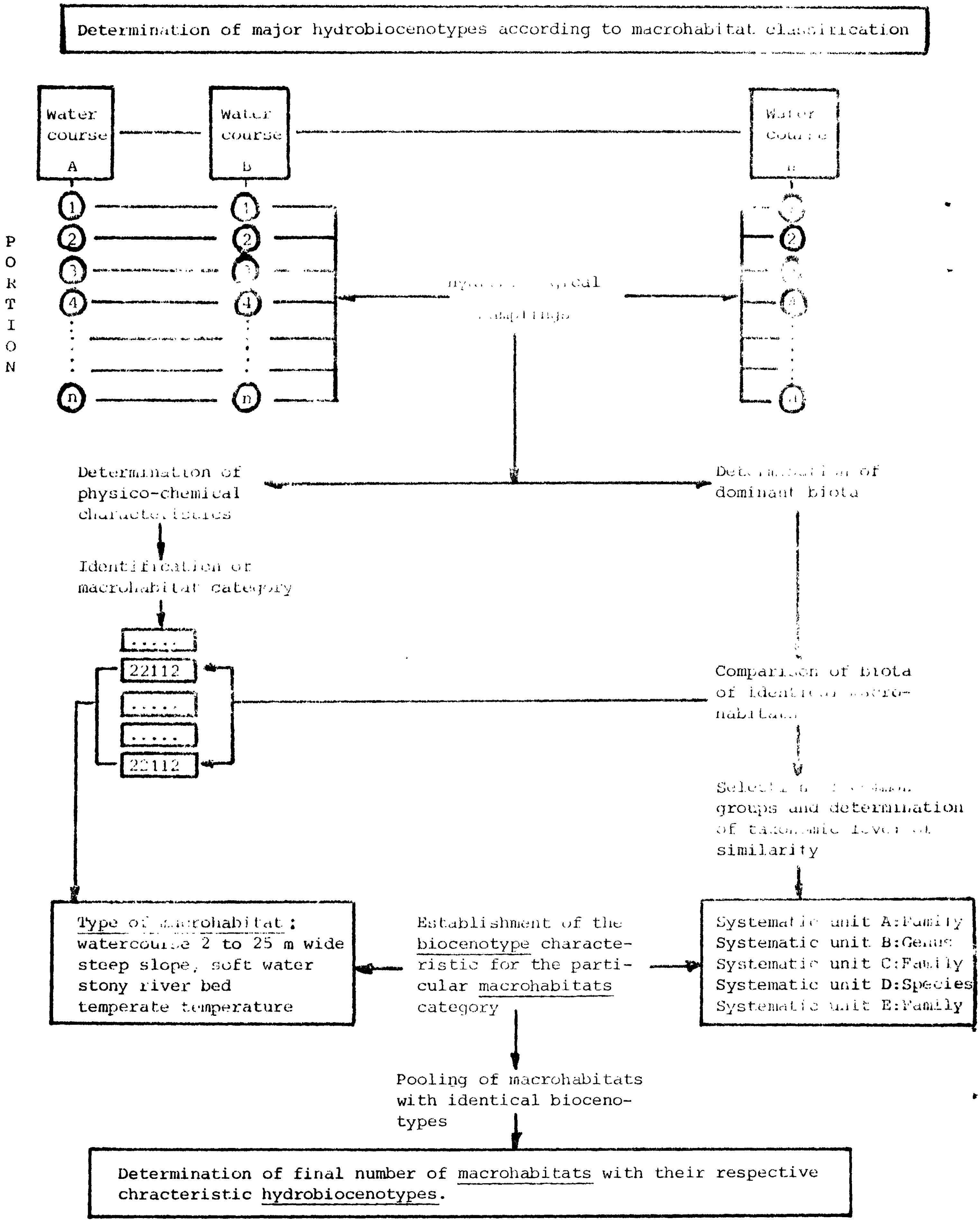
9. SYNOPSIS

The different steps worked out for he establishment of a theoretical classification system of macrohabitats are summarized in chart 1.

The practical implementation i.e. the hydrobiological sampling program which should lead to the reduction of the number of macrohabitats and the selection of systematic units for the establishment of definitive hydrobiocenotypes is outlined in chart 2.

Chart 1


Establishment of theoretical classification system of macrohabitats
Watercourse
Aquatic ecosystem
Habitat
(Abiotic part)
Biota
Selection of physico-chemical parameters for macrohabitat characterization
Selection of group of organisms for characterization of biocenotypes
Width
(W)
Slope
(G)
Water Hardness
(H)
Structure of substratum
(S)
Temperature regime
(T)
Plants
Aquatic weeds
Vascular plants
Animals
Vermes
Mollusca
Crustacea
Insecta
Pisces
Determination of minimum number of subdivisions for each parameter
Taxonomic determination dependent of expertise and availability of keys
3
4
3
3
4
Class
Ordo
Family
Genus
Species
Calculation of theoretical number of macrohabitats
3 x 4 x 3 x 3 x 4
= 432 macrohabitat classes
Macrohabitat identification
WGHST
11111
WGHST
34334
First
Box number
Last


Determination of major hydrobiocenotypes according to macrohabitat classification
Water course A
Water course b
P O R T I O N
1
2
3
4
n
Determination of physico-chemical characteristics
Identification of macrohabitat category
22112
22112
Determination of dominant biota
similarity
Type of macrohabitat :
watercourse 2 to 25 m wide
steep slope, soft water
stony river bed
temperate temperature
Establishment of the biocenotype characteristic for the particular macrohabitats category
Systematic unit A:Family
Systematic unit B:Genus
Systematic unit C:Family
Systematic unit D:Species
Systematic unit E:Family
Pooling of macrohabitats with identical biocenotypes
Determination of final number of macrohabitats with their respective chracteristic hydrobiocenotypes.

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