FAUNA AQUATICA AUSTRIACA

A Comprehensive Species Inventory of Austrian Aquatic Organisms with Ecological Notes

Edited by

OTTO MOOG & ANNE HARTMANN

3. Edition - 2017

With contributions of

Erna Aescht, Ulrike Aspöck, Ernst Bauernfeind, Hans-Martin Berg, Helmut Berger, Georg Bieringer, Hubert Blatterer, Péter Borza, Michaela Brojer, Manfred Car, Andreas Chovanec, Ruth Contreras-Lichtenberg, Iris Dröscher, Erich Eder, Wilhelm Foissner, Lázlo Forró, Andreas Fuchs, Santiago Gaviria, Elisabeth Geiser, Wolfram Graf, Ursula Grasser, Alois Herzig, Walter Hödl, Werner E. Holzinger, Karl Hörner, Thomas Huber, Peter Huemer, Berthold Janecek, Manfred A. Jäch, Christian D. Jersabek, Jan Kodada, Fritz Kohmann, Robert Konecny, Wolfgang Lechthaler, Patrick Leitner, Johanna Mildner, Paul Mildner (†), Werner Mohrig, Otto Moog, Christian Moritz, Hasko F. Nesemann, Thomas Ofenböck, Pjotr Oosterbroek, Claus Orendt, Wolfgang Paill, Manfred Pöckl, Peter Pospisil, Wolfgang Rabitsch, Alexander Reischütz, Peter L. Reischütz, Herbert Reusch, Reinhard Saxl (†), Robert Schabetsberger, Tobias Schernhammer, Ferdinand Sporka, Konrad Thaler (†), Gerhard Tarmann, Rüdiger Wagner, Johann Waringer, Peter Weichselbaumer, Armin Weinzierl, Werner Weißmair, Karl Wittmann, Emmy R. Wöss, Herbert Zettel, Carina Zittra, Peter Zwick

Published by

Federal Ministry of Agriculture, Forestry, Environment and Water Management, Directorate IV/3

3rd edition, 2017

Compiled by the Institute of Hydrobiology and Aquatic Ecosystem Management (IHG), University of Natural Resources and Life Sciences, Vienna (BOKU) on behalf of Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW)

Project supervisor:

DI Dr. Astrid Schmidt-Kloiber, Institute of Hydrobiology and Aquatic Ecosystem Management, University of Natural Resources and Life Sciences, Gregor-Mendel-Straße 33/DG, 1180 Vienna

---

Citation remarks:

When quoting the catalogue as a whole:

Moog, O. & A. Hartmann (Eds.) (2017): Fauna Aquatica Austriaca, 3. Edition 2017. BMLFUW, Wien.

Taxonomic parts of the Catalogue should be quoted as follows:

Author(s) of organism group (year): Organism group. In Moog, O. & A. Hartmann (Eds.): Fauna Aquatica Austriaca, 3. Edition 2017. BMLFUW, Wien.

Published by:

Federal Ministry of Agriculture, Forestry, Environment and Water Management, Stubenring 1, A-1010 Vienna

ISBN: 978-3-85174-074-5

Table of Contents

FAUNA AQUATICA AUSTRIACA

Part I

Preface, Introduction,

Taxonomic groups and Authors

MINISTERIUM
FÜR EIN
LEBENSWERTES
ÖSTERREICH

Preface to the Third Edition

The Fauna Aquatica Austriaca (FAA) contains the species inventory of the Austrian aquatic fauna, listing 3287 metazoa and 650 ciliophora species.

The FAA includes autecological information on the aquatic organisms that form the basis for the ecological status assessment of the biological quality element "macroinvertebrates". By standardising the ecological classifications, the FAA is a fundamental prerequisite for the comparability of investigation results.

The catalogue is valid on a national basis (Austria-wide) and was first published in 1995, a second edition was necessary in 2002; further supplements were continuously added to the ECOPROF software. Through the national monitoring by implementing the Austrian Water Rights Act of 1959 ("Wasserrechtsgesetz") and the Ordinance on the Monitoring of the Status of Waters ("Gewässerzustandsüberwachungsverordnung") as well as through numerous new scientific studies, a long-term, comprehensive data set on the different types of water bodies is available, which made the revision of the catalogue possible.

New species have been recorded in Austria since the first edition of the FAA. Additionally, numerous taxonomic alterations and ecological classifications respectively have been amended based on a plausibility check and according to the current state of knowledge.

In order to improve the international comparability of evaluation results, the ecological classifications of species in the FAA were compared and harmonised (when possible) with those of the freshwaterecology.info database.

We would like to express our sincere thanks to the project leaders, the authors, and editors for their efforts and input leading to the updated version of the FAA!

Vienna, December 2017

Federal Ministry of Agriculture, Forestry, Environment and Water Management
Directorate IV/3 – National and International Water Management

Introduction

25 years have passed since the Department of Hydrobiology, Fisheries and Aquaculture of BOKU University (today: Institute for "Hydrobiology and Aquatic Ecosystem Management") was commissioned by the former Federal Ministry of Agriculture and Forestry Section IV to establish an inventory and ecological classification catalogue for freshwater benthic invertebrates of Austria. This activity created a milestone that terminated methodological uncertainties in freshwater quality assessment and generated a comprehensible database for science, administration and alike.

The Fauna Aquatica Austriaca (FAA), which was first published in 1995, contained the known species inventory of Austria's freshwater fauna and provided a collection of ecological data on aquatic organisms (saprobic indices valencies, functional feeding types and longitudinal distribution within the "biocoenotic regions"). With 292 ciliates and 2924 invertebrate species, over 900 species were added to the catalogue in the second edition (Moog 2002) and the revised version in 2003 (Moog 2004). With the current edition, the number of aquatic macro-invertebrates of Austrian waterbodies increases to 650 ciliates and 3287 metazoa species.

The following taxonomic groups were additionally included in the FAA 2017 (alphabetical order, author name in brackets):

- Acantocephala (Robert Konecny)
- Coleoptera: Chrysomelidae (Donaciinae) (Elisabeth Geiser)
- Ostracoda (Santiago Gaviria)
- Porifera: Spongillidae (Iris Dröscher, Johann Waringer, Johanna Mildner & Paul Mildner)

An updated list of the aquatic invertebrate Neozoa was also included in the catalogue, since the non-indigenous species are increasingly used as a mathematical parameter ("metric") for the assessment of the ecological status of waterbodies. The other ecological classifications have been retained in their structure, as they are an essential computational basis for the current methods for assessing the ecological status of water bodies. The saprobic indices, the composition of the functional feeding types or the longitudinal distribution within the "biocenotic regions" are used as "metrics" in current evaluation methods (e.g. Ofenböck et al. 2010, Meier et al. 2006).

In the 22 years of its use, the FAA has developed into an important tool for quality assurance and forms the basic prerequisite for the comparability of research results within the framework of the national quality monitoring of watercourses. Since the large number of authors guarantees a well-assured knowledge, the FAA also attracts international attention.

As a result of this development, the software ECOPROF – prescribed by the BMLFUW for the calculation of the ecological status – must correspond to the contents of the FAA. ECOPROF is an evaluation program for freshwater-related biological datasets and offers a contribution to the quality assurance for hydrobiological investigations in the sense of precisely defined methods with standardised work steps and procedures (QZV Ökologie OG BGBl II Nr. 99/2010 i.d.g.F., ÖNORM M 6232). It is an important objective of the BMLFUW to obtain a uniform output product, which allows representatives of authorities the interpretation of analysis results in a comprehensible and time-efficient manner, regardless of the data supplier.

The linking of the FAA edition, which is published on a fixed date, with the software ECOPROF, which can be updated at shorter intervals, makes Fauna Aquatica Austriaca a "living" product, adapted to the ever-increasing ecological knowledge. For the users of the FAA, this means that taxonomic or ecological innovations or extensions can be queried in ECOPROF independently of the latest FAA publication through consultation of the taxalists and ecological databases.

Oher countries followed the example of the FAA (e.g. Schmedtje & Colling 1996). In addition, several projects of ecological databases with similar tasks and objectives were launched at European level, stimulated by the European Union's research funding: AQEM, STAR, Fauna Europaea, (Schmidt-Kloiber et al. 2006, 2008, de Jong, Y. et al. 2014). Based on the idea of the Fauna Aquatica Austriaca a database for European freshwater species was established as part of several EU projects, www.freshwaterecology.info (Schmidt-Kloiber & Hering, 2015).

This database also provides knowledge on the ecological preferences of species as an essential basis for understanding the distribution patterns of species, preserving biodiversity, or assessing and evaluating freshwater ecosystems. The freshwaterecology.info-database is available online and is used by numerous scientists. For this reason, the authors of the FAA tried for a high compatibility between the FAA and www.freshwaterecology.info.

With the publication of the 2017 edition of the Fauna Aquatica Austriaca the older versions will be withdrawn from the internet. In order to provide an understanding of the structure and background of the FAA to future and new readers, the introduction, explanations of the first edition (1995) are made available within the following pages.

References

de Jong, Y. et al. (2014): Fauna Europaea – all European animal species on the web. Biodiversity Data Journal 2: e4034. doi: 10.3897/BDJ.2.e4034.

Meier, C., Haase, P., Rolauffs, P., Schindehütte, K., Schöll, F., Sundermann, A. & D. Hering (2006): Methodisches Handbuch Fließgewässerbewertung - Handbuch zur Untersuchung und Bewertung von Fließgewässern auf der Basis des Makrozoobenthos vor dem Hintergrund der EG-Wasserrahmenrichtlinie. Verfügbar über http://www.fliessgewaesserbewertung.de

Moog, O. (Ed.) (1995): Fauna Aquatica Austriaca. Lieferung 1995. Wasserwirtschaftskataster, Bundesministerium für Land- und Forstwirtschaft, Wien.

Moog, O. (Ed.) (2002): Fauna Aquatica Austriaca. Lieferung 2002. Wasserwirtschaftskataster, Bundesministerium für Land- und Forstwirtschaft, Wien.

Moog, O. (Ed.) (2004): Fauna Aquatica Austriaca - Katalog zur autökologischen Einstufung aquatischer Organismen Österreichs. Teil V – Ergänzungen 2003. Wasserwirtschaftskataster, Bundesministerium für Land- und Forstwirtschaft, Umwelt & Wasserwirtschaft, Wien.

Ofenböck, T., Moog, O., Hartmann, A. & I. Stubauer (2010): Leitfaden zur Erhebung der biologischen Qualitätselemente - Teil A2 - Makrozoobenthos, Version Feb. 2010. Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft.

ÖNORM M 6232 (1997): Richtlinie für die ökologische Untersuchung und Bewertung von Fließgewässern.- Österreichisches Normungsinstitut Wien, 38 pp.

QZV Ökologie OG (2010): Qualitätszielverordnung Ökologie Oberflächengewässer. 99. Verordnung des Bundesministers für Land – und Forstwirtschaft, Umwelt und Wasserwirtschaft über die Festlegung des ökologischen Zustandes für Oberflächengewässer, Ausgegeben am 29. März 2010, Teil II – Jahrgang 2010.

Schmedtje, U. & M. Colling (1996): Ökologische Typisierung der aquatischen Makrofauna Informationsberichte des Bayerischen Landesamtes für Wasserwirtschaft 4/96, 543 pp.

Schmidt-Kloiber A., Graf, W., Lorenz, A. & O. Moog (2006): The AQEM/STAR taxalist – a pan-European macro-invertebrate ecological database and taxa inventory. Hydrobiologia 566: 325-342.

Schmidt-Kloiber, A., Graf, W., Moog, O., Lorenz, A. & D. Hering (2008): The indicator database for European freshwater invertebrates. In: Meyer, M. & P. Neu (Eds.), Proceedings of the First Conference on Faunistics and Zoogeography of European Trichoptera. Luxembourg, 2-4 September 2005, Ferrantia 55, pp. 85-88.

Schmidt-Kloiber A. & D. Hering (eds.): www.freshwaterecology.info - the taxa and autecology database for freshwater organisms, version 7.0 (accessed on 05.12.2016).

Schmidt-Kloiber, A. & D. Hering (2015): www.freshwaterecology.info - an online tool that unifies, standardises and codifies more than 20,000 European freshwater organisms and their ecological preferences. Ecological Indicators. http://dx.doi.org/10.1016/j.ecolind.2015.02.007

Taxonomic group	Author(s)
Protozoa	
Ciliophora	Erna Aescht, Wilhelm Foissner, Hubert Blatterer, Fritz Kohmann, Helmut Berger
Metazoa	
Porifera	
Spongillidae	Iris Dröscher, Johann Waringer, Johanna Mildner, Paul Mildner (†)
Acanthocephala	Robert Konecny
Kamptozoa (Entoprocta)	Ferdinand Sporka
Bryozoa	Emmy R. Wöss
Oligochaeta	Karl Hörner, Ferdinand Sporka, Otto Moog
Polychaeta	Karl Hörner, Otto Moog, Ferdinand Sporka
Mollusca	
Gastropoda	Alexander Reischütz, Peter L. Reischütz, Otto Moog, Hasko F. Nesemann
Bivalvia	Alexander Reischütz, Peter L. Reischütz, Otto Moog, Hasko F. Nesemann
Crustacea	
Ostracoda	Santiago Gaviria
Anostraca, Notostraca, “Conchostraca”	Walter Hödl, Tobias Schernhammer, Erich Eder
Amphipoda, Isopoda, Decapoda	Manfred Pöckl, Péter Borza, Hasko Nesemann, Otto Moog
Mysida	Karl Wittmann
Branchiopoda (Cladocera)	Santiago Gaviria, Lazlo Forró, Christian D. Jersabek, Robert Schabetsberger
Copepoda	
Calanoida	Santiago Gaviria, Alois Herzig, Lázlo Forró
Cyclopoida	Santiago Gaviria, Andreas Fuchs, Alois Herzig, Peter Pospisil, Lázlo Forró
Harpacticoida	Santiago Gaviria, Andreas Fuchs
Parasitica	Robert Konecny
Ephemeroptera	Ernst Bauernfeind, Peter Weichselbaumer, Patrick Leitner, Otto Moog

Taxonomic group	**Author(s)**
Odonata	Andreas Chovanec, Johann Waringer, Werner E. Holzinger, Otto Moog, Berthold Janecek
Plecoptera	Wolfram Graf, Ursula Grasser, Armin Weinzierl
Orthoptera	Georg Bieringer, Hans-Martin Berg
Auchenorrhyncha	Werner E. Holzinger
Heteroptera	Herbert Zettel, Wolfgang Rabitsch
Megaloptera	Ulrike Aspöck
Neuroptera	
Osmylidae	Ulrike Aspöck
Sisyridae	Werner Weißmair, Johann Waringer
Coleoptera	
Water Beetles s.l.	Michaela Brojer, Manfred A. Jäch, Jan Kodada, Otto Moog
Carabidae	Wolfgang Paill
Chrysomelidae: Donaciinae	Elisabeth Geiser
Trichoptera	Wolfram Graf, Ursula Grasser, Johann Waringer
Lepidoptera	Peter Huemer, Gerhard Tarmann
Diptera	
Blephariceridae	Peter Zwick
Culicidae	Carina Zittra, Manfred Car, Wolfgang Lechthaler, Werner Mohrig
Simuliidae	Wolfgang Lechthaler, Otto Moog, Manfred Car
Chironomidae	
Podonominae & Buchonomyiinae	Berthold Janecek, Otto Moog, Claus Orendt
Tanypodinae	Berthold Janecek, Otto Moog, Claus Orendt
Diamesinae	Berthold Janecek, Christian Moritz, Claus Orendt, Reinhard Saxl (†)
Prodiamesinae	Berthold Janecek, Otto Moog, Claus Orendt

Taxonomic group	Author(s)
Orthocladiinae	Berthold Janecek, Otto Moog, Christian Moritz, Claus Orendt, Reinhard Saxl (†)
Chironominae	Berthold Janecek, Claus Orendt, Ruth Contreras-Lichtenberg
Tipuloidea	
Cylindrotomidae, Limoniidae, Pediciidae, Tipulidae	Pjotr Oosterbroek, Herbert Reusch
Arachnida	
Araneae	Konrad Thaler (†)
Aquatic invertebrate Neozoa	Otto Moog, Patrick Leitner, Thomas Huber, Wolfgang Rabitsch, Wolfram Graf

FAUNA AQUATICA AUSTRIACA

Part II

Unmodified introduction to the first edition (1995), methodological principles and application examples for the use of this catalogue

MINISTERIUM
FÜR EIN
LEBENSWERTES
ÖSTERREICH

INTRODUCTION TO THE FIRST EDITION, METHODOLOGICAL PRINCIPLES AND APPLICATION EXAMPLES FOR THE USE OF THIS CATALOGUE

English translation by STEVE WEISS

Table of contents:

1. Introduction

The production of this catalogue required the contributions of an unusually large number of independently working authors to insure the most current and accurate treatment of the full spectrum of ciliates and benthic invertebrates found in Austrian rivers. Although this compilation represents only a small subset of possible ecologically-based analyses used in water quality assessment, a methodological foundation linked to an enormous data base has been achieved in a relatively short time which, owing to its comprehensive and detailed structure, allows for additional, reconstructive analyses.

This work is oriented towards the practitioner of water quality assessment and conservation planning. Use of this data base together with the relatively small expenditure of time needed to collect and analyze field samples, to identify the species present and the frequency of their occurrence, will permit the description of the benthic aspects of ecological integrity which are paramount to a limnological evaluation of water quality. A computer software application is being developed that should considerably ease the analysis process, resulting in a modern, user-friendly, flexible and scientifically sound tool for environmental quality assessment and monitoring.

The loose-leaf folder format has been chosen to allow updates and extensions as our ecological knowledge of benthic organisms expands. We cordially invite the scientific community to make contributions and provide constructive criticism to the catalogue in order that it remains current and, ever improving in both its comprehensiveness and utility.

In addition to the catalogue's function as an assessment tool, the species lists contained herein provide the most accurate, up-to-date, and comprehensive inventory of the known Austrian macrozoobenthic fauna. Considering the ciliates, the Bavarian fauna is included as well. We have additionally strived to sort through all the ambiguities in the scientific nomenclature in order to provide the most authoritative list of species names including the citations in which the species was first described. This provides an extraordinary taxonomic reference catalogue for the interested scientific audience

2. Comments on the genesis of the catalogue

The initiation of the saprobic system as a classification tool for water quality in central Europe reaches back more than 150 years into the time of cholera epidemics. Despite the relative simplicity of the saprobic methodology, and the heuristic summaries and descriptions provided by LIEBMANN (1951) and SLADECEK (1973), nearly every group of practitioners developed their own strategies of field sampling, laboratory procedures and analysis. This led to a lack of uniformity in defining water quality classes and a nearly uncontrollable number of saprobic indicator lists, complicating for a quite some time any effort towards a comparative compilation. While the methodology and water-quality classes are becoming standardized, species indicator lists with generally accepted saprobic "valences" or rankings are still lacking. The governmental water assessment offices in each state district use their own lists, whose classifications differ considerably from each other, seemingly without reason. Despite the new DIN-procedure for biological examination of water quality (FRIEDRICH 1990) the situation in Germany is similarly complicated.

Therefore, during the 1988 SIL-Austria annual meeting in Kühtai, a large group of limnologists under the auspices of Univ. Prof. Dr. Roland Pechlaner, decided to unify the lists of Austrian indicator species and to entrust Univ. Doz. Dr. Otto Moog with coordinating this effort. A work group which had been formulated at the SIL-congress could no longer cope with this immense and work intensive task on a voluntary basis. In the course of the water quality improvement decree, the unification of analytical methodologies for biological water quality investigations proved to be both necessary and inevitable. On these grounds, in 1992, Section IV of the Federal Ministry of Agriculture and Forestry authorized the formation of a work group "benthic river ecology". The contract was given to the Department of Hydrobiology, Fisheries and Aquaculture at the University of Agriculture, Forestry and Renewable Natural Resources (BOKU), to compile a classification catalogue of benthic macroinvertebrates in Austria with regard to: (1) special saprobic indices, (2) affiliation with feeding guilds, (3) distribution of longitudinal zonation within "biocoenotic regions" (ILLIES and BOTOSANEANU 1963). In 1994 Univ. Prof. Dr. Wilhelm Foissner was authorized to compile a similar catalogue on ciliates. Phytobenthic indicators are presently be worked on as well by Univ. Doz. Dr. Eugen Rott.

3. The need for a cogent methodology in water quality assessment

Water, once a seemingly unlimited renewable resource, is in direct need of protection and conservation, as aquatic environments are now among our most endangered habitats. Efforts to preserve aquatic habitats and to develop a modern, environmentally-sound manner of managing aquatic resources, rely heavily on water-quality assessment. In order that planners, developers, politicians, and most importantly the general public, can understand the quality of our environment, how it is changed by our actions, and how it can be protected and sanely managed, a feasible, and broadly applicable methodology must come into force. A fundamental step in developing systematic, uniform, and scientifical protocols for environmental quality assessment is a definition of goals. What is clean water? What is a high quality environment? And what can we realistically achieve in terms of the sensitivity of our monitoring efforts in defining the multitudinous complexities of an ecological community? In Austria, the definition of these assessment goals has its important philosophical and legal foundation in the concept of "ökologische Funktionsfähigkeit" which can be roughly translated in ecological integrity, a term introduced in the United State in the late 70thies (CAIRNS 1977; FREY 1977; KARR and DUDLEY 1981). The new and progressive Water Law of 1990 stated that the maintenance of ecological integrity was in the public interest. A theoretical definition of ecological integrity can be expressed as - the maintenance of all internal and external community processes and attributes, interacting with their environment in such a way that the biotic community corresponds to the natural state of the relevant aquatic habitat, and, where the community is preserved by regulation, resilience, and resistance to environmental stress. Hence, the conservation goal is the maintenance, to the degree feasible, of ecological integrity; the methodological challenge is then to find measurable indices that reflect degrees of, and changes in, the natural characteristics of a community and its ability to perform ecological functions. The demand is for a system-level methodology to assess the health of ecological communities and to determine the environmental factors which are responsible for altering this health. The ecological community, however, is among the most difficult entities to measure, define and understand. So, while the concept is attractive, and nearly everyone agrees that our goal is to preserve the integrity of the community, its complexity confounds attempts of singular and concise measurements that elucidate the environmental factors or disturbances which are responsible for deleterious alterations. To approach this problem we must begin with some species-level concepts.

4. Autecological concepts in bioindication methodology

Ecology is the study of organisms and how they interact with both each other and the environment in which they live. Many physical characteristics of the environment have direct influence on, and to a great degree determine, the distribution, abundance, and behavior of individual organisms and the populations to which they belong. The study of how an individual species responds to its environment, or moreover, specific characteristics of the environment, is termed autecology. While it is both the summation and the synergism of interactions between each member of a community and important aspects of the physical environment that constructs an ecological community, and it is the integrity of the community which we must ultimately monitor and maintain, autecological mechanisms are the building blocks and more importantly the epistomologically obtainable components of ecological integrity with which one can build a scientifically valid methodology. Environmental stress, considered here of only anthropogenic origin, can "cause" disruptions in ecological integrity; but the first or primary "effect", is on autecological relations. However, again, there is a fundamental problem. Mechanisms and responses between organisms and the environment are numerous, perhaps infinite. So, while individual mechanisms and interactions are, in principle definable and measurable, it is impractical to measure all but a handful. It is here that we turn to the use bioindicators; these are species that interact with "key environmental factors" which result in observable and characteristic responses that alter both the makeup and the ecological function of, a particular community. We emphasize species as opposed to higher taxonomic groups, as the authors of this catalogue strongly agree that most higher taxonomic groups are either too heterogeneous in their response to environmental stress or lack the useful sensitivity that individual species have to environmental factors. Many assessment programs are based on the use of higher taxonomic groups as indicators, a practice from which we strongly dissent.

The primary physical characteristics or "key factors" which influence aquatic organisms are temperature, oxygen content, the current-substrate relation, nutrient composition and availability, and habitat structure or cover. Within the biologically relevant range of these factors are minimum and maximum values between which each organism can be found. For our methodological purposes this range between the minimum and maximum values will be called the "amplitude". The ecological importance or "valence" of each factor will be determined by the amplitude as well as the position and width of various qualitative optima. The reaction of an individual or population - generally measured in some term of abundance - to a factor gradient can be shown with a uni-modal curve on which the highest point is considered the optimum. From this optimum an optimal area can be formed which reflects the ideal conditions within which a relatively stabile population of an organism is insured. This graphically depicted area - with a few exceptions - defines the tolerance region that each organism has for a factor; the abscissae define the minimum and maximum values. Within this tolerance region various sub-regions can be defined that depict the conditions in which various levels of the biological potential of an organism can be realized. Near the minimum and maximum values the mere survival of an individual is possible, for example, through diapause or other forms of dormancy. Beyond these marginal conditions is a zone of tolerance wherein all physiological demands, concerning nutrition and respiration etc., of the organism are met, but, reproduction is not possible due to some environmental hindrance on the reproductive cycle. The optimal area defines the conditions that provide for the full reproductive potential of an organism.

The temporal and spatial distribution of an organism is tightly connected to its physiological responses to varying levels of environmental factors. If these responses are known, than the distribution of an organism can be used to indicate the magnitude of these environmental factors. This applies to the herein described factors which were estimated based on the average distribution of organisms. Hence these organisms are called bioindicators. The calculation of a factor’s valence for each individual species was based on the allocation of a 10-point scale, comparable to the ZELINKA-MARVAN method (1961).

Not all environmentally-based responses are bell shaped and a multifactorial response curve for an organism’s ecological potential has different properties. For instance, a passive response to resources such as plant nutrition follows the Michaelis-Monod-Kinetic. If the tolerance for a factor at some particular level is approximately zero, e.g. involving a toxic substance, the response curve obeys an all or nothing principle: a range of neutral response over low levels of the inhibiting or toxic agent is followed by a short range of tolerance up to a threshold, beyond this threshold the organisms response ranges from simple avoidance to mortality. These points concerning ecotoxicology are covered in KOLLER-KREIMEL (1989).

The ecological potential of particular species across varying environmental factors is very often unknown and even with well understood species, it is often impossible to measure in the field, especially considering all the spatial and temporal distributions of all relevant factors. It is therefore necessary to fall back on the few, well researched factors, in order to most efficiently transfer existing knowledge into applied practice. The environmental factors used here, in conjunction with the practice of a bioindicator-based water-quality assessment are defined by MOOG (1991; 1993 a; 1994) and in the AUSTRIAN STANDARDS M 6232 (1995).

5. General ecological factors affecting aquatic organisms

In addition to the key factors - water temperature, flow velocity, oxygen balance and food composition and availability - there are other abiotic and biotic factors which will not be covered within this system, such as climate, geology, topography, physical-chemical conditions, discharge, discharge regime, habitat structure, and competition. Because the fauna depends upon the primary productivity and this productivity in turn depends upon light, the incidence of sunlight must additionally be considered in any monitoring methodology. While the factors not specifically covered are of immense importance in determining which species are present and in what percentages they occur in a particular body of water, many are not relevant to assessment issues as they are not altered by man’s activities; the sum of their effects must in any case be incorporated into the formulation of a reference state under site-specific conditions. This ideal or "Leitbild" is an important component of the modeling concept as it represents the undisturbed reference conditions against which all community descriptions will be compared. This concept helps define what the expected community should look like, within a hierarchical model that includes knowledge of the ecoregion, geomorphological landscape, the altitude-latitude determined vegetation zone, the stream order, the longitudinal and latitudinal zonation within a stream, and a meso-, or even micro-habitat typology. The methodology used within this catalogue to define a reference condition, considers all of these typological characteristics excepting for habitat. Some realism is included in defining the ideal community; reference states, whenever possible, are constructed from existing sites within a particular river or catchment area and thus to some degree include the moderate historical influences that man has had on the aquatic environment.

Even by reducing the analysis of community integrity to a handful of key-factors and the functional responses of species to these factors, it is still not practical to obtain enough information on these individual responses and most importantly the multi-factorial effect that they have on a community. We therefore need a group of empirically derived, response characteristics, which can be measured and do indeed reflect meaningful variations in the key-factors.

The community’s response to the combined effect of many single factors can be approximated in the form of indices which evaluate the saprobic conditions, longitudinal distribution patterns, and functional-feeding guilds. The saprobic index primarily represents the state of oxygen balance in the system as well as the presence of fine particulate organic matter (FPOM); the functional-feeding-guild classification allows a statement concerning nutrient availability and the dominant bioprocessing functions of the community; the longitudinal zonation, based on the concept of uni-directional spatial succession within river systems, corresponds to temperature, nutrient cycling, and to some degree the relation between current velocity and substrate. Thus we have empirical tools for 3 of the 4 key-factors adequately covered, with the current velocity and substrate partially represented. The fourth index required to insure that variations in the current/substrate relation are sufficiently accounted for would be a habitat typology. These indices contain the desired information and most importantly, degrees of response to multi-variate environmental factors. The use of these indices allows a statement about the worth, or ecological integrity of the benthic invertebrate community.

We began by stating our system-level goal of monitoring the influence of environmental factors on the integrity of an ecological community but point out that the complexity of community-level functions challenges attempts to directly measure the relation between the environment and the community. Autecological relations, i.e., the interactions between individuals and specific environmental factors, are clearly the tangible components of the puzzle and, closer to the causes of community disturbance, but again, the enormous number of these interactions defy their practical use. Therefore, we use a set of empirically-derived relationships which have proven to represent not only many of the most important factors in autecological relations but also a community-level response to these factors. In essence the logic is to some degree indirect and circular, for we construct community-level indices from a multitude of autecological valences, constructed from theoretical species-level reactions to environmental stress; in the end it is the whole community's response to environmental stress which we wish to understand. But the logic is supported by our theoretical and empirical understanding of the autecological relations which we use to construct the community-level indices, and more importantly by extensive field testing that supports the assumption that our empirical observations do indeed represent the response of specific stresses on the integrity of a community.

6. Key factors

Temperature

It is well known that temperature has an important effect on the intensity of metabolic activity as well as most other biological processes of aquatic organisms. Temperature is also of decisive importance for the occurrence of specific organisms in an environment and hence can determine the composition of a community. While mean temperatures and temperature sums (degree days) are of some importance, it is primarily the temperature range or extreme values which largely determine the suitability of a site as habitat for a particular species. Both the optimal and the tolerable temperature ranges for some benthic organisms or their specific life-stages i.e., egg, larvae, pupa, and adult, are already known and can be used in assessing some temperature related problems.

To a large degree the temperature data used in this catalogue has been extracted from the literature. There have been adequate summaries and reviews of this topic as it relates to fish communities (COUTANT 1977; BUTZ 1985) but presently the scientific knowledge is insufficient to offer a useful model for temperature related analyses of entire benthic communities. Until more autecological information is available the use of temperature in macrozoobenthic-based assessment strategies is limited to the knowledge gained from empirical distributions of organisms across the largely temperature-determined biocoenotic regions.

The details on the relationship between amplitude, water temperature, and stream zonation have been provided by MOOG and WIMMER (1994).

Oxygen

The response of macrozoobenthic organisms to oxygen concentration is relatively uni-directional as their distribution is never limited by increasing oxygen saturation and, only rarely is oxygen supersaturation considered injurious to organisms. Accordingly, evaluating oxygen-dependent distributions is limited to determining an organism's sensitivity to low-levels of oxygen particularly in regards to their ability to recover from extremely low oxygen concentrations. Organisms that are the most sensitive to oxygen deficiencies are those with thick skins and no gills (many plecopteran larvae) or immovable gills (ephemeropteran larvae of the genera Eporus, Rhithrogena etc.). The swift oxygen-rich currents which these species are dependent on can at the same time be stressful for anoxic-tolerant organisms such as sludge worms of the family Tubificidae, and midge larvae of the genera Chironomus and Chaoborous. Benthic organisms which live independently from a water's oxygen content are those which, have respiratory tubes (e.g. rat-tail maggots), exchange gases at the water's surface (water bugs and pulmonate molluscs), or live within their own oxygen filled webs (water spiders).

While many individual scientific publications contain detailed information on the saprobic theme there is yet no practice-oriented synopsis or review. For routine monitoring, knowledge of saprobic conditions can reveal the effects of organic load and decomposition on the oxygen content of the environment. Although the oxygen content alone is insufficient in describing the saprobic conditions it is nevertheless an important factor in discriminating water-quality classes. Organisms which are insensitive to oxygen conditions (rat-tail maggots) can also be very useful indicators for poor water-quality classes such as GK[1] IV. Proliferate occurrence of tubificids and Chironomus larvae indicate GK III-IV; frequent occurrence of water-asellus and leeches such as *Erpobdella octoculata* can indicate GK III; and many organisms without gills are found in GK I.

[1] GK refers to "Güteklasse" a rating system of water quality.

Nutrients

Practical knowledge concerning trophic-relations, food chains, fodder quotient, and essential nutrients is readily available. The analysis of the distribution of functional-feeding guilds (chapter 7.5) permits a relatively dynamic view of nutrient state of a particular river site. Functional-feeding-guild analysis must not only consider point or static changes in the biocoenotic zonation of the reference state but natural temporal variation as well, that is, both the spatial succession along the stream's course and, the temporal succession of individual sites. For example, theoretical guild distributions - such as those derived from the River Continuum Concept - should be compared to actual guild distributions along a river, taking into account stochastic or seasonal physiographic conditions (fallen leaves, algal growth, etc. (MOOG 1993a; MOOG and GRASSER 1992b; SCHWEDER 1992)). In this way, seasonal changes or inputs such as algae blooms or the sudden organic input of leaf-fall in autumn are considered normal components of the nutritional spectrum.

Current and substrate

The importance of current velocity in determining the occurrence and distribution of aquatic organisms can not be overstated (PEETERS et al. 1994). The optimal current velocities typically vary for each species and their specific life stages but as of yet are largely unknown, again, due to the lack of autecological investigations. Nonetheless, the work of STATZNER and HIGLER (1986) has demonstrated the importance of current patterns close to the substratum for aquatic organisms and subsequently several useful models have been developed, particularly the "FST-hemisphere-method" (SCHMEDTJE, KOHMANN and STATZNER 1991). SCHIB (1991) and LAMOUROUX (1992) have simplified that FST methodology and an up-coming book produced by the Bavarian department of water engineering contains flow velocity preferences of various benthic invertebrate species including different life-history stages (SCHMEDTJE 1995).

Such methodologies and autecological data bases should prove to be excellent tools for the applied practitioner in assessing potential or realized environmental impacts of river engineering projects. There are upper tolerance limits for some species above which they are simply washed away; other species display unique behavioral changes at flow below their optimum, for example, some net-spinning caddis flies leave their cases at current velocities below 0.3 m/s in order to feed themselves rather than feeding off the collected prey of their nets. Such autecological knowledge is useful, e.g. in determining the effects of hydro-peaking surges or in the setting of minimum flow requirements.

The habitat or substrate structure requirements of benthic species can also be in themselves extremely important but also important in how they relate directly to flow velocity. Although many substrates are primarily formed concomitant with river-bed formation they nevertheless directly reflect the present flow-velocity conditions due to the dynamics of aggregation, degradation and tractive forces. Strong evidence exists for typical, substrate-specific faunal assemblages.

7. Community classification and its practical uses

Similar to the categorization of terrestrial vegetation assemblages, where it is rare that the occurrence of a single character or diagnostic species determines a community type, in running waters the presence of several member organisms is necessary to define a macrozoobenthic community. An ideal classification of macrozoobenthic communities, would utilize all of the species present in making a determination. The more species that are included in an assessment methodology, considering the incomplete autecological knowledge of so many species, the more likely the model will become both quantitatively powerful and increasingly sensitive to the full range of possible environmental influences.

7.1 Species inventory

The foundation of any community-level analysis is the description of the species composition and the physical habitat in which they are found. In ecosystems uninfluenced by man, the species composition is the result of zoogeographic history and both individual and community-level responses to the natural spectrum of environmental influences. Anthropogenic interference in these systems can alter the species spectrum. The elimination of autochthonous species, or the colonization of species exotic to a site-specific community, are seen as negative alterations of a community's ecological integrity. One way of assessing the damage that such alterations have on a community's integrity is to determine to what extent the original species spectrum can recover; this ability to recover is traditionally referred to as the resilience of a community. Whether a community recovers from stress on its own or with the help of man, the process can be monitored. The immigration or reintroduction of species can be evaluated to determine a species' ability to establish viable, stable, self-reproducing populations. When such populations are self-sustaining than the integrity of the community has been, in principle restored.

The following assessment methods are based on the species spectrum as a criterium for evaluating the ecological integrity of a site-specific community. The species list used for comparison is derived from the "ideal" or expected site-specific reference state. A complete species spectrum is indication of an undisturbed ecosystem.

7.2 Dominant structure

The species-dominance structure of a community is a reflection of the natural state of equilibrium between species and the total number of individuals; and hence the manifestation of the species spectrum under present conditions. The structure is naturally influenced by the site-specific conditions which themselves vary temporally due to the seasonal succession of both the flora and fauna (developmental cycles) and are subject to modification by numerous stochastic variables. Thus, the analysis of this structure is not useful without knowledge of a reference community including its natural variability. When an uninfluenced reference stretch is not available than the ecological integrity can be assessed by concentrating on dominant representatives of each biocoenosis.

7.3 Abundance

Species abundance is the area-related frequency of individuals or their biomass, and can be used to show the balancing, promoting or hindering influences that a specific site has on a species' population. Abundance is an important assessment tool wholly separate from the species spectrum; atypically high abundances can increase a system's biological oxygen demand and atypically low abundances may prohibit an assemblage of organisms from performing community-level functions. These disturbances of the ecological integrity can occur without any change in the species spectrum of a particular assemblage. For instance, an increasing saprobic load can directly result in increased abundances and an increase of substrate cover - by algae and macrophytes - that is often associated with an increase in the zoobenthic biomass, all resulting from increased nutrient load (eutrophication processes). Decreases in abundance may occur directly in hydro-peaking flush zones, or after toxic spills; and indirectly by reducing surface area through a host of river-engineering measures such as water abstraction, channel straightening, flood control dams, etc.

7.4 Saprobic valency; Description of water quality classes in flowing waters

Each water quality class has a corresponding saprobic state that is based on the amount of decomposable, organically-rich material present. Because organisms do not clearly fall into one water quality class or another, the proven saprobic system of ZELINKA and MARVAN (1961) was called into use. This system essentially allots each organism a rank, or index of tolerance, for each of the five proposed saprobic states. This ranking, termed herein "a saprobic valence" reflects the tolerance an organism has for organically rich substances. Thus, a saprobic valency has a nutritional basis and represents the integration of an organism's membership in a particular functional-feeding guild and its oxygen requirements. Using the list of species caught in a site and their corresponding saprobic valencies, one can calculate a saprobity index for this site.

The following list assigns a water quality class to each of the 4 saprobic zones and a 5th so-called xenosaprobic zone.

ZONES	SYMBOL USED	QUALITY STATE	QUALITY CLASS
Xenosaprobic Zone	x	Fully clean water	O
Oligosaprobic Zone	o	Little to no influence	I
Beta-mesosaprobic Zone	β	Moderately influenced	II
Alpha-mesosaprobic Zone	α	Heavily polluted	III
Polysaprobic Zone	p	Extremely polluted	IV

The saprobic model of the various water quality classes can also be presented with verbal descriptions, even when, in special circumstances, all the analytical criteria are not available. Based on published information and the assistance of numerous specialists in the field, a synthesis of water quality class descriptions has been completed by MOOG (1991), the contents of which can be found in the AUSTRIAN STANDARDS M 6232. The word pollution should be understood in a relative sense, considering the natural longitudinal gradient in nutrient content along a river's course. This is especially true with quality classes I and II.

The following definitions are presented, because water quality assessment must be based on strict definitions of quality units. On the basis of generally understandable and acceptable verbal definitions of water quality classes, the often misleading overvaluing of inidces can be put into perspective. Due to the fact that a multitude of different definitions has been used in Austria as well as in the other European countries, the following synthesis of verbal descriptions of water quality classes has been conducted. These definitions are based on the national and international scientific literature, including the collaboration of many scientists.

DESCRIPTION OF WATER QUALITY CLASSES (SAPROBIC LEVELS) IN FLOWING WATERS DUE TO ORGANIC POLLUTION

A. Limnosaprobity

Water quality class I (oligosaprobic)
Degree of pollution: none to very slight
Mapping color: blue

Xenosaprobic level (degree of pollution: none)

The xenosaprobic river reaches carry clean, always clear (with the exception of glacier-fed brooks) and well-oxygenated water. Suspended organic matter is not detectable. The water is nearly free of natural organic matter. In the substrate no reduction phenomena are visible. The bed sediments are sparsely colonized by algae, mosses, planarians and other benthic invertebrates (predominantly insect larvae). This water quality class is mostly associated with springs or the upper reaches of extremely clear mountain streams which, due to the fact that their catchment area is made up of clean rock, carry very clear, clean precipitation and snow melt water. This unpolluted water quality class is accounted for but in assessment falls into the oligosaprobic water quality class.

Oligosaprobic level (degree of pollution: very slight)

The oligosaprobic level characterizes river reaches with clean, clear (with the exception of glacier-fed brooks), nutrient-poor water that is almost always, nearly saturated with oxygen. Only small amounts of suspended organic matter or bacteria are detectable. Even fine sediments (psammal, pelal) are always of a brownish or light color throughout and are extremely rich in minerals. No reduction phenomena exist. The substrate is predominantly colonized by algae, mosses, Turbellaria and insect larvae (in middle and upper reaches several plecopteran species occur). The fauna is usually species rich, but low in abundance. Chironomids are found in low abundance; mainly the periphyton-dwelling chironomids (Diamesinae, Orthocladiinae). Worms are generally represented by planarians and sensitive oligochaetes The moss flora is represented by several species, sometimes in high frequencies. Periphyton (predominantly diatoms and cyanobacteria) is visible almost exclusively due to its "coloring" Aufwuchs. Green algae are scarce, and do not stand out. Oligosaprobic river reaches with their corresponding availability of structure contain excellent spawning areas for salmonids and sculpins. This water quality class is associated with spring areas and the very slightly polluted headwaters of summer-cold rivers.

Water quality class I-II (oligosaprobic to β-mesosaprobic)
Degree of pollution: slightly polluted
Mapping color: blue/green

This transitional water quality class describes river reaches with little inorganic and organic nutrient content and, with the exception of glacier-fed brooks, clear water. The oxygen content is high. The concentration of suspended organic matter is very low. Fine substrates are of a brownish or light color throughout; the undersides of stones have no visible black reduction spots. Primarily, these reaches are in salmonid rivers, which are densely and diversely colonized by algae, mosses, Turbellaria, Plecoptera, Ephemeroptera and Trichoptera larvae as well as Coleoptera (Elmidae, Hydraenidae) and dipteran larvae.

Worms are generally represented by planarians, and sensitive oligochaets. Of the leeches (Hirudinea), at most *Dina punctata* and *Erpobdella vilnensis* exist in considerable quantities; net-spinning trichopterans appear only sporadically. The chironomids (predominately Orthocladiinae and Diamesinae) are slightly more numerous than in water quality class I.

Water quality class II (β-mesosaprobic)
Degree of pollution: moderately polluted
Mapping color: green

This water quality class is found in river reaches with moderate organic pollution, increased nutrient content and still a good oxygen supply (despite possible oxygen supersaturation or depletion). The water in middle and higher reaches is usually clear and at most contains a low amount of suspended organic particles. In lowland rivers the suspended solids can increase due to natural processes. The sediment is light or dark, but not black, and is often slippery due to algal growth; the undersides of stones are not colored with black reduction-spots. Processes of biodegradation take place in aerobic areas. Reduction phenomena occur only occasionally, here and there, in lentic sites of potamal waters (e.g. backwaters).

Species diversity and abundances are very high for nearly all animal groups in addition to algae (all groups) and other aquatic plants. The percentage of individuals and the taxon diversity of Chironomidae further increases (predominantly Orthocladiinae, in quietly flowing reaches Tanytarsini and Chironomini). The net-spinning trichopterans are usually numerous only where suitable current velocities are available; whereby Polycentropodidae can appear in large quantities in potamal regions. Macrophytes can cover areas but usually green algae (Chlorophyceae) do not yet appear in large quantities. These rivers yield high numbers of fish of various species.

Water quality class II to III (β-mesosaprobic to α-mesosaprobic)
Degree of pollution: critically polluted
Mapping color: green/yellow

This transitional water quality class contains river reaches whose load of eutrophicating nutrients as well as organic, oxygen-consuming substances is clearly visible. Because of the heavier load of organic matter, the water is in certain circumstances slightly turbid. In localized lentic areas, under large stones, sludge may occur. Fine-grained substrates are brown or light colored at the surface, and in deeper areas sometimes dark (chemically reduced). Black spots can appear beneath stones. In certain circumstances, and with sensitive species or life-history stages, fish kills are possible due to strong fluctuations in the oxygen budget.

The diversity of macro-organisms is sometimes reduced and certain species show an abnormal tendency toward mass development. Macrozoobenthic colonization occurs by sponges, moss animals, crustaceans, molluscs, leeches and insect larvae (with Plecoptera only certain species of the genera Leuctra, Nemurella and Nemoura). Leeches clearly increase. Among the oligochaets on occasion Naididae occur in large quantities. For the first time, Tubificidae occur in remarkable numbers. Net-spinning trichopterans (predominantly Hydropsyche) often appear in large quantities as well as chironomids, especially tunnel-building forms in the fine sediments. In addition to the tolerant Orthocladiinae and Diamesinae, in the psammal the Prodiamesinae stand out; in the pelal the Chironomini (mainly Polypedilum), and Tanytarsini (mainly Micropsectra).

Filamentous algae (e.g. Cladophora) and macrophytes frequently form stands covering large areas, or, develop as mass colonies. Green algae are more abundant than in water quality class II. Sewage bacteria may often be seen as tufts with the unaided eye, but are not yet outstanding. The most diverse group is the ciliates but colonies of ciliates that can be seen with the unaided eye, on hard substrates and living benthic organisms, are rare. Usually, these river reaches still produce high yields of fish.

Water quality class III (α-mesosaprobic)
Degree of pollution: heavily polluted
Mapping color: yellow

Water quality class III is found in river reaches that contain heavy organic, oxygen-consuming loads and usually large oxygen deficits. The water is partially colored or turbid as a result of suspended matter from sewage discharge. In lentic areas, sludge is deposited. Stone, gravel, and sandy substrates usually display blackened spots of ferrous sulfide. In lentic areas, nearly all the undersides of stones can be strikingly black colored. Fine-grained substrates are often slimy, in deeper areas black and sludge-like. The fish population often is reduced due to disrupted reproduction; periodically occurring fish kills can be expected. Only a few benthic invertebrates which are tolerant to oxygen deficiency, such as sponges, leeches and aquatic isopods can occur in large quantities.

Among the worms, Tubificidae dominate, and to some degree Naididae, Enchytraeidae and the genus Lumbriculus. Besides euryoecious Orthocladiinae, the groups of Chironomidae that most often appear are Tanytarsini and Chironomini. Net-spinning trichopterans are strikingly more scarce than in the preceding water quality class and it is often difficult for the critical pupal stage to survive. The typical ciliate-community is composed of *Trithigmostemometum cucullulae*. Colonies of sessile ciliates (Charchesium, Vorticella), can be clearly seen with the unaided eye as well as filamentous sewage bacteria and -fungi (e.g. Sphaerotilus, Fusarium and Leptomitus) which grow on hard substrates and living benthic organisms. Filamentous green algae found in the preceding water quality class are mostly substituted by Stigeoclonium; sewage-tolerant, blue-green algae; and diatoms which sometimes cover large areas in lentic locations. Sewage-tolerant macrophytes are still able to grow in masses.

Water quality class III to IV (α-mesosaprobic to polysaprobic)
Degree of pollution: very heavily polluted
Mapping color: yellow/red

The river reaches of this transitional water quality class, to a large degree, provide limited conditions for life due to the very heavy loading of organic, oxygen-consuming substances. Occasionally anoxic conditions prevail; the water is often colored and extremely turbid due to suspended matter from sewage discharges and drifting tufts of sewage bacteria; the river bottom is mostly covered with sludge. Fine substrates in deeper areas are nearly black throughout, sludgy, and occasionally release a clearly detectable odor of hydrogen sulphide. In lentic areas nearly all undersides of stones are blackened. The most extensive sludge deposits in lentic areas are densely colonized by larval chironomids of the genus Chironomus, tolerant Tanypodinae, tubificid worms, and Enchytraeidae (e.g. Lumbricillus). In hard substrates leeches can be found; the accompanying fauna is composed of euryoecious species.

Compared to water quality class III the algal cover is reduced in both qualitative and quantitative terms. In lotic sites, blooms of filamentous, sewage-bacteria occur (typical "sewage fungus-development"), and sulfur bacteria can form striking macroscopic layers. The microbenthos mainly consists of ciliates, flagellates and bacteria, which often show mass development. The existence of a self-sustaining and balanced fish populations are no longer possible.

Water quality class IV (polysaprobic)
Degree of pollution: extremely polluted
Mapping color: red

Water quality class IV is found in river reaches with extreme loading by organic, oxygen-consuming sewage. The water is often colored and extremely turbid due to the suspended matter of sewage discharge and sewage bacteria. The river bottom is usually characterized by heavy deposits of sludge. In lotic sites nearly all the undersides of stones are covered with large black patches of ferrous (II) sulphide; in lentic areas both sides of stones are totally black. Fine substrates are totally black. Processes of putrefaction predominate, and there is often the odor of hydrogen sulphide. Oxygen concentrations can be very low, or occasionally, anoxic conditions occur. Colonizers are predominantly bacteria, flagellates and bacteriophagous ciliates which often develop in masses. The typical ciliate-community is *Colpidietum colpodae*. The filamentous sewage bacteria are less abundant than in the preceding water quality class. Sulfur bacteria reach their peak abundance and form clearly-visible lawns. Compared to water quality class III the algal cover is reduced in both qualitative and quantitative terms. Besides a few chironomids (*Chironomus riparius*-agg. and *Chironomus plumosus*-agg.) and individual tubificids, the macrofauna is only further represented by air-breathing forms (e.g. mosquito larvae, moth flies, soldier flies and syrphids).

B. Eusaprobity (according to FOISSNER et al. 1995):

Degree of saprobity	Quantity of organisms/ml and community (c.)[1]	Examples	Technological standpoint; treatment	Hygienical standpoint
Isosaprobity (i)	Ciliata 10-50 000 Flagellata 1000-20 000 (Amoebia 0-1000) Bacteria in mass (Fungi in mass) *Euglena-c.*	Raw sewage; less than 1 ppm H_2S	Biological oxidation treatment (biofilters; activated sludge; irrigations; oxidation ponds) applicable with or without mechanical pretreatment	Great danger of infection by pathenogenic germs
Metasaprobity (m)	Flagellata 5000-300 000 Ciliata 0-5 Bacteria in mass *Thiotrix nivea-c.* *Beggiatoa-c.* Chlorobacterium-c. Rhodobacterium-c. *Bodo-c.* Bacterium and *Bodo-c.*	Septic sewage; waters containing much H_2S (less than 100 [1000] ppm)	Before application of biological oxidation processes the wastes have to be aerated (hydrogen sulphide)	Great danger of infection by pathenogenic germs; also toxic compounds present
Hypersaprobity (h)	Bacteria in mass Fungi in mass Flagellata 0-5 Bacterium-c. (= coprozoic zone)	Concentrated industrial wastes; digestion of sludge; less than 10 ppm H_2S	Anaerobic treatment; lagooning; before application of oxidation processes chemical treatment inevitable	Danger of infection by pathenogenic germs and of poisoning by ptomeins of some cases
Ultrasaprobity (u)	Bacteria 0-10 (Fungi 0-10) abiotic	Industrial liquids; sulphite liqour; beet-sugar process wastes; 0 ppm H_2S	Anaerobic treatment; chemical treament and/or dilution are suppositions for further aerobic biological treatment	Spores of pathenogenic germs can be present

[1]: communities according to FJERDINGSTAD (1964)

7.5 Functional-feeding guilds

Analysis of functional-feeding guilds provides a perspective of the dynamic ecological relations between construction, reconstruction, and mineralization processes. These processes flow uninterrupted in a steady-state equilibrium within a longitudinal section of a river, encompassing the biochemical cycles responsible for the chain of events ranging from assimilation to respiration. Because these processes in running water occur on the channel bed and within the interstitial zones, they are difficult to detect. A functional-feeding guild distribution offers a method of indirect and empirical assessment of these processes. A shift in the equilibrium state of a river-type, from one governed by production to one dominated by decomposition, would indicate a disturbance, and this disturbance would be reflected in compositional changes in the feeding guild structure (SCHWEDER 1992; KOHMANN et al. 1993; MOOG 1993 a, 1994).

The feeding habits of organisms allows for their classification based on what they consume and accordingly, the role this consumption plays in the ecological integrity of a community. The following classification is based on modifications of CUMMINS (1973, 1974), CUMMINS and KLUG (1979), MERRITT and CUMMINS (1984).

FEEDING TYPE	ABBREVIATION	SOURCES OF FOOD
Shredders	SHR	Fallen leaves, plant tissue, CPOM
Grazers	GRA	Epilithic algal tissues, biofilm, partially POM
Scrapers, raspers)*		Endo & epilithic algal tissues, partially tissues of living plants
Filtering collectors		Suspended FPOM, CPOM, prey
active filter-feeders	AFIL	Food in water current is actively filtered
eddy filterers)*		Suspended FPOM, micro prey is whirled
passive filter-feeders	PFIL	Food brought by flowing water current
Detritus feeders (gathering collectors)	DET	Sedimented FPOM
Leaf borers, miners	MIN	Leaves of aquatic plants
Piercers)*		Algae & cells of aquatic plants
Xylophagous	XYL	Woody debris
Predators	PRE	Prey
Parasites	PAR	Host
Other feeding types	OTH	Cannot be classified into this scheme
Omnivorous animals		Diverse

*) Feeding groups must be calculated from the pool of types described above

The categorization of organisms into functional-feeding guilds is methodologically based on the morphology of mouthparts, feeding behavior, and food consumed. Autecological studies on the feeding biology of specific species are rarely available and hence the literature has been plagued with contradictory and partially false classification lists. This flawed information is also reflected in the fact that although there are many publications using the analysis of functional-feeding guilds, few if any reveal the methods used to classify the organisms.

In addition, the following circumstances often prevent the unambiguous classification of organisms into functional-feeding groups:

- Few species are obligate feeders on a specific food resource and many use and select a wide range of items.
- Certain organisms shift there diet during their ontogeny.
- Because some organisms are opportunistic feeders, unspecified nutritional requirements do not allow for a feeding guild classification.

The classification of an organism to a feeding guild cannot be accomplished simply through evaluating its anatomy or morphology but requires instead an integrated view of its ecological function within the community. The authors recognize that considerably more research is required to confirm and complete these classifications. Nevertheless, we have presented above an arrangement of species according to functional-feeding guilds; although the concept has been extensively used, outside of general descriptions given by MERRITT & CUMMINS (1984), only in a few isolated works have specifications of feeding guilds been provided. For further information on the topic see SCHWEDER (1992), SCHWINGSHANDL (1992), SCHÖNBORN (1992), LAMPERT and SOMMER (1993), SCHWOERBEL (1993).

When the frequency distribution of functional-feeding guilds of a particular zone deviates from the expected reference state, system functions have clearly been altered and thus the level of ecological disturbance can be addressed. When reference states are unknown a priori, they must be constructed based on the physiographic conditions of a site (leaf-fall, insolation, algal growth, and substrate distribution) or, for example, through the predictions of functional-feeding types found in "river concepts" like the "River Continuum Concept" by VANNOTE, MINSHALL, CUMMINS, SEDELL and CUSHING (1980).

The concept of the River Continuum for instance states that the physico-chemical conditions continually change as one follows the longitudinal course of a river and, biological components along this gradient are adapted to these conditions: the producer and consumer communities stand in dynamic juxtaposition, maintaining a steady-state equilibrium as the river alters it character over geomorphologic, hydrologic, and physiographic gradients. Corresponding to stream order, which generally depicts the size of a stream in terms of length, width and discharge, the authors have defined three limnologically distinct reaches.

upper reach i.e., springs	1-3 (4) stream order
middle reach i.e., small streams	4-6 (7) stream order
lower reach i.e., big rivers	from 7(8) stream order

The classical concept of VANNOTE et. al. (1980) begins with potentially shaded headwaters of a river system and postulates a sequence of corresponding river types:

- The upper reach is under the strong influence of its surrounding vegetation. The vegetation canopy restricts the input of sunlight and thus limits autochthonous production. The high input of coarse particulate organic matter (CPOM) results in a benthic community dominated by representative shredders, subsequently followed by detritivores, and finally filter feeders of ever finer particles. The feeding guild distribution in unshaded headwater reaches does not correspond to this system, but is more closely associated with the physiographic situation. Upstream from the tree-line these reaches are normally dominated by grazers and detritivores.

- Along the middle reach of the river, the influence of riparian vegetation decreases while there is a steady increase in primary production. Grazers, raspers, scrapers, filterers and likewise detritivores become increasingly important as the importance of shredders declines.

- The lower reaches of rivers accumulate the FPOM that was produced upstream. Filter feeders reach their dominance at the interface between stream order 6 and 7, after which sediment-inhabiting, detrital feeders dominate the faunal assemblages.

The individuality of a reach of river can not be described with such a singular and simple concept. The development of Serial Discontinuity Concepts arose to explain the clearly observed interruptions in the longitudinal gradients of a river system (WARD and STANFORD 1983, 1995; STANFORD, HAUER and WARD 1988). And accordingly, "Patch dynamics" considers the heterogeneity and distribution of sediments along a river’s cross section which along upper, middle and lower reaches of a system display a varying dynamic in spatial and temporal scales (PRINGLE et al. 1988). A profound and constructive criticism of the River Continuum Concept has been widely embraced by the scientific audience (STATZNER and HIGLER 1985). Besides several other concepts contribute to our knowledge about riverine systems and their dynamics: the concept of serial discontinuity, the flood-pulse-concept (CASTELLA et al. 1984), the conectivity concept (JUNK et al. 1989) and others more.

These concepts are to a degree insufficient in accounting for the observed spatial and temporal discontinuities in a river system, but nonetheless offer useful thinking models that allow one to intelligently conjecture on the mechanisms which create a natural river’s complexity. SCHÖNBORN (1992) personifies these concepts when he writes "a river is a highly elastic continuum, which integrates its inherent discontinuities without interrupting the continuum. By first understanding the interplay between continuum and discontinuum, one can begin to develop an understanding of a what river ecosystem is".

Attempts to describe a succession of feeding types along the longitudinal river gradient have been made by the following authors: BENNISON (1975); MACMILLAN (1975); COLEMAN (1977) and analyzed by LAKE et al. (1988); CUSHING et al. (1980); CUMMINS et al. (1981); HAWKINS and SEDELL (1981); CULP and DAVIES (1982); MINSHALL et al. (1982); MINSHALL et al. (1983); MINSHALL et al. (1985 a & b); WILEY et al. (1990). MINSHALL et al. (1985a) described the longitudinal distribution of the feeding types along a 12th-order river and SCHWEDER (1992) presented a special method for the analysis of selected feeding types.
Investigations of feeding guild distributions in Austrian rivers between orders 1 and 4 resulted in an excellent correspondence with the River Continuum Concept (SCHWINGSHANDL 1992).

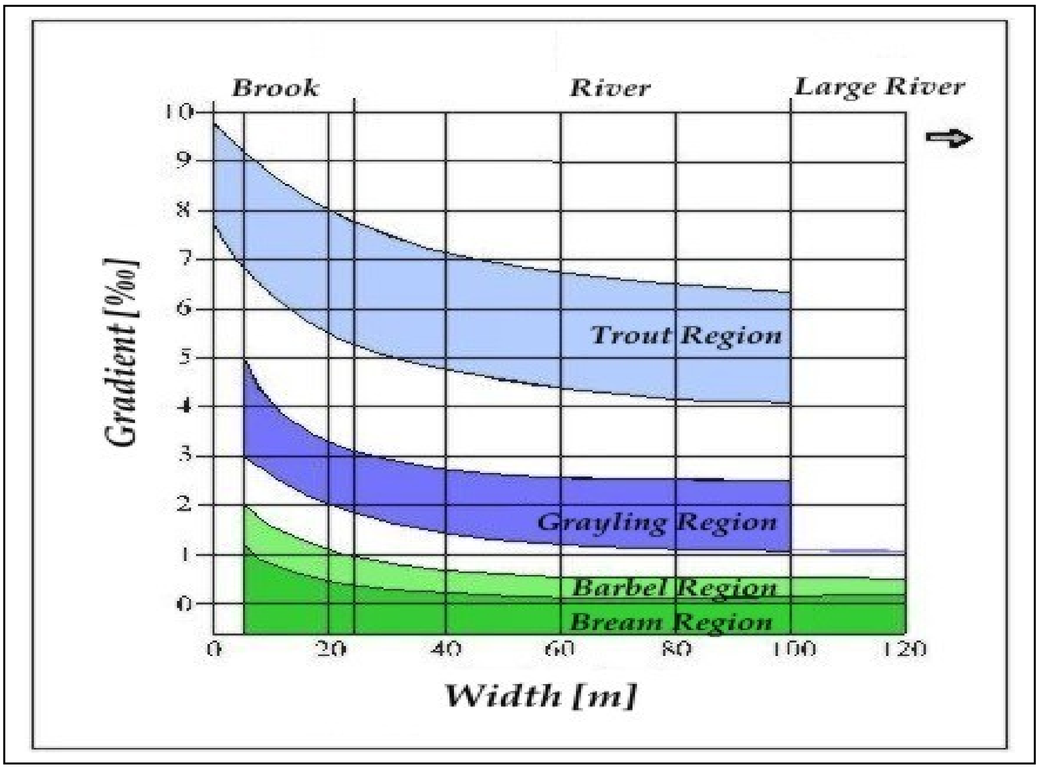
7.6 Stream zonation

A very sensitive method used to evaluate the stream zonation patterns of a river is based on the longitudinal distribution along biocoenotic regions of riverine organisms. This method is based on the fact that, along the longitudinal course of a river section, when legitimately-serial trends in physiographic and physico-chemical conditions change, typical zones are mutually removed. This is in essence a phenomena of spatial succession, driven by both physiographic and biological inputs, along the longitudinal gradient of a river.

This phenomena has been observed for almost 130 years and in Europe it has led to a subdivision of rivers into typical fish regions. Nearly 50 years ago, the German limnologist ILLIES expanded upon this notion and between 1952-1961 developed the concept of biocoenotic regions. The Rhithron-Potamon Concept is now a well known system within temperate biomes that not only covers the distribution of fish species but benthic organisms and abiotic characteristics as well. Among a couple of other distinctive abiotic characteristics the current (with its associated substrate size fraction) and the water temperature may prove to be the most useful abiotic indicators in distinguishing the longitudinal river zones.

As there exists various and partially incongruous models using water temperature for longitudinal distinction, a number of well documented Austrian rivers have been analyzed. MOOG and WIMMER (1994) demonstrated that the annual range of minimum and maximum, as well as, but to a lesser degree, mean summer water temperatures (July to September) are able to describe the different zones quite adequately; applying primarily the temperature ranges given in the table below.

In addition to temperature, the stream flow (or current velocity) is the second abiotic variable that dictates the biocoenotic composition of the aquatic fauna. HUET (1949) found that a general description of the current conditions of a river can be obtained by analyzing the gradient-width relationship. HUET's findings have been applied to Austrian rivers and were found to be a useful tool for the abiotic description of the biocoenotic regions with respect to current.



Gradient-width related zonation of the European fish fauna
(according to HUET 1949)

Further zonation has been made possible by considering the assemblages of the littoral and profundal zones. Littoral zone are the shallow shoreline areas and associated lentic sites, where the limnological dynamics are dominated by benthic processes. For the use of this catalogue, all faunal assemblages along the shoreline of a river, as well as in ponds, stagnant backwaters, swamps, etc., are classified as belonging to the littoral zone. Assigned to the profundal zone, are the organisms found on the bottom of lakes at depths greater than about 10 m, which for limnological reasons is influenced by the pelagic living environment. A review of the relevant literature and the methodology of identifying biocoenotic regions is covered in MOOG and WIMMER (1990, 1994), MOOG and GRASSER (1992 b), MOOG (1993 a), and JUNGWIRTH (1995). By comparing a reference stretch with the actual state of a succession in a disturbed system, some predictable patterns, or shifts in the longitudinal zonation can be seen. As examples in this text will demonstrate, channel straightening and the subsequent influence that these measures have on the sediment balance and organic inputs and residency time, often lead to the "rhithralization" of a community; whereas impounding, heating, retaining organic matter, and bed load suspension all lead to the "potamalization" of faunal structure. By this way the phenomenon as described in the serial discontinuity concept can be clearly demonstrated in a qualitative way (WARD and STANFORD 1983, 1995; STANFORD, HAUER and WARD 1988). A description of this classification system,

applicable to central Europe, is given below. Similar, though less well defined zonation patterns exist for other temperate regions.
The table below displays the biocoenotic regions, their corresponding dominant fish communities (ILLIES and BOTOSANEANU 1963) as well as the maximum and summer mean temperatures (MOOG and WIMMER 1994).

LONGITUDINAL DISTRIBUTION OF THE ZONES

Zone	Abbreviation	Region	Temperature	
			maximum	summer mean
Eucrenal Zone	EUK	Mountain spring	< 9	-
Hypocrenal Zone	HYK	Mountain stream	< 9	-
Epirhithral Zone	ER	Upper-Trout Region	< 9	5-10
Metarhithral Zone	MR	Lower-Trout Region	< 13	5-10
Hyporhithral Zone	HR	Grayling Region	< 18	8-14
Epipotamal Zone	EP	Barbel Region	≥ 20	12-18
Metapotamal Zone	MP	Bream Region	> 20	16-20
Hypopotamal Zone	HP	Brackish-Water Region	> 20	16-20
Littoral Zone	LIT	Lake shorelines, lentic sites, ponds etc.		
Profundal Zone	PRO	Lake bottom		

8. Ecological integrity

The ecological integrity of an aquatic system, though a holistic concept, is fundamentally based on the ability of all naturally occurring plant and animal species to maintain healthy, reproducing populations. The disruption of this integrity can be seen in quantitative and qualitative changes in the assemblage of species which can eventually lead to either the disappearance of naturally occurring species or the appearance of atypical ones. An acceptable and sustainable use of aquatic environments would not overburden the capacity of the system and hence the ecological integrity would remain intact.

The creation of the term ecological integrity and its use in jurisdictional documents has made the conservation and protection of aquatic systems legally binding. Moreover, it has drawn focus, both legally and scientifically to the industrial, domestic, and agricultural use of the landscape over which all precipitation falls. This precipitation collects both beneficial and harmful substances, and ultimately drains into aquatic environments. Judgement is passed on the acceptance of these primarily land-use practices, based on the effect they have in altering the deviation between the present conditions and the reference conditions of a site-specific flowing-water habitat. The degree to which alteration is tolerated is only descriptively put into law by a single term "wesentlich" - essential, important, fundamental, considerable, substantial etc., which would by itself defy practical application. To overcome this problem several authors have made suggestions on how to determine when alteration is "substantial" in the legal sense (CHOVANEC et al. 1994; MOOG 1994; SCHMUTZ and WAIDBACHER 1994).

8.1 A system of classification of ecological disturbance

Any attempt to classify levels of ecological disturbance into discrete classes with scientific meaning will be fraught with insurmountable difficulties. Nonetheless some level of classification must be attempted as it is unfortunately impossible for our current political-legal system to act upon descriptive information alone. Such a first step toward blending science and application has been put forth by CHOVANEC et al. (1994). The following list of 7 levels of disturbance, or disruptions in the ecological integrity of a community, provide a comprehensive rating that can be used as an administrative tool in the legal and logistic attempts to help progressively manage our aquatic systems.

LEVEL	ECOLOGICAL INTEGRITY
1	pristine
1-2	slightly disturbed
2	moderately disturbed
2-3	significantly disturbed
3	heavily disturbed
3-4	very heavily disturbed
4	completely disrupted

The most comprehensive characterization of ecological integrity reaches beyond our herein described community indexes and includes a multi-disciplinary perspective of what essentially amounts to the entire ecosystem. We list some of these various disciplines below and their currently used criteria to judge the disruption of ecological integrity. In viewing this list one must be careful not to overly confound causes, proximate physical effects, and finally community-level or ultimate effects on the ability of an ecological system to function. The ultimate effects are ultimate not only in that they are actualized at the community level but that they impart a change that hinders the system’s ability to recover to its natural state. The listed disciplines below investigate a multitude of factors that all have some influence on an aquatic system’s integrity but include a necessary mixture of causes, proximate physical effects, and community-level disturbances.

DISCIPLINE	CRITERIA USED	DESCRIPTION OF DISTURBANCE
Hydrology	Deviation from natural discharge regime, ground water retention	Verbal
Flood plain, river morphology and sediment load	Deviation from natural state	7 levels, verbal
River continuum	Deviation from natural state	Verbal
Physico-chemical situation	Federal emissions decree	Minimum border values
Toxicology	threshold values	Dilution factor
Macrophytes and algae	Deviation from natural state together with saprobic conditions for various species	Verbal 7 levels
Macrozoobenthos	4 judgement criteria	7 levels
Fish	3-4 judgement criteria	7 levels
Plants and animals of the riverine landscape	Deviation from the natural state	Verbal

8.2 Criteria to classify ecological integrity based on macrozoobenthic analyses

A proposal is set forth to define the variations in characteristics that would allow one to classify a reach of river within the above suggested 7 levels of ecological disturbance. The criteria used include the species spectrum and the dominance structure - including at least relative abundance - and 3 community-level response characteristics, namely the composition of functional-feeding guilds, shifts in the longitudinal zonation of biocoenotic communities, and the saprobity index.

Level 1: **Pristine -** The species inventory, dominance structure, abundances, longitudinal zonation and composition of functional-feeding guilds all conform to the site-specific reference state.

Level 1-2: **Slightly disturbed** - The species inventory conforms to the site-specific reference state but the dominance structure can deviate slightly. The abundances of individual species can likewise deviate either up or down from the expected conditions. The longitudinal and functional-feeding group distributions for the most part meet the ideal expectations.

Level 2: **Moderately disturbed** - The species inventory corresponds to the site-specific reference state but the occurrence of additional species is possible. The dominance structure is altered but, in form, resembles the reference conditions. The abundances of individual species can deviate considerably from the reference state. With some exceptions, seasonal deviations in the longitudinal zonation and functional-feeding guild distributions fundamentally resemble the reference state. A moderate flattening of the longitudinal zonation curve or a shift in the regions - not more than one region - can also be observed.

Level 2-3: **Significantly disturbed** - The species inventory is altered but generally comparable to that found in the site-specific reference state. The most sensitive species will not be found and the occurrence of unexpected species is possible. The abundances of individual species as well as the dominance structure of the community compared with the reference state is clearly altered. The longitudinal zonation curve does not conform to the reference state and a shift in regions - not more than two - is witnessed. An alteration in the composition of functional-feeding groups occurs though their natural relation is still maintained.

Level 3: **Heavily disturbed** - The species inventory is altered from that found in the site-specific reference state. Site-specific species disappear and unexpected species adapted to the altered conditions occur. The abundances of individual species do not conform to the reference conditions. Large alterations in the dominance structure are seen and the longitudinal zonation and the distribution of feeding guilds deviates from expectations considerably. The distributional curve is flattened considerably or its focal point is shifted up to two regions from the site-specific reference state.

Level 3-4: **Very heavily disturbed** - The species inventory is noticeably altered from that found in the site-specific reference state. Site-specific species disappear and species atypical to this site occur. The dominance structure is significantly changed and bares little resemblance to the reference state. Abundances of most species do not conform to the reference state. The longitudinal zonation and the composition of functional-feeding groups clearly deviates from the reference condition. Remaining assemblages may include animals and plants adapted to specific conditions promoted in unnatural habitats such as hygropetric animals on the walls of outflow channels and thermally tolerant fauna near heating or cooling outflows. The distribution curve of longitudinal zonation is extremely flat and scarcely reveals a known community.

Level 4: **Completely disrupted** - Few if any species are found that would conform to the reference state. Completely new assemblages, monocultures, and species especially adapted to extreme saprobic conditions may be all that is found. Accordingly, the dominance structure and abundances of individual species in no way corresponds to the reference state. The distribution curve depicting longitudinal zonation relates to no known natural community.

8.3 Fish fauna as an indicator of ecological integrity

Ecological integrity, in principal, is not a taxon-specific concept. The pristine or reference conditions in a particular body of water would contain not only all the expected macrozoobenthic organisms but the full spectrum of both aquatic and semi-aquatic species. The methods with which one evaluates a fish community are, partly by tradition and partly due to circumstance, different from the perspectives taken by a benthic biologist. The major advantage of using fish species is that the autecological knowledge, particularly regarding the needs in terms of the physical environment, are not so difficult to obtain, at least in central Europe. Some major disadvantages, especially in the rhithral zones, is the paucity of species leading to a necessarily less-sensitive response curve to environmental stress; and additionally, the mobility of fish species confounds the spatial sensitivity of many assessment methods. In North America, using the relatively species-rich fish fauna of small Midwestern streams, an index of biotic integrity (IBI) was developed using 12 different metrics concerning varying characteristics of the faunal assemblage (KARR et al. 1986). These metrics were divided into three classes, namely, species richness and composition, trophic composition, and fish abundance and condition; included are such characteristics as rates of hybridization, parasites loads, the percent occurrence of various feeding groups and even the weighting of the index based on the presence of indicator species. This index has been tested for spatial and temporal variability and overall has proven useful in these systems in recording anthropogenic disturbance (ANGERMEIER and SCHLOSSER 1987; KARR et al. 1987). Such a detailed system has not yet been attempted in Austria. It is doubtful that it could be utilized to its fullest extent in many of the rhithral zones of central Europe where as few as 2-3 species of fish are expected; especially those metrics that include trophic level, or in essence the equivalent of functional-feeding groups. Nonetheless, the following four criteria, reflect in part such a system and may be used to evaluate the ecological integrity of a site using the fish community as the response characteristic:

- the spectrum of species
- abundance
- dominance
- population structure

As with the benthos-oriented methodology, the degree that these four criteria correspond to the site-specific reference state of a sampled river stretch determines the integrity of the ecological community. The amount of deviation from the expected species spectrum, dominance structure, general abundance, and population structure - in terms of age structure - is a measure of the degree of disruption in community-level functions and hence ecological integrity. The criteria differ from the benthic-oriented methodology in Austria in that saprobity is in a broad sense of little use due to the increased mobility of most fish species and their ability to use a wide range of oxygen levels for short periods of time, so long as amply saturated environments are locally available. Longitudinal zonation is also probably not sensitive enough in all but extreme cases - such as when hypolimnetic releases create a trout fishery in a previously potamal river - due to the lack of species diversity.

The classification can be presented as follows:

Species inventory

The spectrum of species is determined by the availability of ecological niches for the different developmental stages of each fish species. Because the physical causes influencing the species diversity are more or less well known, and partly due to tradition, assessment of a river reach regarding fish often includes a close inspection of the macro and mesohabitat characteristics, and especially the freedom of passage along the longitudinal and lateral continuum. While it corresponds in principle to the hierarchical concept of defining a reference state of a benthic community, traditional macro and mesohabitat characteristics are often the center point of analysis. It should be made clear that in considering such aspects as dams, land-use practices, riparian vegetation, etc, that one is determining causes of environmental stress and not investigating empirically derived response characteristics. The absence of individual species, which due to their size, or commercial importance, are well known, is not necessarily a good indicator of ecological integrity beyond stating that the system is not in its pristine state. Even this statement can be somewhat misleading if the species was removed through over-fishing or simply prevented from migrating into a river system because of a dam far downstream. The conservation of these species is important in their own right but as indicators to be used in an assessment methodology they can play a confounding role. Because fish have been significantly manipulated, domesticated, and stocked outside of the natural range, and the introduction of species atypical to a site or even ecoregion is known to often have a negative influence on a native fauna, this aspect must also be considered.

Abundance and dominance

The percentage of individual fish species found in an assemblage, as with macrozoobenthic organisms, can depend on the ecological integrity of the system. In determining these relative percentages caution must be taken not to allow natural seasonal fluctuations, as well as stocking policies and sport or commercial fishing harvest, to confound the results. These influences can result in deviations from the expected natural state that only represent superficial or short term disturbances in the ability of a system to function. Nevertheless these same disturbances if carried out over a long period of time, or taken beyond the resilience threshold of the system, can impart permanent damage to a fish community and the overall ecological integrity as well. While these same cautions apply to the use of macrozoobenthic organisms as system indicators, the almost universal and incessant use of fish as a quarry for food and sport make fluctuations in their abundance and dominant structure somewhat cryptic in terms of indicating causal mechanisms.

Population structure

The occurrence of a fish species in a particular stretch of river can only be stable over time if there exists the proper environmental conditions for all of its life stages. An assessment of a fish community in a particular water body or site can be made by analyzing the age-structure of individual species with particular attention given to the juvenile age class, which reflects the most recent or current environmental conditions. As spawning and rearing time varies for each species it is especially important to time sampling appropriately and to know what to expect in terms of the size of juvenile fish of each potentially occurring species. One must also exercise caution in reaching conclusions about missing age classes as many species can be sensitive to wholly natural conditions such as a timely flood during a critical larval or incubation period. Such natural disturbances need not be extreme to temporarily disrupt the age structure of a particular species, and likewise do not necessarily reflect disturbances in the ecological integrity of the system. Thus, qualitative point samples taken only once in the course of the year are normally not useful for such assessment.

9. Methods of biocoenotic indication and other relevant environmental factors

9.1 Calculation procedures

ZELINKA and MARVAN (1961) in calculating a saprobic index, considered the fact that few species are characteristically found within a narrow limit of the saprobic spectrum. Most indicator species not only occur extensively in their corresponding saprobic category but also occur in other saprobic areas. Both authors compensated for missing information that is connected to the conventional species-specific saprobic index, by including the relative abundances of the specific species in question in each water quality class. Based on these relative abundances the authors than were able to calculate the strength that each species had in its ability to serve as an indicator of saprobic conditions within various saprobity levels. This methodology is explained with the following examples.
The sum total of relative abundances for each species across the 5 classes is set to 10. In this first example the relative frequencies of the organism was evenly distributed across the 5 classes so the "saprobic valencies" are as follows (see legend chapter 7.4):

x	o	β	α	p
2	2	2	2	2

A species which lives exclusively in the xenosaprobic section of the river would have the following saprobic valency:

x	o	β	α	p
10	-	-	-	-

The weight, or strength of the bioindicator, is calculated based on the distribution of saprobic valency. A broadly tolerant (eurysaprobic) species, as given in the first example, would receive an indication weight of 1. A species with a very narrow tolerance to saprobic conditions (stenosaprobic), shown in the second example, would receive the highest weight 5. SLADECEK (1964) has fixed some rules for establishing indicator values. These indication weights are of great value in calculating the saprobic index of a particular site. The saprobic valency of a xenosaprobic water quality class, for instance, is calculated as,

$$V_X = \frac{\Sigma\, x_i\, h_i\, g_i}{\Sigma\, h_i\, g_i}$$

where,
h_i is the estimated abundance of a species collected in a particular site
x_i is the saprobic valence (listed in catalogue) of the individual species in the X class
g_i is the indicator weight value as described above

Replacing X with the saprobic valence in each of the other 4 classes one uses the same formulas to calculate a saprobic valency for each of the saprobic classes (oligosaprobic, β-mesosaprobic, α-mesosaprobic, polysaprobic).

The abundance can be readily substituted with species density or biomass. The result of this equation will be a number from 1 to 10. This procedure is then repeated with a calculation for each of the 5 saprobic classes, the sum total of these saprobic valencies necessarily equaling 10. In this way the saprobic condition of a site can be represented with a simple histogram with 5 classes where the Y-axis is scaled to 10. The saprobic index of a site can then be calculated by multiplying the Y-axis value of each class by a factor value of each quality class (0-4 for xeno- to polysaprobic water quality classes) and dividing the sum total by 10. This calculation corresponds to the formulation of a weighted mean of frequencies, indicator weights, and species-specific saprobic valencies of a zone. The index value is based on the summation of all the saprobic valencies and weights of all the species present. Examples are given in SCHWOERBEL (1993).

The calculation of indexes for biocoenotic regions and functional-feeding guilds follows the identical procedure and formula except that there are no indicator weight values, and instead of 5 classes as is listed for saprobity, there are 10 classes each for biocoenotic regions and functional-feeding guilds. The 10 point system however is maintained. Again, a brief example is given below for the eucrenal region.

$$R_{EUC} = \frac{\Sigma\, euc_i\, h_i}{\Sigma\, h_i}$$

where,
h_i is the estimated abundance of the organism
euc_i is the biocoenotic valence (listed in catalogue) of the individual species in the eucrenal zone

This procedure is then repeated for each biocoenotic region (functional feeding guild).

9.2 Comments on the index values of individual species

Valency values of individual species for saprobity, biocoenotic regions, and functional-feeding guilds were not calculated quantitatively. A team of taxonomic specialists as well as other field-practitioners first constructed a "proposed" list of known Austrian species and their valencies in an earlier release of this catalogue based upon the integration of known descriptive information, educated assumptions and professional judgement. Each taxon was treated by specialists most familiar with this group and intensive consultation between authors was conducted. Authors responsible for a specific taxon are listed as such in the catalogue. These draft catalogues were put through a review process by sending them to various institutions throughout Austria and Germany. Criticisms and comments were discussed by the authors before this now standardized list was agreed upon. Lists of the collection sites, primarily from grey literature sources or personal comments, were included.

All contributors to this effort fully recognize that this descriptive and empirically based valence system represents a large compromise between the standards of basic and applied science but these authors nonetheless jointly acknowledge that this information is currently the best available. Again, the fundamental motive behind this loose-leaf format is to encourage updates, improvements, and additions as more autecological data become available. Considering the dire need for the unification of these assessment methods and the sparse funding available for species-specific autecological studies, this compromise was indeed the only realistic alternative. The following paragraphs further detail the methodology used and the treatment of species with unknown responses to environmental factors.

Saprobiological categories

Those species which are unsuitable as saprobic indicators are indicated as such in catalogue text. Species with unknown saprobic valencies are not categorized but nonetheless included in the species list. Species which reveal little knowledge about saprobic conditions are characterized with a valence of strongly preferred (*) and preferred (+) regarding their presently known saprobic ranges. Species that have a valence of 10 in one saprobic class but are known to occur, very rarely, in another class were also given a (+) for a valence in those classes where they occasionally appear.

Facts about longitudinal distribution along the biocoenotic regions

The determination of a fixed site's biocoenotic region utilized all available data on the slope/width-relationship and annual temperature regime together with literature on the fish fauna as well as other faunal groups (HUET 1949; MOOG and WIMMER 1990, 1994; MOOG and GRASSER 1992 b; MOOG 1993a). This concept has been clearly illustrated in chapter 10, examples 2 & 3. These results were also compared with the saprobic classification system in order that contradictions between these two systems could be considered more closely. When difficulties arose, or blatant ambiguities existed, the species in the zone in question, was again characterized with a plus sign (+) and omitted in the calculations. For broadly tolerant species (eurytopic), i.e., species occurring throughout the longitudinal zonation of a river, a value of 1 was allocated in each of the ten biocoenotic regions. When the occurrence of a species was known with certainty in some regions, but not at all in other regions, the known regions were allocated a (*) and the remaining zones by a plus sign (+).

Arrangements of feeding types

Trustworthy characterizations of functional-feeding guilds could not be adequately compiled. Many species remain without a rank at all. The current listing demonstrates the scarcity of available information concerning this theme for the Austrian macrozoobenthic fauna. A considerable amount of basic research must be accomplished to fill this information deficit and make this community-level index useful for environmental quality assessment. To the extent feasible, general nutritional preferences are symbolized: stars (*) are given for strongly preferred and plus (+) for the less strongly preferred. The symbol (+) was used together with numerical values in some categories in order to give some rough indication of differences between organisms that are presumed to grazers, detritus feeders, or filter feeders.

10. Examples of the systematic and practical use of environmentally relevant zonal characteristics

The procedures of macrozoobenthic-based river quality assessment rest firmly on the extensive and critically evaluated reference data sets. These data include the categorization of individual species to various zones or regions, i.e. saprobic, longitudinal and functional feeding. These categorizations are the principal contribution of this catalogue. The procedures used to categorize a species are presented in example 1 for *Prosimulium hirtipes*.

The second set of reference data is the typology of a specific river site. The procedures currently used to characterize a river site, i.e. to define its expected biocoenotic typology in terms of the rhithral-potamal-concept, are displayed in example 2 and 3.

Examples 3-10 demonstrate how the characterization of a macrozoobenthic assemblage in relation to its expected zonal distribution is used to assess the anthropogenic influences on particular river sites. A range of environmental conditions are covered revealing the importance of including the entire fauna as an effective and broadly applieable bioindication tool. The direction and magnitude of zonal shifts in the fauna can be, with experience, used to pinpoint specific structural changes that have occurred in the riverine environment.

The examples given base on quantitative methods. The area or volume of space sampled was used to calculate the quantitative variable - the abundance parameter in the equations illustrated. The process follows guidelines given in the AUSTRIAN STANDARDS M 6232. First, all macrozoobenthic individuals from within a designated area in the bottom sediments of the river are sampled. Normally 4 to 6 replicate samples per sampling site are collected (0.04-0.1 m^2) and effort is taken to achieve some spatial interspersion. The species spectrum is identified, individuals are counted, and then weighted. Methodological details are given in MOOG and GRASSER (1992b).

Example 1: Tabulating the basic data and systematic categorizing taking an example from *Prosimulium hirtipes*

Data collection - *Prosimulium hirtipes* FRIES 1906

Occurrence

This species is distributed throughout Europe and Siberia (CROSSKEY 1987). KNOZ (1965) mentions mountain brooks and small streams at altitudes 450-600 m asl (above sea level) as habitat of the larvae. According to KNOZ and SASINKOVA (1969), *P. hirtipes* is a blood-sucking species and is distributed throughout the Palaearctic region occurring in streams flowing through forested montane regions. SCHRÖDER et al. (1988) distinguished *P. hirtipes* as a montane species from mountain brooks and streams. ZWICK (1974) included *P. hirtipes* as a species found in strongly-flowing rhithral streams, to torrential high-mountain streams. CAR (1981) found this animal in the Alps and in Waldviertel above 500 m altitude in swift-flowing larger rivers. BRAUKMANN (1987) considers it a typical member of mountain-stream assemblages. SCHMEDTJE and KOHMANN (1988) stated that only clear, swift and turbulently-flowing streams, with stony bottoms in higher altitudes 300-700 m, represent suitable habitat for this species. SCHRÖDER and REY (1991) list *P. hirtipes* as a species distributed in alpine and montane regions. According to SEITZ (1992) it is a characteristic species of metarhithral to hyporhithral regions, and occupies the middle to lower reaches of forested streams in Bavaria at an average of 500 m altitude.

Species-association

In individual collections, *Prosimulium hirtipes* has been found together with *Simulium monticolum, S. argyreatum, S. variegatum, S. cryophilum, S. ornatum, S. venum* and *S. costatum*. SCHRÖDER and REY (1991) mention associations with *Prosimulium tomosvaryi*. According to ZWICK (1974) the imagos of *Prosimulium tomosvaryi, Simulium monticolum* and *Simulium cryophilum* are found in association with each other.

Sapro-biological categorization of *P. hirtipes* according to various authors

Author	Saprobic Valency					Indicator Value	Saprobic Index
	x	o	β	α	p	G	SI
HANUSKA (1956)		os					1.0
ZELINKA, MARVAN & KUBICEK(1959)	2,5	1,5					0.3
DITTMAR (1960)	-	8	2	-	-		1.2
ZELINKA & MARVAN (1961)	7	3	-	-	-		0.3
MAUCH (1976)		os	bms				1.5

Author	Saprobic Valency					Indicator Value	Saprobic Index
	x	o	β	α	p	G	SI
SLADECEK (1973)	7	3	-	-	-	4	0.3
GULYAS (1983)	7	3	-	-	-	4	0.3
SLADECEK et al. (1981)	4	6	-	-	-	3	0.6
WEGL (1983)	-	8	2	-	-		1.2
BRAUKMANN (1987)	-	4	5	1	-	2	1.7
Styria (1989)						4	1.2
MAUCH et al. (1985)						3	1.5
Bavaria (1993)						3	1.5
KOHMANN & SCHMEDTJE (1988)						3	1.5
FRIEDRICH (1990)							1.5
POLZER & TRAER (1991)						3	0.6
SEITZ (1992)							1.5
Upper Austria							0.6

List of Austrian records:

River	**sampling date**	**biological water quality**	**dominance %**	**altitude**	**biocoenotic region**	**stream order**
Upper Austria:						
Höllmühlbach 9	23.5.1986	I - II	8.45	460	MR	1
Höllmühlbach 10	23.5.1986	I -(II)	0.76	370	MR	3
Katzbach 43	4.6.1986	I - II	0.75	430	MR	2
Pflasterbach 20	22.5.1986	(I)- II	2.60	320	MR	1
Haselbach 21	21.5.1986	I - II	0.15	470	ER	1
Haselbach 22	21.5.1986	II	1.08	490	ER	1
Haselbach 24	21.5.1986	I -(II)	0.15	430	MR	2
Haselbach 30	21.5.1986	(I)- II	1.14	360	MR	4
Diesenleitenbach 6.5	29.5.1985	II		580	ER	2
Diesenleitenbach 9.4	29.5.1985	I	2.50	800	HYK	1
Vöckla, km 1.66	26.2.1985	II	0.10	428	HR	5
Vöckla, km 0.35	6.12.1990	II		425	HR	5
Teichl (Car 1981)						
BH Hinterstoder		I-(II)		470		4
Krumme Steyerling (Car 1981)						
Messerer		I		562		
Köhlerschmiede		I		457		3
Brücke Gstadt		I-(II)		446		
vor Steyrmündung		I-(II)		435		4

River	sampling date	biological water quality	dominance %	altitude	biocoenotic region	stream order
Raning. Engelhartszell						
(Zwick 1976)				290		
Bach bei Waizenkirchen						
(Zwick 1976)				367		
Kremsmünster (Franz 1989)		II		350		
Lower Austria:						
Melk 2	25.4.1982	II		237	HR-EP	5
Ob. Lunzer Seebach						
(Car 1981)		I		620	MR	2
Unt. Lunzer Seebach						
(Car 1981)		I-II		610	MR-HR	2
Mausrodlteichbach						
(Car 1981)		I-II		659	MR	1
Teichbach, Lunz						
(Kazimirova 1981)		I-(II)		620	MR	1
oberster Abschnitt der Ybbs						
(Supperer & Kutzer 1967)						
Salzburg:						
Alterbach VII		II	0.06	490	MR	3
Alterbach 9/3		II	1.0	520	ER-MR	3
Wagrainer Ache						
Hallmoosberg	9.7.1985	I-	0.05	806	ER-MR	4
Salzach						
Urreiting	13.12.1990	(I)-II		530	MR-HR	7
Bischofshofen	13.12.1990	(I)-II		550	MR	7
Pfarrwerfen	20.2.1990	II-III		530	MR-HR	7
Tenneck-Blühnbach	21.2.1990	II-(III)		495	MR-HR	7
Stegenwald	12.12.1990	II-(III)		500	MR-HR	7
Golling	12.12.1990	II		470	HR	7
Styria:						
Granitzenbach, Obdach	17.5.1967 (Car 1981)			880		3
Granitzenb. v. Murmdg.	17.5.1967 (Car 1981)			660		5
Carinthia:						
Gerinne bei Miklausdorf	17.5.1967			610		
Waidischbach. Unterferl.	18.5.1967			450		
Vorarlberg:						
Ebniterach oh.Wehr	15.3.1991	I-II	2.05	780	ER	4
Ebniterach uh. Wehr	15.3.1991	I-II		750	ER	4
Dornbirnerach, Gütle	16.3.1991	II	0.87	510	MR	5
Waldbad	16.3.1991	II		470	MR	5
oh. Waldbad	4.12.1990	II		490	MR	5
Gschwendbach III	15.3.1991	II-(III)	0.18	700	MR-HR	3
Rickenbach,Wolfurt	16.3.1991		1.28	416	ER-MR	4
Rickenbach 1	15.3.1991	I-II	0.18	800	ER	1
Rickenbach 2	15.3.1991	I-II	0.07	720	ER	2
Rickenbach 3	15.3.1991	I-II	0.11	680	ER-MR	3

River	sampling date	biological water quality	dominance %	altitude	biocoenotic region	stream order
Schwarzach 1	15.3.1991	II	0.47	900	ER	1
Schwarzach 2	15.3.1991	II-(III)	0.18	665	MR-HR	2
Schwarzach 3	15.3.1991	II	0.81	575	HR	3
Schwarzach 4/2	15.3.1991	II	0.69	570	MR-(HR)	4
Schwarzach 4/1	17.3.1991	II-(III)	0.16	418		4
Müselbach	15.3.1991	I-II	6.49	700	ER	3
Kobelach u. Müselbachmünd.	15.3.1991	I-(II)	0.38	670	ER-MR	4

Analysis of Austrian sampling sites and the categorization of *Prosimulium hirtipes* according to saprobic zones:

Saprobic categories:

Saprobic tolerance of *Prosimulium hirtipes* has been noted as broad-ranged, as it is found in xeno-to β-mesosaprobic conditions, and occasionally in α-mesosaprobic conditions as well. The saprobic characterization of this species is somewhat heterogenous as it has been reported as a valid xenosaprobic species with frequent occurrence in the α-mesosaprobic range as well (SCHRÖDER and REY 1991). In Austria, 50 saprobic rankings across 6 states, viewed together, clearly show that this species occupies sites in the oligo and ß-mesosaprobic state. This characterization conforms well with the saprobic rankings given to this species in lower Bavaria, Germany (SEITZ 1992).

Tabular analysis of Austrian collections:

Water quality class	I	I-II	II	II-III
No. of records	15	11	22	1

Saprobic ranking derived from the literature and the tabular analysis of Austrian collections:

Saprobic class	x	o	β	α	p	Saprobic Index
Valence (catalogue allotment)	+	4	6	+	-	1.6

Note that one can not simply use this tabular data to calculate directly the valencies listed in the catalogue. First, the number of records within each saprobic class was not necessarily unbiasedly sampled but merely reports, in a tabular format, the frequency of the known collections of this species within each saprobic class. To arrive at the catalogued values all available information on this species including literature accounts and "expert consulting" is integrated.

Biocoenotic regions

Tabular analysis of Austrian evidences:

Biocoenotic region	EUC	HYC	ER	MR	HR	EP	MP	HP	LIT	PRO
No. of sampling sites		1	12	20	11					
Valence (catalogue allotment)	-	+	3	5	2	-	-	-	-	-

As explained above for saprobic valences, again, this tabular summary cannot directly produce the valences listed in this catalogue.

Nutritional needs

Prosimulium hirtipes is a passive filter feeder, obtaining its food with the help of a premandibular fan. The first-stage larvae (Larvula) according to ZWICK (1984) are grazers. To cover this ontogenetic change in feeding behavior, and to incorporate the knowledge that this first larval stage is short lived but abundant, a valence of 1 is given for the functional-feeding guild of grazers, and a valence of 9 is given for the passive-filtering guild.

Example 2: Determination of a biocoenotic region of a mountain river reach (rhithral) using abiotic characteristics and bioindicators

The designation of a biocoenotic region using macrozoobenthic data is further supported by considering such characteristics as temperature, width-gradient relation and the fish fauna. The following characteristics are given as an example of how one determines the biocoenotic region for a particular reach of river.

Wagrainer Ache between Wagrain and St. Johann (Salzburg)

Typological characteristics of the river stretch:
The middle reach of the Wagrainer Ache is a 4th-order, submontane river with a nivalic discharge regime (PARDÉ 1947) flowing through the crystalline, central alps.

Abiotic characteristics and longitudinal zonation:

	Characteristic	Biocoenotic region	Reference
Yearly maximum temperature amplitude	>12.7 °C *	ER/MR	MOOG and WIMMER (1994)
Width-Gradient	10 m, 22 m/km	ER/MR	HUET (1949)

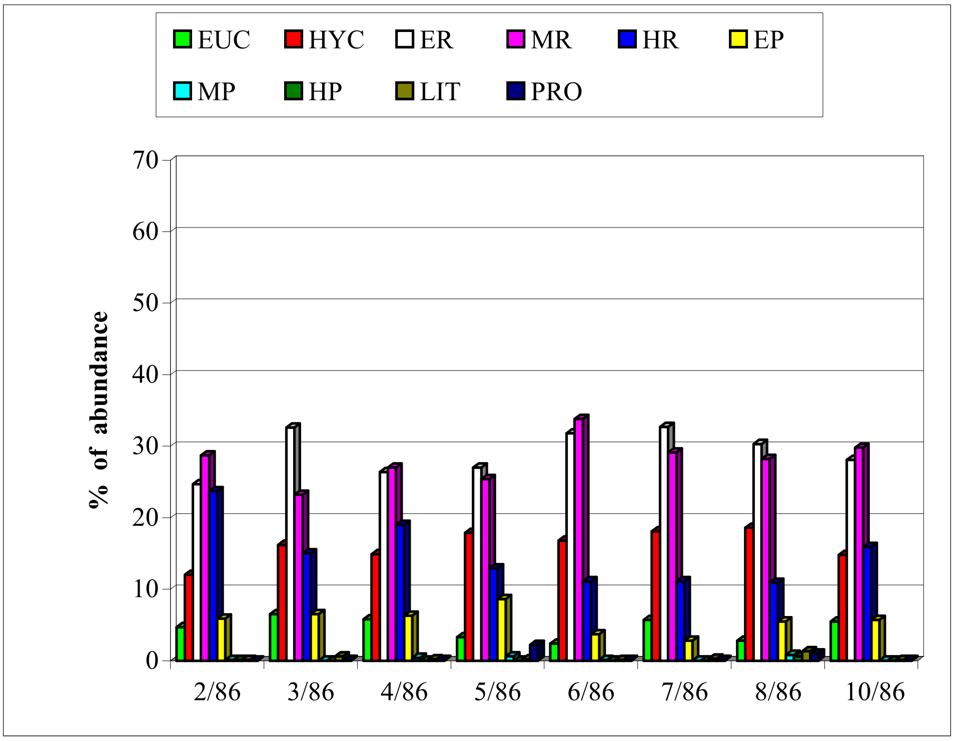
Bioindicators of the longitudinal zone:

Fish fauna	Species composition	ER/MR	JUNGWIRTH, unpubl. report
Macrozoobenthos	Species, abundance	ER/MR	MOOG and JANECEK (1991)

Refer to chapter 7.6 for the abbreviations of biocoenotic regions.

* Temperature gauge 1 kilometer below collection site

The abiotic characteristics and the biological indicators correspond to a transition zone between the epirhithral and metarhithral section of this river. The longitudinal zonation displays little temporal variation across the entire year.



Characteristic saisonal distribution of a rhithral river following biocoenotic regions: Wagrainer Ache at Hinterreit (details in MOOG and JANECEK (1991))

Example 3a: Determination of a biocoenotic region of a lowland potamal river using abiotic characteristics and bioindicators

Thaya between Bernhardsthal and Rabensburg

Typological characteristics of the river stretch:
This reach of the Thaya is an 8th-order lowland river, flowing through a mixed-oak forest in the Bohemian mass, with a pluvio-nivalic discharge regime, located in the eastern "Weinviertel".

Abiotic characteristics and longitudinal zonation:

	Characteristic	Biocoenotic region	Reference
Yearly maximum temperature amplitude	>20.8 °C	EP/MP	MOOG and WIMMER (1994)
Width-Gradient	36 m, 0.37 m/km	EP/MP	HUET (1949)

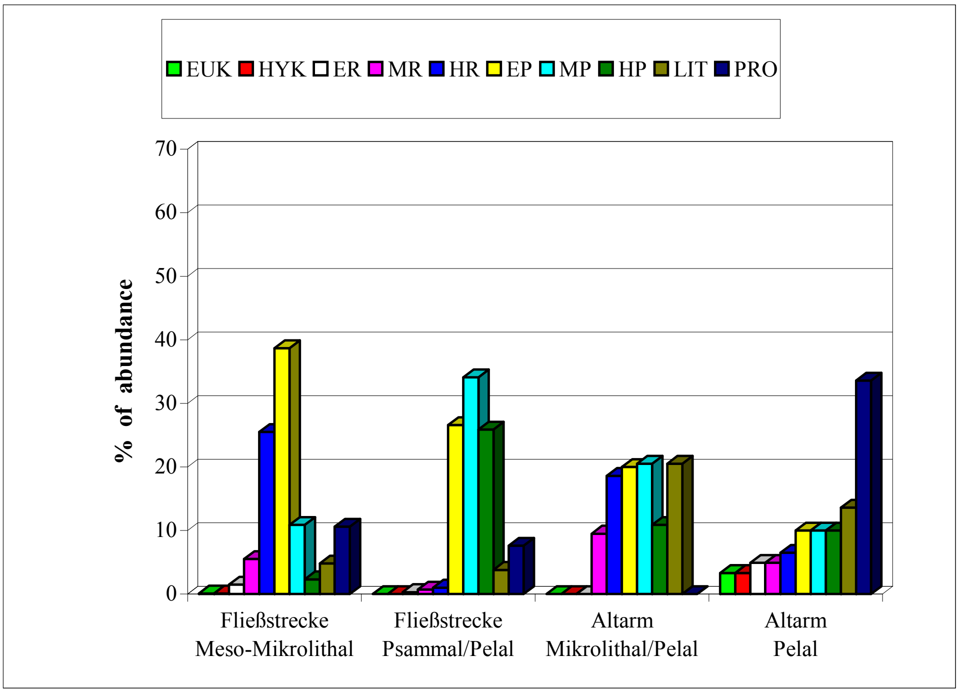
Bioindicators of the longitudinal zone:

Fish fauna	Species composition	EP/MP	ZAUNER (1993)
Macrozoobenthos	Species, abundance	EP/MP	GRAF and GRASSER (1993)

The abiotic characteristics and the biological indicators correspond to a transition zone between the epipotamal and metapotamal zone.

Example 3b: Longitudinal distribution along biocoenotic regions in sections with different flow regimes

The longitudinal distribution of organisms along biocoenotic regions is generally ruled by the temperature regime, but in detail, clearly a result of current velocity and substrate character. The "lithal" (> 2 cm) substrate is occupied by an assemblage composed of members characteristic for a transitional zone between the hyporhithral and epipotamal zones. "Rhithralization" of the fauna in the Thaya river is the end result of channel straightening and channel restriction measures which have altered the normal sediment balance. The primary result is that the finer substrates and corresponding lentic zones are lost (ZAUNER 1993). In a large side-arm channel, separated from the main channel, the more typically potamal aspects of this faunal zone were found due to a higher percentage of fine sediments. The clear dominance of typically profundal organisms, in the very fine sediments of the side-arm, are the result of waste-water discharges into this section of the Thaya.



Graphical representation of longitudinal distribution along biocoenotic regions in the main channel (lotic) and a stagnant backwater (lentic) (details in GRAF and GRASSER (1993))

Example 4: Distribution of the most important functional feeding guilds along a river's length from stream order 1 to 5 (Schwarzach system, Vorarlberg)

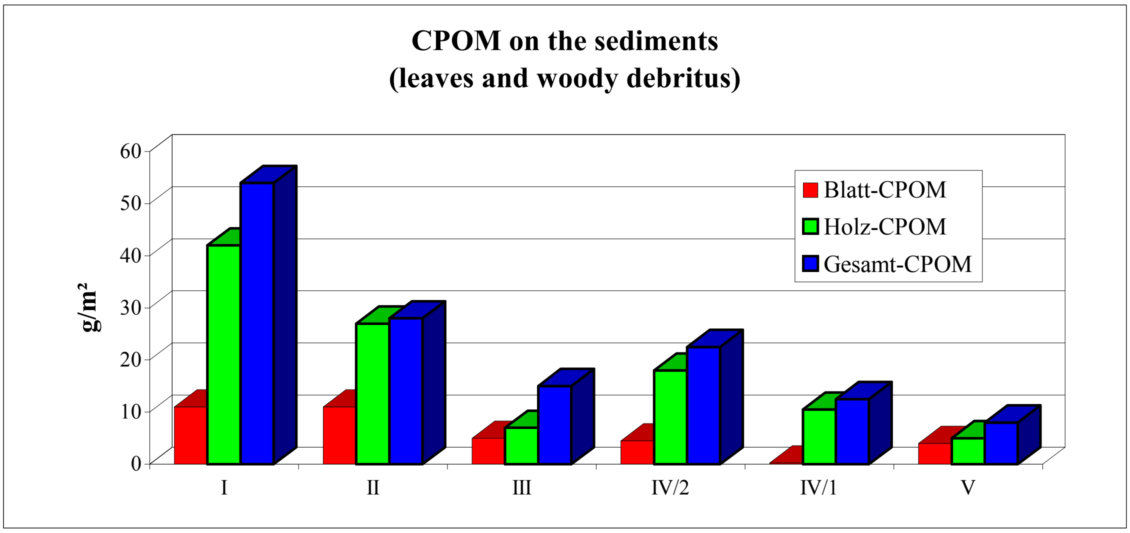
Schwarzach

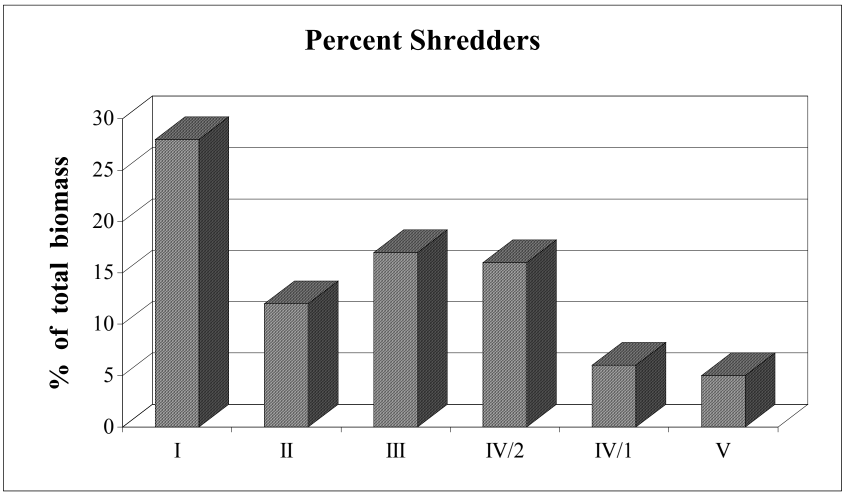
Typological characteristics of the river stretch:
The upper reach of Schwarzach is a 1st to 2nd order, montane to sub-montane stream, with a mixed snow regime (nivalic flow regime after PARDÉ 1947) in the subalpine molasse in the forests of Bregenz. The middle reach is stream order 3-4 and is also described as a submontane stream with a nivalic flow regime.

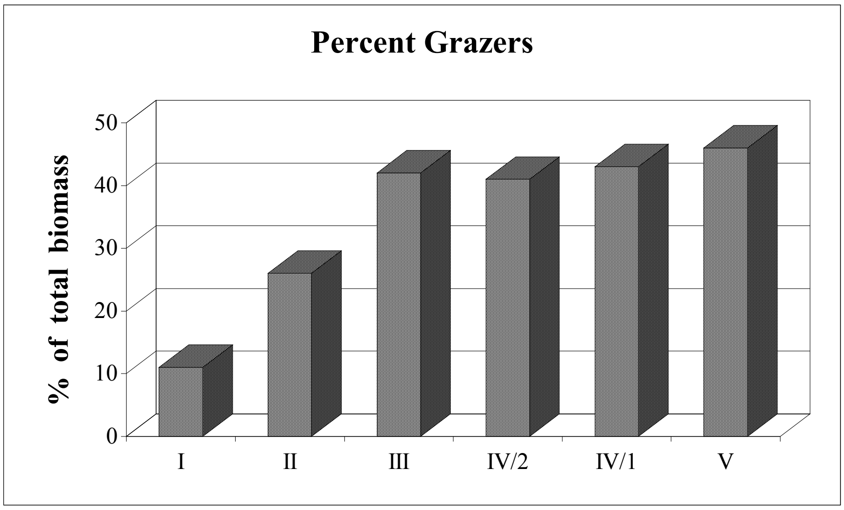
In agreement with the River Continuum Concept, the percentage of decomposed leaves and coarse woody debris decreases in lower reaches of the river. This pattern is shown in the graph below where Roman numerals on the x-axis correspond to stream order. The increase in CPOM in site IV/2 was clearly due to debris-influx from a tributary stream. This tributary, with a low stream order - Rothenbach - deposits woody debris and leaf particles into the bed sediments of the Schwarzach.

Continuing towards the lower reaches - stream order 5 - as leaves and wood particles become more scarce, the percentage of shredders within the community decreases. An increase in shredders is seen at the mouth of the Rothenbach due to the input of CPOM.

A second characteristic shift in the distribution of functional feeding guilds is seen in the increasing percentage of grazing organisms; woody debris decreases and the algal component increases with increasing stream order. The increase in algae is primarily a result of the increase in solar incidence over an ever-widening river channel.





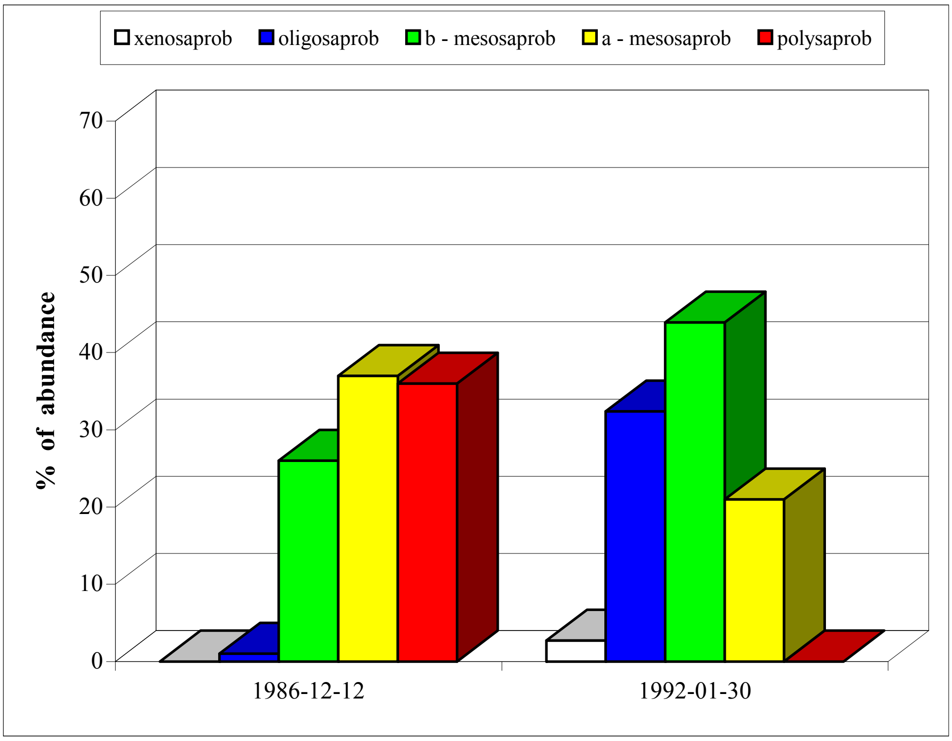


Percent coarse detritus (leaves and wood) and distribution of shredders and grazers across different stream orders in the Schwarzach (details in SCHWINGSHANDL (1992) and MOOG, WIMMER and GRASSER (1993)).

Example 5: Saprobic valency of a macrozoobenthic community and the composition of functional feeding guilds downstream from waste water discharge

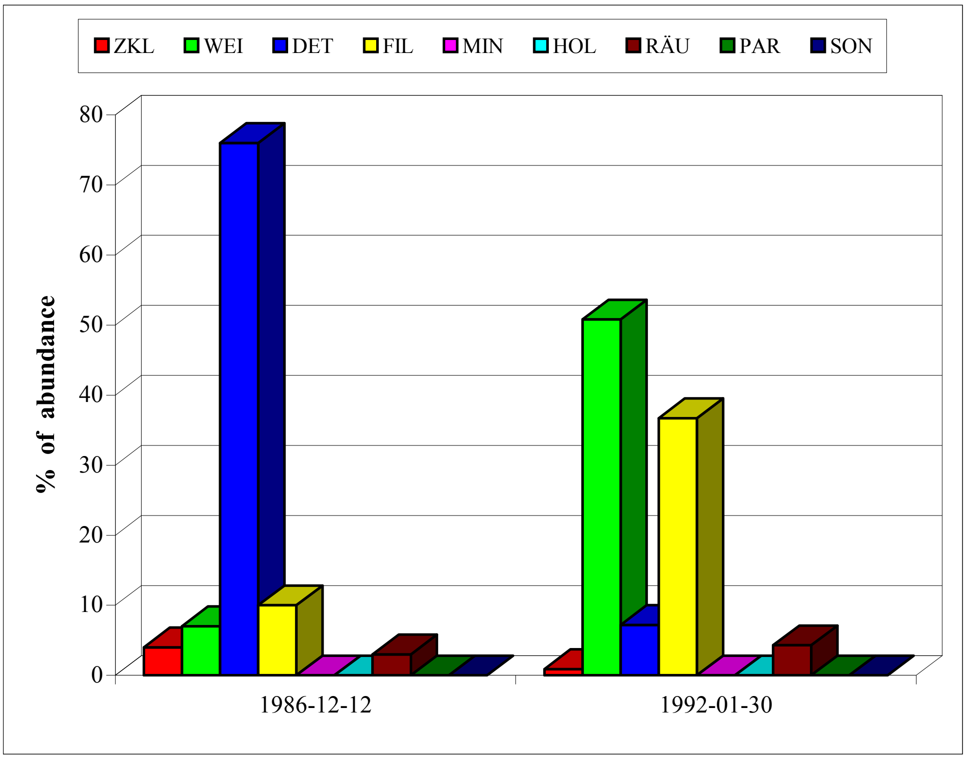
River Ager at Fischerau

Typological characteristics of the river stretch:
This reach of the Ager is a 6th-order, lowland river with a pluvio-nivalic discharge regime flowing through deciduous forests of the piedmont region in a mixed geological range (limestone/flysch/molasse) in the northern limestone alps. The river course starts at the outlet of lake Attersee, an ultra-oligotrophic lake, but the water quality deteriorates due to an industrial pollution load (pulp and paper mill), that corresponds to roughly 1 million inhabitant equivalents.



Graphical representation of the water quality improvement in the Ager at Fischerau from December 1986 to January 1992 (details in MOOG 1984; MOOG and GRASSER 1992 b)

Within this very strongly disturbed stretch of river (saprobic water quality class III-IV in Dec. 1986) detritivores were the dominant guild. After an industrial waste-water treatment plant began to operate in Lenzing, the biological component of water quality improved. After five years of operation the river stretch could be classified as mesosaprobic; water quality class II-III (January 1992). The composition of functional feeding guilds corresponds to theoretical characterizations put forth in the River Continuum Concept for stream order 6; that is, under favorable light conditions which promote typical algal growth, the community should be dominated by grazers followed by filter feeders and detritivores.



Graphical representation of the distribution of functional feeding guilds in the Ager at Fischerau in December 1986 and January 1992 (details in MOOG 1984; MOOG and GRASSER 1992 b)

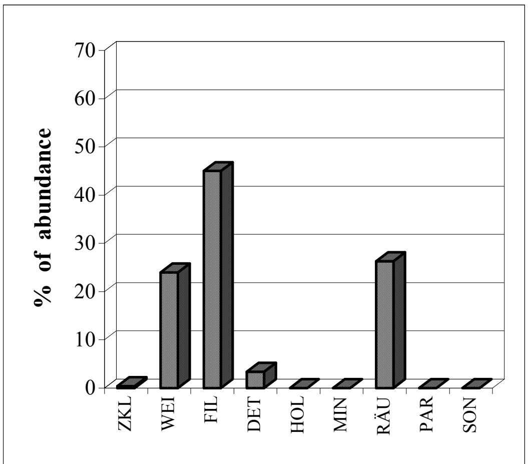
Example 6: Composition of functional feeding guilds in varying flow and substrate conditions: free-flowing river stretches, lake outlets, an impoundment with gravel substrate and an impoundment with a muddy substrate

Traun between Gmunden and Linz

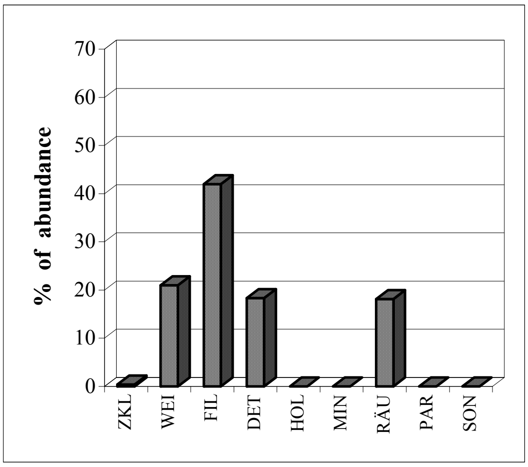
Typological characteristics of the river stretch:
The lower Traun is a 5th-order, sub-montane to lowland river, growing to a 6th-order river after its confluence with the Ager at the town of Lambach. It flows through forests with a nivo-pluvialic discharge regime located in the piedmont of the northern limestone alps (lime-flysch-molasse mixed range).

The macrozoobenthic community from Gmunden downstream to Steyrermühl, is characteristic for a lake outlet with warm water temperatures in the summer. The faunal elements correspond to those in an epipotamal river. Likewise, the organisms which occur in relatively high individual densities in the Traunsee (in all of its littoral zones), occupy the river bed of the Traun.

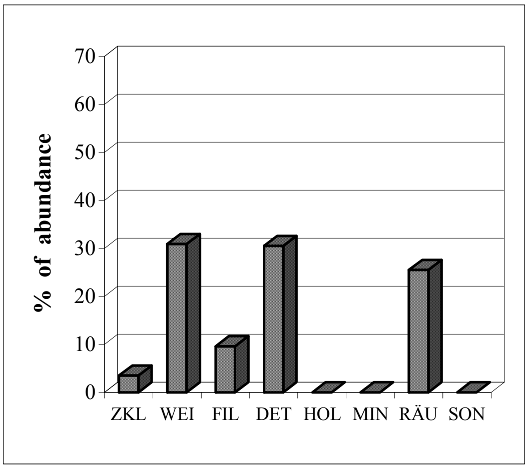
Correspondingly, the most dominant functional-feeding guild is the filter feeder which utilize the FPOM originating in the sediments of the Traunsee: dominating the fauna were several species of mussels, the first of which immigrated - or was introduced - into the Salzkammergut region in the mid 1970’s, *Dreissena polymorpha* and *Anodonta anatina*; several snails, *Valvata piscinalis* and *Bithynia tentaculata*; and free-living caddisflies of the genus *Polycentropus* and *Hydropsyche* which primarily gather their nourishment from a finely-woven net waving in water’s current. Other filter feeders include the simuliid *Odagmia ornata* and the chironomid *Prodiamesa olivacea*. Hence, the faunal composition on the river bed of the Traun is in accordance with ecologically-based expectations of a lake outlet.



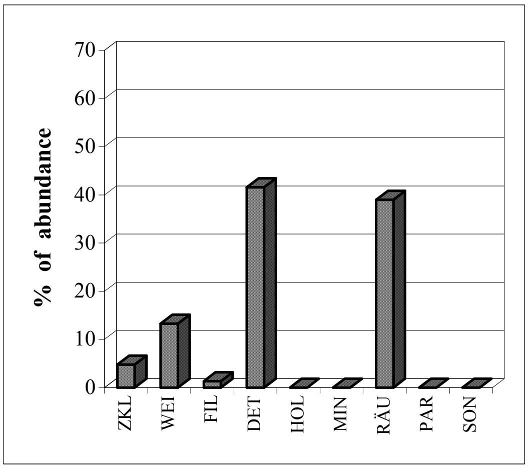
Distribution of the functional feeding guilds in the tailwaters of the power plant Gmunden (Nov. 1984)



Distribution of the functional feeding guilds in the tailwaters of the power plant Gmunden (Dec. 1990)



Composition of the functional feeding guilds in the flowing section at Steyrermühl (Dec. 1990)

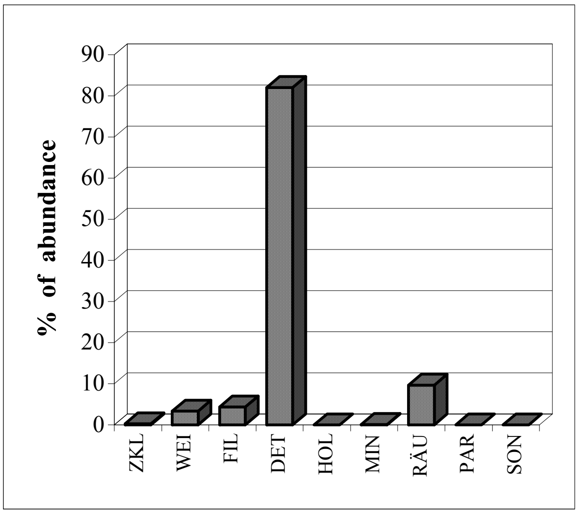


Composition of the functional feeding guilds in the partially impounded stretch Viecht (Dec. 1990)

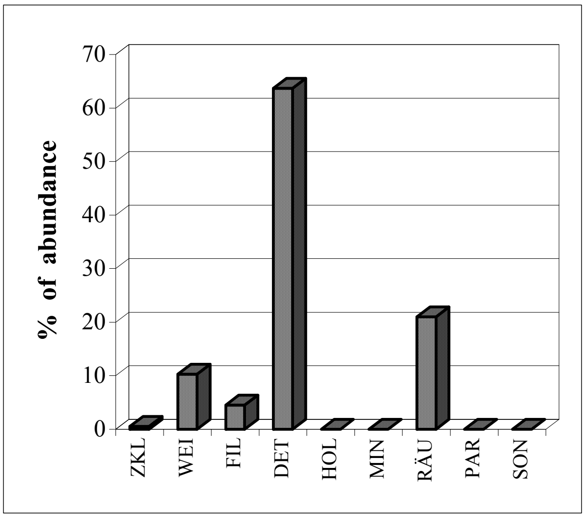
Further downstream, as the influences of the lake outflow diminish, both the dominance of the filter feeders and the overall benthic biomass declines. Due to increasing algae growth on the river's substrate, the community becomes dominated by grazers. This spread of algal cover promotes the occurrence of all organisms which depend on aquatic vegetation including midges, mayflies and caddisflies.

Numerous dams are constructed in the narrow valley of the Traun between Gmunden and Stadl-Paura to facilitate the transport of logs and the production of hydropower. These dams are relatively small, accommodate comparatively high current velocities, and are to some degree constructed to conform to natural gradients in the river corridor. In comparison to free-flowing river stretches, the bottom fauna in these impounded river sections contains a comparably high number of detritus feeders due to the deposition of gravel, sand and fine sediments (e.g., the impounded stretch in Viecht).

The impoundments throughout the river stretch below Lambach (e.g., the Pucking power plant) cause a much larger disturbance on the expected community structure. A few functional-feeding guilds, overwhelmingly dominated by detritivores, result from the heavy accumulation of fine sediments and the lack of current velocity. This community structure has deviated so far from the reference state, that even in the swift-flowing, tail-water stretches below the dams, detritivores still dominate.



Composition of the functional feeding guilds in the impoundment behind the Pucking (Dec. 1990)



Composition of the functional feeding guilds power plant in the tailwater of Pucking (Dec. 1990)

Details to the graphs are given in MOOG and GRASSER (1992 b).

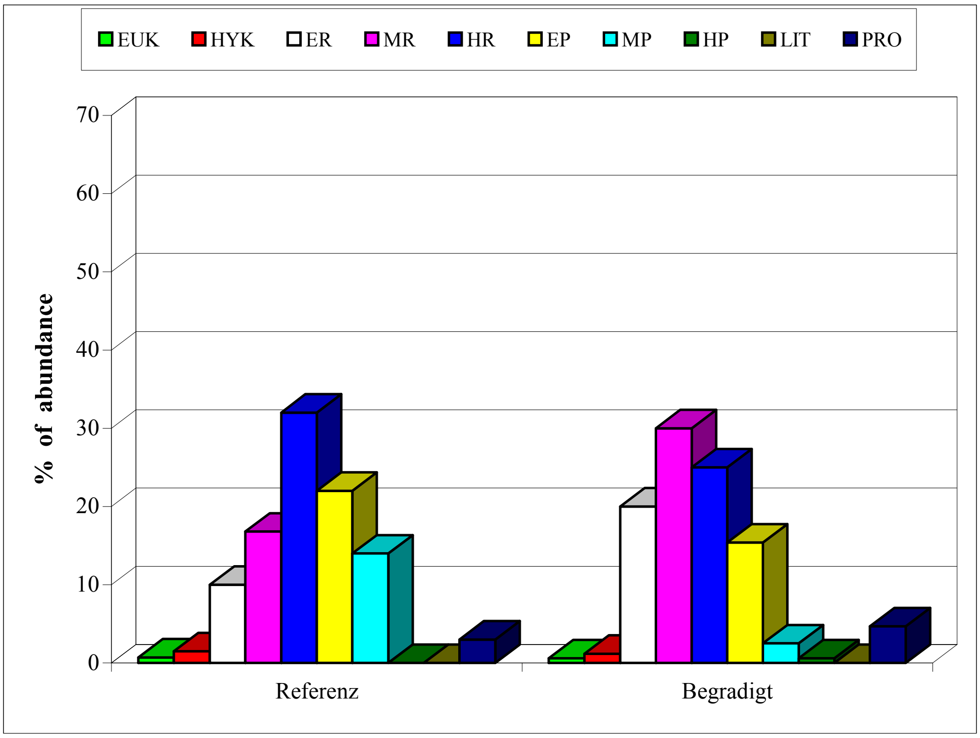
Example 7: Effects of river channel straightening on the longitudinal distribution along biocoenotic regions

Two rivers, the Schwarzach in Vorarlberg and the Mattig in Upper Austria, demonstrate the ecological disturbances caused by flood-water protection measures which straightened and constricted the river's channels.

Example 7a: Schwarzach in Dornbirnerach System

Typological characteristics of the river stretch:
The lower reach of the Schwarzach is a sub-montane, 5th-order, lowland mountain stream with a mixed nivalic discharge regime. Helvetikum (a geological formation) dominates the catchment basin of Dornbirnerach (Vorarlberg).

The unimpacted reference section of this river (shown in the figure below) is dominated by a typical hyporhithralic fauna with clear components of the metarhithral and epipotamal as well. In the straightened river channel of the disturbed site this community has changed. The species composition shifted to one typical for upper courses dominated by metarhithralic elements with clear components of the epipotamal and hyporhithral regions. This change in community structure is due to increased current velocities which in two regards regulates the composition of the community: (1) organisms with low velocity preferences find no suitable micro-habitats; (2) the size-fraction of the bed sediments increases favoring a fauna adapted to lithal (cobbles and boulders) substrate sizes, as fine sediment, sand and gravel are no longer deposited.

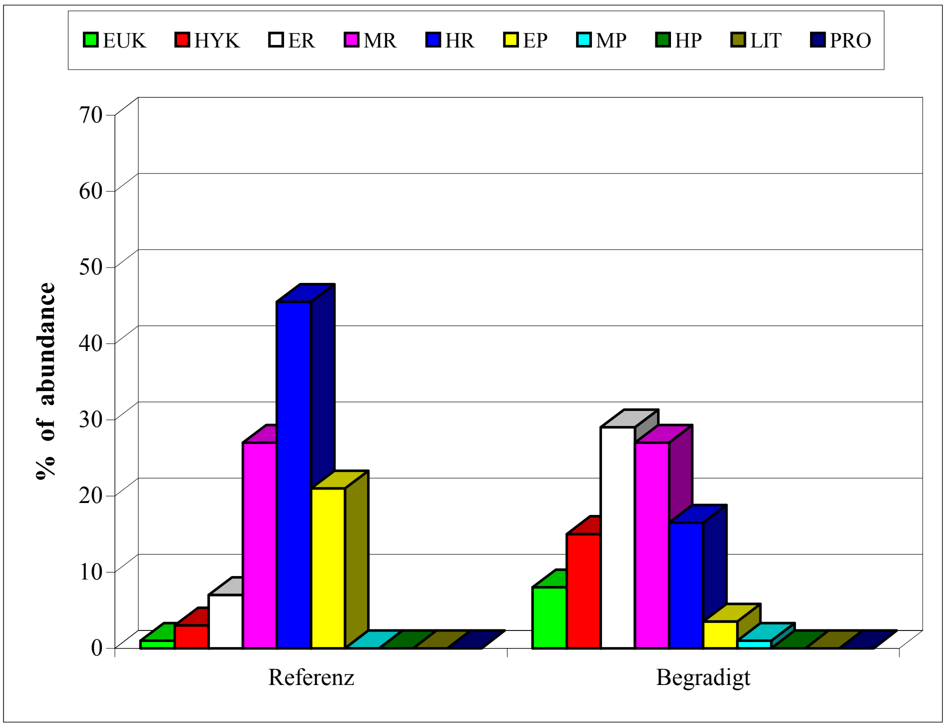


Longitudinal distribution of macrozoobenthos following biocoenotic regions within "natural" and disturbed river stretches (Schwarzach, March 1991) (calculated with raw data from MOOG, WIMMER and GRASSER (1993))

Example 7b: Mattig at Uttendorf

Typological characteristic of the river stretch:
The Mattig at Uttendorf is a typical 4th-order, lowland river with a pluvio-nivalic discharge regime flowing through the basin landscape of the Flachgau district of Salzburg.

The reference stretch, meandering through a natural floodplain area, depicted below is clearly dominated by a hyporhithralic fauna, although, due to a moderate channel straightening many decades prior, this stretch has already undergone a degree of degradation. In a "disturbed" site (straightened river channel) this community composition is further shifted to one dominated by epi to meta-rhithralic elements clearly indicating an artificial juvenilization of this river (details in GRASSER, JANECEK and MOOG 1991).



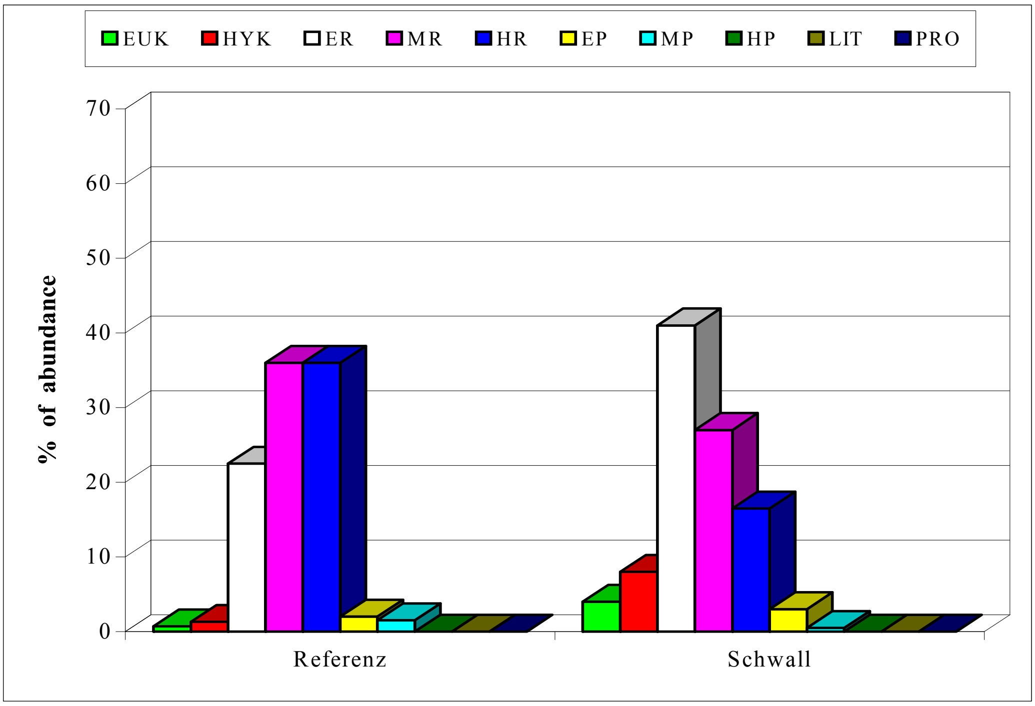
Longitudinal distribution of macrozoobenthos following biocoenotic regions within "natural" and disturbed river stretches (Mattig, August 1989)

Example 8: The effects of hydro-peaking on the composition of communities related to longitudinal zonation

The changes in a macrozoobenthic community below a power station, which is operated with hydro-peaking, is shown in the Drau river at Sachsenburg (Kärnten) and in the tail waters of the power plant Urreiting in the Salzach river (Salzburg). The term hydro-peaking refers to a special type of reservoir-operated hydroelectric power generation. Water is stored in base load run-off river plants or retired in storage basins to generate electricity at times of peak demand. The water released leads to diurnally variable water pulses in the river section below the power station. The artificial discharge variations affect the riverine biota immensely (MOOG 1993 b)

Example 8a: Salzach at Urreiting

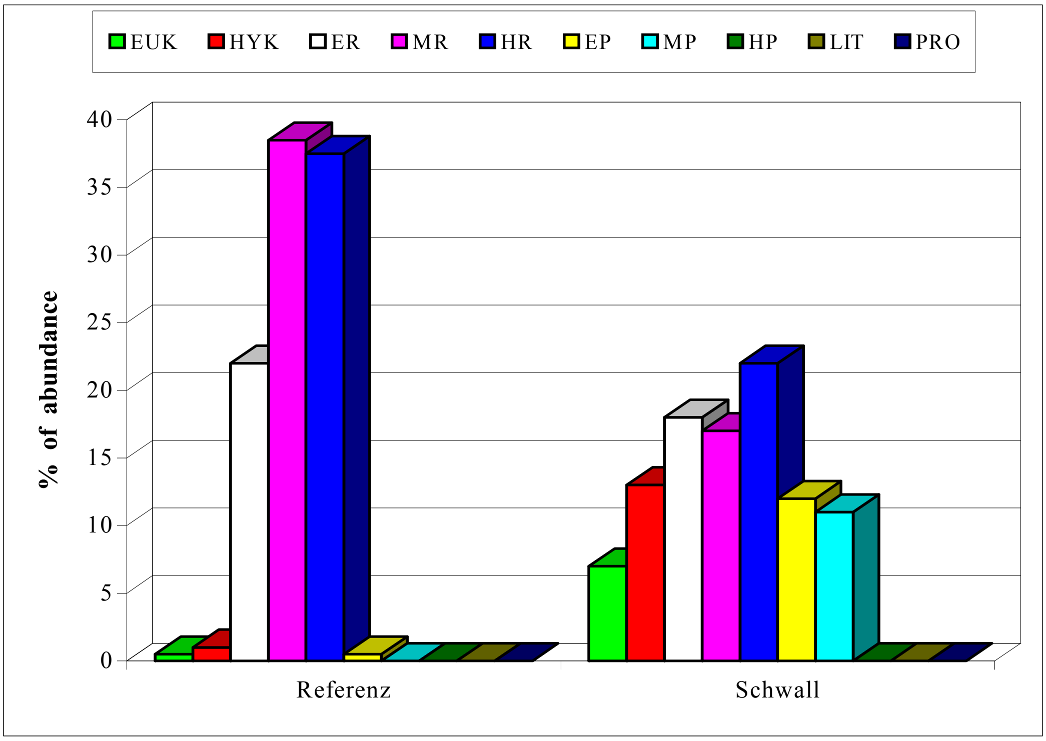
Typological characteristics of the river stretch:
At Urreiting, the Salzach river is a 7th-order sub-montane river, partially glacier-fed, with a nivalic discharge regime flowing through a mountain range of mixed limestone and crystalline composition in the Pongau of Salzburg. Besides the 85% reduction of the benthic invertebrate biomass in the peak affected section, below the power plant the benthic community has clearly shifted to one dominated by a epirhithralic fauna; for comparison, a reference stretch in this reach contains faunal characteristics of the meta- and hyporhithral zones. Correspondingly the distribution of functional-feeding guilds clearly shows a decrease in shredders presumably because their food base has been washed out - particulate organic matter - in the flushing zone below the power plant (figure taken from MOOG (1993b)).



Longitudinal distribution of macrozoobenthos following biocoenotic regions in near-natural and hydro-peaking influenced stretches (Salzach, December 1990 (calculated with raw data from MOOG and GRASSER (1992 a))

Example 8b: Drau at Sachsenburg

Typological characteristics of the river stretch:
The Drau River at Sachsenburg is a glacier fed, 7th order mountain river with a nivalic discharge regime. Below the confluence of the hydro-power plant's flushing zone, the community structure shows a complete reformation from its original form and is dominated by elements characteristic of the meta- and hyporhithral zones (raw data in MOOG and TRAER (1990)). An interesting aspect of this community is the relatively equal frequency distribution of faunal elements characteristic of regions from the crenal through metapotamal zones; this community structure results from the occurrence of "zonal-generalists" from each of these biocoenotic regions, i.e., species with broad habitat tolerances.



Longitudinal distribution of macrozoobenthos following biocoenotic regions in near-natural and hydro-peaking influenced stretches (Drau, February 1989) (details in MOOG and TRAER (1990))

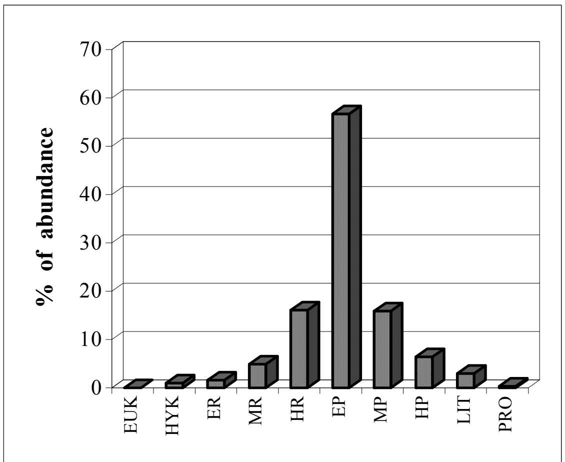
Example 9: Effects of impoundments on longitudinal distribution along biocoenotic regions

Lower Traun

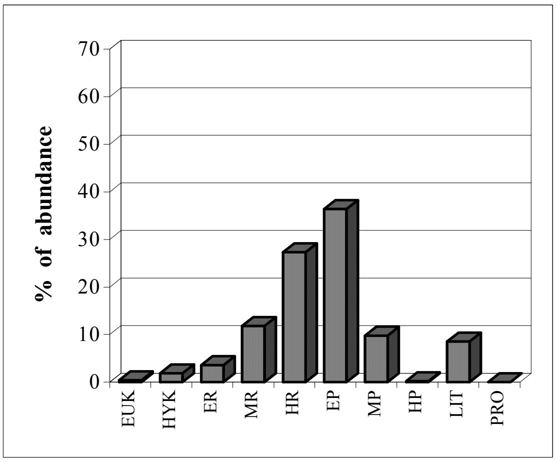
Typological characteristics of the river stretch:
The Lower Traun at Pucking is a 6th order stream, originating in the mixed geologic area of the northern limestone Alps and flowing through deciduous forests with a nivo-pluvialic discharge regime.

Benthic species typical of hyporhithral and epipotamal zones were represented in the impoundment-influenced stretch, with species occurring that are typical of lakes and lowlands (MOOG and GRASSER 1992 b). The first diagram shows the epipotamal natural character of the Traun: downstream from the outlet of the Traunsee, a typical lake-outlet fauna is present. Further downstream from the lake as the influences of the lake decreases (Fischerinsel) the hyporhithral elements are more strongly represented (typical of the transition zone between the barbel region and grayling region). The impoundment of the Traun in Danzermühle results in a shift in community structure to one more resembling typical assemblages of the littoral zones. Further downstream at Steyermühl, the assemblage of this free flowing section begins to resemble the fauna of the hyporhithral-epipotamal zones. The dam at Viecht (power plant Siebenbrunn) has promoted faunal elements typical of the potamal region. The effects of numerous springs emptying into the Traun in this area is evident in the appearance of typical headwater species. In lower reaches of the Traun, the straightening and constricting of the river channel results in an assemblage dominated by elements of the hyporhithral.

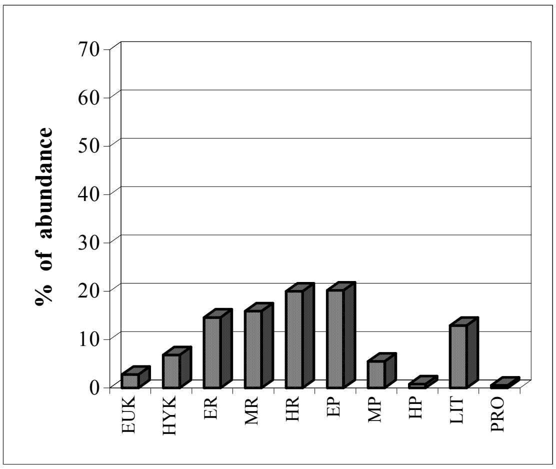
Due to reduced flow velocities in the head race of the impoundment of Marchtrenk (Lichtenegg) additional elements of the littoral and profundal zones can be seen. In the large and relatively deep reservoir behind the power plant Pucking a noticeable increase in profundal faunal elements is found.



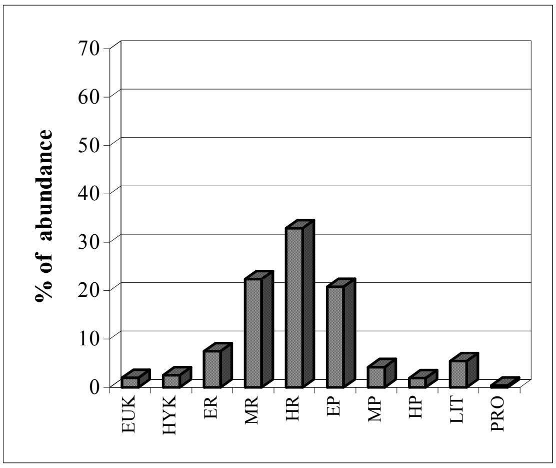
Biocoenotic regions in the Traun downstream the power plant Gmunden (Feb. 1985)



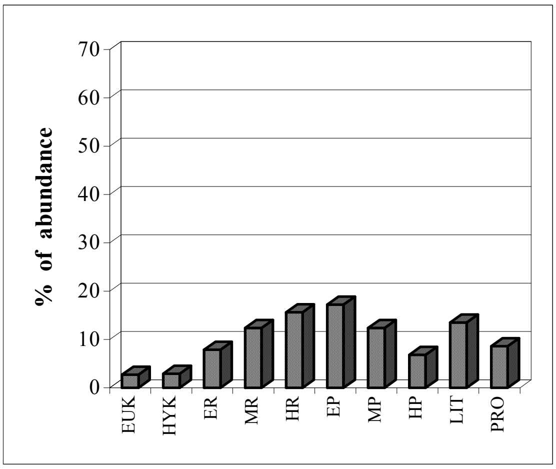
Biocoenotic regions in the Traun in the region of Fischerinsel (Feb. 1985)



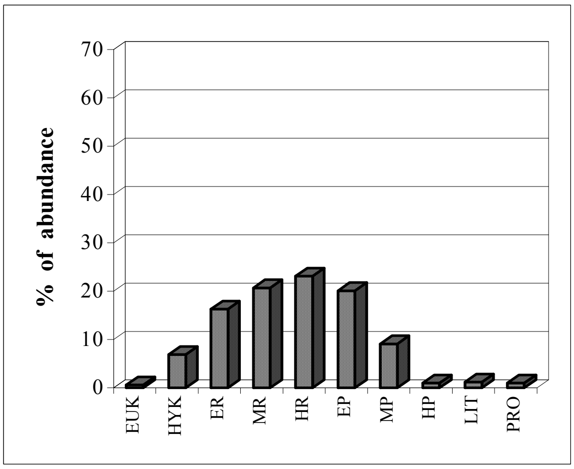
Biocoenotic regions in the Traun in the region of Danzermühl (Dec. 1990)



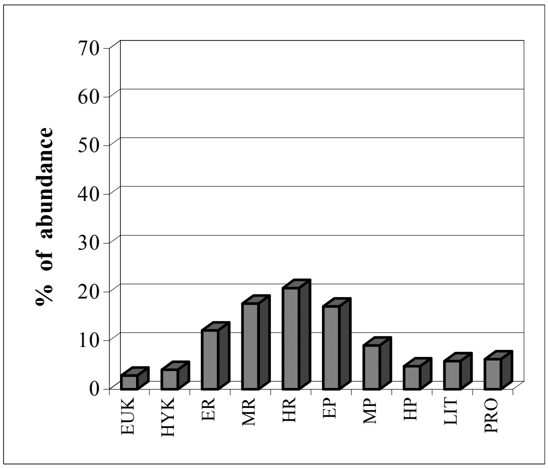
Biocoenotic regions in the Traun in the region of Steyrermühl (Feb. 1990)



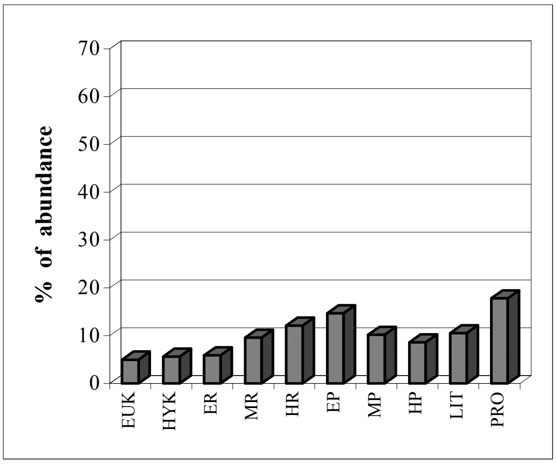
Biocoenotic regions in the Traun in the region of Viecht (Feb. 1990)



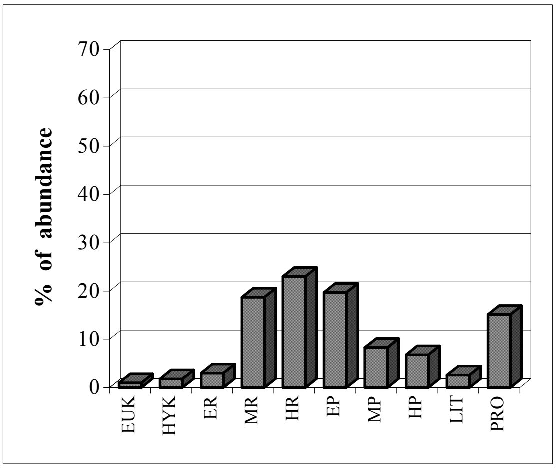
Biocoenotic regions in the Traun in the region of Graben (Feb. 1990)



Biocoenotic regions in the Traun in the region of Wels-Lichtenegg (Feb. 1990)



Biocoenotic regions in the Traun in the region of the impoundment behind the power plant Pucking (Feb. 1990)

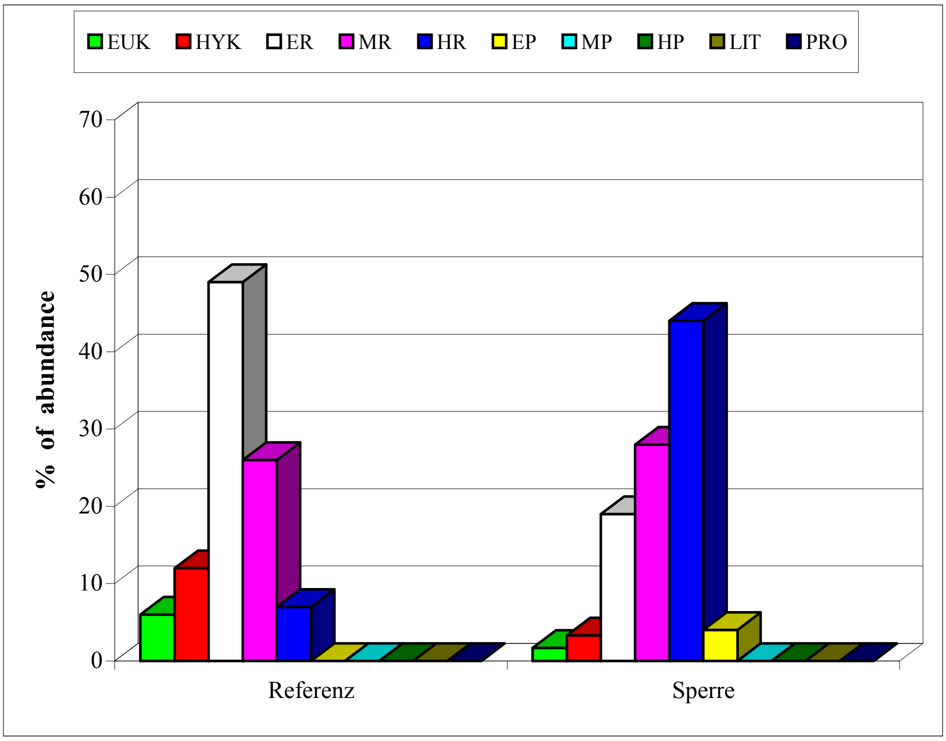


Biocoenotic regions in the Traun in the tailwater below Pucking (Feb. 1990)

Example 10: Effects of bedload suspension on the longitudinal distribution pattern

Ebniterach, System of Dornbirnerach

Typological characteristics of the river stretch:
Ebniterach is a 4th order, montane stream, with a mixed-nivalic discharge regime in the Helvetikum region of the forests of Bregenz. To provide flood water protection for a high population density, about 3000 engeneering measurements (primarily grade-stabilizing structures have beed carried out in an area of only about 150 km^2. The example documents the ecological impacts of one out of these flood protection measures.
Although the lithal fraction of the substrate is always predominant, bedload suspension, in combination with an artificially broadened-river channel, results in an increasing deposition of smaller substrates. The reference site is overwhelmingly dominated by elements of the epirhithral due to the large substrate sizes whereas the fauna in the broadened channel sites consists of more metarhithralic elements (raw data from MOOG, WIMMER and GRASSER (1993)).



Ebniterach: Longitudinal distribution along biocoenotic regions in "natural" stretches and stretches influenced
by bed load retention

The citation of some grey literature was necessary to demonstrate what is supported by extensive data sets. All citations herein can be obtained by contacting the author.

11. References

ANGERMEIER, P.L. and SCHLOSSER, I.J. 1987. Assessing biotic integrity of the fish community in a small Illinois stream. North American Journal of Fisheries Management 7, 331-338.

Amt der oberösterreichischen Landesregierung. Makrozoobenthos-Einstufungslisten für den internen Gebrauch, unveröffentlichte Listen der Abt. Gewässerschutz.

Amt der steiermärkischen Landesregierung.1989. Makrozoobenthos-Einstufungslisten für den internen Gebrauch, unveröffentlichte Listen der Abt. Gewässeraufsicht und Gewässerschutz.

AUSTRIAN STANDARDS M 6232, 1995. Richtlinien für die ökologische Untersuchung und Bewertung von Fließgewässern, Österreichisches Normungsinstitut, Wien.

BENNINSON, G. 1975. An ecological method of classification of the Coal River in southeast Tasmania, B.Sc. Honours Thesis, University of Tasmania.

BRAUKMANN, U. 1987. Zoozönologische und saprobiologische Beiträge zu einer allgemeinen regionalen Bachtypologie, Arch. Hydrobiol./Beiheft 26. 355 pages.

BUTZ, I. 1985. Wassertemperaturen und Gewässer. 4.Teil. Wassertemperatur und Fische , Österr. Fischerei 38, 8/9, 241-244.

CAIRNS, J. Jr.1977. Quantification of biological integrity. in BALLANTINE, R.K. and GUARRAIA, L.J. (Ed.). The integrity of water. Proceedings of a symposium, March 10-12, 1975, U.S. Environmental Protection Agency, Washington D.C.

CAR, M. 1981. Die Simuliiden-Fauna (Diptera) Österreichs und ihre veterinärmedizinische Bedeutung, Diss. Univ. Wien.

CASTELLA, E., RICHARDOT-COULET, M., ROUX, C. and RICHOUX, P. 1984. Macroinvertebrates as "describers" of morphological and hydrological types of aquatic ecosystems abandoned by the Rhone River. Hydrobiologia 119, 219-225.

CHOVANEC, A., HEGER, H., KOLLER-KREIMEL, V., MOOG, O., SPINDLER T. and WAIDBACHER, H. 1994. Anforderungen an die Erhebung und Beurteilung der ökologischen Funktionsfähigkeit von Fließgewässern - eine Diskussionsgrundlage, ÖWAW 11/12, 257-264.

COLEMAN, D.J. 1977. The downstream effects of the Gordon Dam, Lower Gordon River scientific Survey Nr. 10, The Hydro-Electric Commisson, Hobart, Tasmania.

COUTANT, C.C. 1977. Compilation of temperature preference data, J. Fish. Res. Board Can. 34, 739-745.

CROSSKEY, R.W. 1987. An annoted checklist of the world blackflies (Diptera. Simuliidae), in: KIM, K.C. & R.W. MERRITT (Eds.). Blackflies, The Pennsilvania State University, University Park and London, 425-520.

CULP, J.M. and DAVIES, R.W. 1982. Analysis of longitudinal zonation and the river continuum concept in the Oldman-South Saskatchewan River system, Can. J. Fish. Aquat. Sci. 39, 1258-1266.

CUMMINS, K.W. and KLUG, M.J. 1979. Feeding ecology of stream invertebrates, Ann.Rev.Ecol.Syst. 10, 147-172.

CUMMINS, K.W. 1973. Trophic relations of aquatic insects, Ann.Rev.Entomol. 18, 183-206.

CUMMINS, K.W. 1974. Structure and function of stream ecosystems, BioScience 24, 631-641.

CUMMINS, K.W., KLUG, M.J., WARD, G.M., SPENGLER, G.L., SPEAKER, R.W., OVINK R.W., MAHAN, D.C and PETERSEN, R.C. 1981. Trends in particulate organic matter fluxes, community processes and macroinvertebrate functional groups along the Great Lakes Drainage Basin river continuum, Verh. Internat. Verein. Limnol. 21, 841-849.

CUSHING, C.E., MCINTIRE, C.D., SEDELL, J.R., CUMMINS, K.W., MINSHALL, G.W., PETERSEN, R.C and VANNOTE, R.L. 1980. Comparative study of physical-chemical variables of streams using multivariate analyses, Arch. Hydrobiol. 89, 343-352.

DANECKER, E. 1986. Markozoobenthos-Proben in der biologischen Gewässeranalyse, Wasser & Abwasser 30, 325-406.

DITTMAR 1960. zit. ex MAUCH, E. 1976.

ELLENBERG, H. 1986. Die Vegetation Mitteleuropas, 4., verbesserte Auflage, Ulmer Verlag, Stuttgart.

FOISSNER, W., BLATTERER, H., BERGER, H. and KOHMANN, F. 1991. Taxonomische und ökologische Revision der Ciliaten des Saprobiensystems, Band 1. Cyrtophorida, Oligotrichida, Hypotrichia, Colpodea, Informationsberichte des Bayer. Landesamtes für Wasserwirtschaft, Heft 1/91, 478 pp.

FOISSNER, W., BERGER, H. and KOHMANN, F. 1992. Taxonomische und ökologische Revision der Ciliaten des Saprobiensystems, Band 2. Peritrichia, Heterotrichida, Odontostomatida, Informationsberichte des Bayer. Landesamtes für Wasserwirtschaft, Heft 5/92, 502 pp.

FOISSNER, W., BERGER, H. and KOHMANN, F. 1994. Taxonomische und ökologische Revision der Ciliaten des Saprobiensystems, Band 3. Hymenostomata, Prostomatida, Nassulida, Informationsberichte des Bayer. Landesamtes für Wasserwirtschaft, Heft 1/94, 548 pp.

FOISSNER, W., BLATTERER, H., BERGER, H. and KOHMANN, F. 1995. Taxonomische und ökologische Revision der Ciliaten des Saprobiensystems, Band 4. Gymnostomatea, Loxodes, Suctoria, Informationsberichte des Bayer. Landesamtes für Wasserwirtschaft, Heft 1/95, 540 pp.

FOISSNER, W. and BERGER, H. 1996. A user-friendly guide to the ciliates (Protozoa, Ciliophora) commonly used by hydrobiologists as bioindicators in lakes, rivers, and waste waters, with notes on their ecology. Freshwater Biology Vol. 35 (2), 375-482.

FREY, D.G. 1977. Biological integrity of water - an historical approach. in BALLANTINE, R.K. and GUARRAIA, L.J. (Ed.). The integrity of water. Proceedings of a symposium, March 10-12, 1975, U.S. Environmental Protection Agency, Washington D.C.

FRIEDRICH, G. 1990. Eine Revision des Saprobiensystems, Z. Wasser-Abwasser-Forsch. 23, 141-152, Weinheim, BRD.

GRAF, W. and GRASSER, U. 1993. Insecta Untere Thaya. in: ZAUNER, G. 1993 (Verf.). Fischökologische Studie Untere Thaya, unveröffentl. Studie i.A. Wasserstraßendirektion.

GRAF, W., GRASSER, U. and MOOG, O. 1992. The role of *Allogamus auricollis* (Trichoptera. Limnephilidae) in benthic communities of a 4th-order crystalline mountain stream with some ecological notes, Proc. 7th Symp. Trichoptera, Umea, Sweden, 297-303.

GRASSER, U., JANECEK, B.F.U. and MOOG, O. 1991. The effects of human impacts on the macrozoobenthic communities of a 4th order stream (River Mattig, Austria), Proc. 4th ECE/XIII SIEEC, Gödöllö, Ungarn. 450-460.

GULYAS, P. 1983. KGST Biologiai Modszerek, Vizügyi Hidrobiologia 12.

HANUSKA 1956. Handbuch der biologischen Gewässeranalyse, zit.ex MAUCH, E. 1976.

HAWKINS, Ch.P. and SEDELL, J.R 1981. Longitudinal and seasonal changes in functional organization of macroinvertebrate communities in four Oregon streams, Ecology 62 (2), 387-397.

HUET, M. 1949. Aperçu des relations entre la pente et les populations piscicoles des eaux courantes, Schweiz. Z. Hydrol. 11, 3-4, 332-351.

HUMPESCH, U. H. 1981. Ökologische Auswirkungen der thermischen Gewässerbeeinflussung, Wasserwirtschaft - Wasservorsorge. Bundesministerium für Land- und Forstwirtschaft, Wien 1981.

ILLIES, J. and BOTOSANEANU, L. 1963. Problèmes et methodes de la classification et de la zonation ecologique des eaux courantes, considerées surtout du point de vue faunistique, Int. Verein. theor. und angew. Limnologie 12, 1-57.

INFORMATIONSBERICHTE BAYER. LANDESAMT FÜR WASSERWIRTSCHAFT 1993. Biologische Gewässeranalyse in Bayern.

JUNGWIRTH, M. 1995. Allgemeine Hydrobiologie, Skriptum zur Vorlesung, Eigenverlag der Abteilung Hydrobiologie, Fischereiwirtschaft und Aquakultur der Universität für Bodenkultur, 101 pp.

JUNGWIRTH, M., MOOG, O. and SCHMUTZ, S 1990. Auswirkungen der Veränderungen des Abflußregimes auf die Fisch- und Benthosfauna anhand von Fallbeispielen, Landschaftswasserbau 10, 195-234, Wien.

JUNK, W.J., BAYLEY, P.B. and SPARKS, R.E. 1989. The flood pulse concept in river-floodplain systems. in: DODGE, P.D. (Ed.). Proceedings of the international larre River Symposion. Can. Spec. Publ. Fish. Aquat. Sci. 106, 110-127.

KARR, J.R. and I.J. DUDLEY 1981. Ecological perspective on water quality goals. Environmental Management 5: 55-68.

KARR, J.R., FAUSCH, K.D., ANGERMEIER, P.D., YANT, P.R. and SCHLOSSER, I.J. 1986. Assessing biological integrity in running waters: a method and ist rationale. Illinois Natural History Survey Special Publication 5, Champaign, Illinois.

KARR, J.R., YANT, P.R., FAUSCH, K.D. and SCHLOSSER, I.J. 1987. Spatial and temopral variability of the Index of Biotic Integrity in three midwestern streams. Trans. Am. Fish. Soc. 116, 1-11.

KINZELBACH, R. 1990. Besiedelungsgeschichtlich bedingte longitudinale Faunen-Inhomogenität am Beispiel des Rhein, Limnologie aktuell 1, KINZELBACH/FRIEDRICH (Hrsg.). Biologie des Rheins.

KNOZ, J. 1965. To identification of Czechoslovakian Black-Flies (Diptera. Simuliidae), Folia Fac.scient.nat.Univ.Purkyn.Brunensis 6 (5), 1-97.

KNOZ, J. and SASINKOVA, V. 1969. Zur Kenntnis der Kriebelmücken (Diptera. Simuliidae) im Dyje-Gebiet in Morava, Folia Fac.scient.nat.Univ.Purkyn.Brunensis 10 (8), 13-44.

KOHMANN, F., BINDER, W. and BRAUN, P. 1993. Leitbilder für die Erstellung ökologisch begründeter Sanierungskonzepte kleiner Fließgewässer, Langfassung eines Vortrages, Tagung "Wasser" Berlin (30.4.1993).

KOLLER-KREIMEL, V. 1989. Methoden zur Durchführung von Ökotoxizitätstests mit Organismen aller trophischen Niveaus, Wasser and Abwasser 33, 363-371.

KRESSER, W. 1961. Hydrographische Betrachtung der österreichischen Gewässer, Verh.Internat.Verein.Limnol. 14, 417-421.

LAKE, P.S., BARMUTA, L.A., BOULTON, A.J., CAMPELL, I.C. and. ST. CLAIR, R.M. 1988. Australian streams and northern hemisphere streams. comparisons and problems, Proc. Ecol. Soc. Aust. 14, 61-82.

LAMOUROUX, N. 1992. Comment on ‘The nature of the fluid boundary layer and the selection of parameters for benthic ecology’ (CARLING 1992). Freshwater Biology 30, 331-332.

LAMPERT, W. and. SOMMER, U. 1993. Limnoökolgie, G. Thieme Vlg. 440 pp.

LIEBMANN, H. 1951. Handbuch der Frisch- und Abwasserbiologie, Oldenburg, München, 588 pp.

MACMILLAN, L. 1975. Longitudinal zonation of the benthic invertebrates in the Acheron River, Victoria. B.Sc. Honours Thesis, Monash University, Victoria.

MARGREITER-KOWNACKA, M., PECHLANER, R., RITTER, H. and SAXL, R. 1984. Die Bodenfauna als Indikator für den Saprobitätsgrad von Fließgewässern in Tirol, Ber.nat,med. Verein Innsbruck 71, 119-135.

MAUCH, E. 1976. Leitformen der Saprobität für die biologische Gewässeranalyse, Cour.Forsch,Inst. Senckenberg, 21, Bd. 1-5, Frankfurt/Main.

MAUCH, E., KOHMANN, F. and SANZIN, W. 1985. Biologische Gewässeranalyse in Bayern, Informationsberichte Bayer. Landesamt für Wasserwirtschaft 1/85, 254 pp.

MERRITT, R.W. and CUMMINS, K.W. 1984 (Ed.). An introduction to the aquatic insects of North America, Second Edition, Kendall/Hunt Publishing Company.

MINSHALL, G.W., PETERSEN, R.C., CUMMINS, K.W., BOTT, T.L., SEDELL, J.R., CUSHING, C.E. and VANNOTE, R.L. 1983. Interbiome comparison of stream ecosystem dynamics, Ecological Monographs 53, 1, 1-25.

MINSHALL, G.W., PETERSEN, R.C., CUMMINS, K.W., CUSHING, C.E., BURNS, D.A., SEDELL, J.R. and VANNOTE, R.L. 1985 a. Developments in stream ecosystem theory, Can. J. Fish. Aquat. Sci. 42. 1045-1055.

MINSHALL, G.W., PETERSEN, R.C. and NIMZ, C.F. 1985 b. Species richness in streams of different size from the same drainage basin, Am. Nat. Vol. 125, 16-38.

MOL, A. 1978. Skizze einer Typologie europäischer Fließgewässer. Europäisches Übereinkommen zum Schutz internationaler Wasserläufe vor Verschmutzung, Europarat EXP/EAU/ff(77), überarbeitete Fassung, 1-37.

MOOG, O. and JANECEK, B.F.U. 1991. River flow, substrate type and Hydrurus density as major determinants of benthic macroinvertebrate abundance, composition and distribution, Verh.Internat.Verein.Limnol. 24, 1888-1896.

MOOG, O. and TRAER, K. 1990. Fachbeitrag Makrozoobenthos, in: JUNGWIRTH, M., MOOG, O., SCHMUTZ, S. and WIESBAUER, H. 1990. Teilgutachten Ökologie des aquatischen Lebensraumes - Raum- und Umweltverträglichkeitsprüfung der Kraftwerksprojekte Obere Drau I, Gutachten i.A. Amt der Kärntner Landesregierung, Abt. 20 - Landesplanung.

MOOG, O. and WIMMER, R. 1990. Grundlagen zur typologischen Charakteristik österreichischer Fließgewässer, Wasser and Abwasser 34, 55-211, Wien.

MOOG, O. and WIMMER, R. 1994. Comments to the water temperature based assessment of biocoenotic regions according to ILLIES and BOTOSANEANU, Verh. Internat. Verein. Limnol. 25, 1667-1673.

MOOG, O. and GRASSER, U. 1992 a. Limnologische Untersuchung der Mittleren Salzach II - Benthosbiozönotische Studie Mittlere Salzach, unveröffentl. Gutachten i.A. Tauernkraftwerke AG und SAFE.

MOOG, O. and GRASSER, U. 1992 b. Makrozoobenthos-Zönosen als Indikatoren der Gewässergüte und ökologischen Funktionsfähigkeit der Unteren Traun, Wiss. Beitr. zu Traun - Fluß ohne Wiederkehr, Kataloge des OÖ Landesmuseums N.F.Nr. 54, 109-158.

MOOG, O. and GRASSER, U. 1993. Limnologische Beweissicherung Gasteiner Ache - Zwischenbericht II, Teil Makrozoobenthos, unveröffentl. Gutachten i.A. SAFE.

MOOG, O. 1984. Die Auswirkungen organischer Industrieabwässer auf Fische und Bodenfauna eines Voralpenflusses (Ager, Oberösterreich), Mitt. 24. Arbeitstagung der IAD, Szentendre, Ungarn 1984, 171-174.

MOOG, O. 1990. Anforderungen des Makrozoobenthos an naturnahe Umgestaltungen, Wiener Mitt. 88, 55-103.

MOOG, O. 1991. Biologische Parameter zum Bewerten der Gewässergüte von Fließgewässern, Landschaftswasserbau 11, 235-266, Wien.

MOOG, O. 1992. Das Konzept der biozönotischen Regionen - ein Hilfsmittel zur Charakteristik anthropogener Einflüsse auf benthische Fließgewässerzönosen, Erw. Zusammenfassung der DGL Jahrestagung 1992, Bd. II, 622-626.

MOOG, O. 1993 a. Makrozoobenthos als Indikator bei ökologischen Fragestellungen, Landschaftswasserbau 15, 103-143, Wien.

MOOG, O. 1993 b. Quantification of the impacts of daily peak-hydropower effects on aquatic fauna and management to minimize environmental impacts, Regulated Rivers, Vol. 8, 5-14.

MOOG, O. 1994. Ökologische Funktionsfähigkeit des aquatischen Lebensraumes, Wiener Mitt. 120, 15-59.

MOOG, O., JUNGWIRTH, M., MUHAR, S. and SCHÖNBAUER, B. 1993. Berücksichtigung ökolgischer Gesichtspunkte bei der Wasserkraftnutzung durch Ausleitungskraftwerke, Österr. Wasserwirtschaft, Jg. 45, Heft 7/8, 197-210.

MOOG, O., WIMMER, R. and GRASSER, U. 1993. Teilprojekt Limnologie, in. GRABHER, G. (Ed.). Fließgewässerinventur Vorarlberg - Pilotprojekt Dornbirner Ach, Studie i.A. Bundesministerium für Land- und Forstwirtschaft und Amt der Vorarlberger Landesregierung.

PEETERS, E.T.H.M., GARDENIER and TOLKAMP, H.H. 1994. New methods to assess the ecological status of surface waters in The Netherlands. Part 1: Running waters. Verh. Internat. Verein Limnol. 25, 1914-1916.

PARDÉ, M. 1947. Fleuves et Rivières, 3. Aufl., Paris 1947.

POLZER, E. and TRAER, K. 1991. Ökologische Funktionsfähigkeit und biologische Gewässerbeschaffenheit in Fließgewässern und Flußstauen, Wasserwirtschaft, Wasservorsorge, Bundesministerium für Land- und Forstwirtschaft, Wien, 324 pp.

PRINGLE, C.M., NAIMAN, R.J., BRETSCHKO, G., KARR, J.R., OSWOOD, M.W., WEBSTER, J.R., WELCOMME, R.L., WINTERBORN, M.J. 1988. Patch dynamics in lotic ecosystems. the stream as a mosaic, J. N. Am. Benthol. Soc. 7, 4, 503-524.

ROSENBERG, D.M. and RESH, V.H. 1992 (Eds.). Freshwater biomontoring and benthic invertebrates, Chapman and Hall.

SCHIB, J.L. 1991. Die FST-Halbkugelmethode. Eine neue Methode zur Ermittlung der biologisch relevanten hydraulischen Parameter in Fließgewässern ? Diplomarbeit, Institut für Gewässerschutz und Wassertechnologie, ETH Zürich.

SCHMEDTJE, U. 1995. Ökologische Grundlagen für die Beurteilung von Ausleitungsstrecken, Beziehung zwischen sohlnaher Strömung, dem Gewässerbett und dem Makrozoobenthos in Fließgewässern. Schriftenreihe des Bayerisches Landesamt für Wasserwirtschaft, Heft 25, 156 pp.

SCHMEDTJE, U. and KOHMANN, F. 1988. Bestimmungsschlüssel für die Saprobier-DIN-Arten (Makroorganismen), Informationsberichte des Bayer. Landesamtes für Wasserwirtschaft, Heft 2/88, Loseblattsammlung.

SCHMEDTJE, U., KOHMANN, F. and STATZNER, B. 1991. Stream pattern comparison - applying FST-hemispheres in determining instream flow requirements in diverted streams. Verh. Intern. Verein. Limnol. 24, 1869-1871.

SCHMUTZ, S. & WAIDBACHER, H. 1994. Definition und Bewertung der fischökologischen Funktionsfähigkeit im Rahmen von Gewässerbetreuungskonzepten (GBK).- Wr.Mitt.Bd 120, 62-88.

SCHÖNBORN, W. 1992. Fließgewässerbiologie, G. Fischer Vlg. 504 pp.

SCHRÖDER, P. and REY, P. 1991. Fließgewässernetz Rhein und Einzugsgebiet - Milieu, Verbreitung und Austauschprozesse der Wirbellosenfauna zwischen Bodensee und Tauberspießen, IFAH-Scientific Publications Vol. 1.

SCHRÖDER, P., REY, P. and ORTLEPP, J. 1988. Verbreitungsmuster und Ökologie der Simuliidae im Rhein und seinem Einzugsgebiet zwischen Bodensee und Tauberspießen, Vortrag V. Deutschsprach. Simuliiden - Symp. Hamburg 8./9.10.1988.

SCHWEDER, H. (1992). Neue Indices für die Bewertung des ökologischen Zustandes von Fließgewässern, abgeleitet aus der Makroinvertebraten-Ernährungstypologie, Limnologie aktuell Bd. 3. 353-377, G. Fischer Vlg. Stuttgart-New York.

SCHWERDTFEGER, F. 1978. Lehrbuch der Tierökologie, Pareys Studientexte 42. Vlg. Parey Hamburg und Berlin. 384 pp.

SCHWINGSHANDL, A. 1992. Analyse der funktionellen Ernährungsgruppen benthischer Invertebraten im Längenschnitt eines Baches der subalpinen Molasse im Bregenzerwald (Schwarzach, Vorarlberg), Diplomarbeit, Universität für Bodenkultur, 160 pp.

SCHWOERBEL, J. 1993. Einführung in die Limnologie, 7., vollständig überarbeitete Aufl., UTB Nr. 31, UTB-ISBN 3-8252-0031-0.

SEITZ, G. 1992. Verbreitung und Ökologie der Kriebelmücken (Diptera.Simuliidae) in Niederbayern, Lauterbornia 11, 1-230.

SLADECEK, V. 1961. Zur biologischen Gliederung der höheren Saprobitätsstufen. Arch. Hydrobiol. 58 (1), 103-121.

SLADECEK, V. 1964. Zur Ermittlung des Indikator-Gewichtes in der biologischen Gewässeruntersuchung, Arch. Hydrobiol. 60, 241-243.

SLADECEK, V. 1973. Systems of water quality from the biological point of view, Arch. Hydrobiol., Beih. 7.

SLADECEK, V. et al. 1981. Biologicky rozbor povrchove vody, Komentar k CSN 830532.

STANFORD, J.A., HAUER, F.R. and WARD, J.V. 1988. Serial discontinuity in a large river system, Verh. Internat. Verein. Limnol. 23, 1114-1118.

STATZNER, B. and HIGLER, B. 1985. Questions and comments on the Continuum Concept, Can. J. Fish. Aquat. Sci. 42, 1038-1044.

STATZNER, B. and HIGLER, B. 1986. Stream hydraulics as a major determinant of benthic invertebrate stream zonation patterns. Freshwater Biol. 16, 127-139.

VANNOTE, R.L., MINSHALL, G.W., CUMMINS, K.W., SEDELL, J.R. and CUSHING, C.E. 1980. The River Continuum Concept, Can. J. Fish. Aquat. Sci. 37, 130-137.

WARD, J.V. and STANFORD, J.A. 1983. The serial dicontinuity concept in lotic ecosystems, in. FONTAIN, T. D. and BARTELL, S. M. (eds.). Dynamics of lotic ecosystems, Ann. Arbor. Science Publisher Inc., Ann. Arbor. MI., 29-41.

WARD, J.V. and STANFORD, J.A. 1995. The serial discontinuity concept: extending the model to floodplains. in: Regulated Rivers: Research and Management, Vol 10, 159-168.

WEGL, R. 1983. Index für die Limnosaprobität, Wasser and Abwasser 26, 1-175.

WILEY, M.J., OSBORNE, L.L. and LARIMORE, R.W. 1990. Longitudinal structure of an agricultural prairie river system and its relationship to current stream ecosystem theory, Can. J. Fish. Aquat. Sci. 47, 373-384.

WIMMER, R. and MOOG, O. 1994. Katalog der Ordnungszahlen österreichischer Fließgewässer, Monographien Bd. 51, Umweltbundesamt, Wien, 581 pp.

ZAUNER, G. 1993 (Verf.). Fischökologische Studie Untere Thaya, unveröffentl. Studie i.A. Wasserstraßendirektion.

ZELINKA, M. and MARVAN, P. 1961. Zur Präzisierung der biologischen Klassifikation der Reinheit fließender Gewässer, Arch. Hydrobiol. 57, 389-407.

ZELINKA, M., MARVAN, P. and KUBICEK 1959. Hodnoceni cistody povrochvych vod, Ceskoslov. Akademie ved - Slezsky ustav. 155 pp., Opava. zit. ex MAUCH, E. 1976.

ZWICK, H. 1974. Faunistisch-ökologische und taxonomische Untersuchungen an Simuliidae (Diptera) unter besonderer Berücksichtigung der Arten des Fulda-Gebietes, Abh. dtsch. naturforsch. Ges. 33, 1-116.

FAUNA AQUATICA AUSTRIACA

Part III

Abbreviations

MINISTERIUM
FÜR EIN
LEBENSWERTES
ÖSTERREICH

Directory of abbreviations used in the catalogue

Saprobic catagorization:

x	Xenosaprobic level
o	Oligosaprobic level
β	Beta-mesosaprobic level
α	Alpha-mesosaprobic level
p	Polysaprobic level
G	Indikator weight
SI	Saprobic index

Eusaprobity:

i	Isosaprobic level
m	Metasaprobic level
h	Hypersaprobic level
u	Ultrasaprobic level

Longitudinal distribution along biocoenotic regions:

EUC	Eucrenal
HYC	Hypocrenal
ER	Epirhithral
MR	Metarhithral
HR	Hyporhithral
EP	Epipotamal
MP	Metapotamal
HP	Hypopotamal
LIT	Littoral
PRO	Profundal

Functional feeding guilds:

SHR	Shredders
GRA	Grazers
AFIL	Active filter-feeders
PFIL	Passive filter-feeders
DET	Detritus feeders (gathering collectors)
MIN	Miners
XYL	Xylophagous
PRE	Predators
PAR	Parasites
OTH	other feeding types

For a more precise definition of the respective abbreviations, see Part II (introduction to the first delivery, methodological principles and application examples for the use of the catalog) of Fauna Aquatica Austriaca (Chapter 5).

Note symbols

The symbol star (*) has been replaced by two plus signs (++).

FAUNA AQUATICA AUSTRIACA

Part IV

Protozoa, Ciliophora -

species inventory,

saprobic valencies, eusaprobity,

ecological characteristics

MINISTERIUM
FÜR EIN
LEBENSWERTES
ÖSTERREICH

FAUNA AQUATICA AUSTRIACA

Part V

Metazoa –

species inventory, saprobic valencies, longitudinal distribution, functional feeding guilds - species level

FAA

MINISTERIUM FÜR EIN LEBENSWERTES ÖSTERREICH

FAUNA AQUATICA AUSTRIACA

Part VI

Functional feeding guilds -

family/genus level

MINISTERIUM
FÜR EIN
LEBENSWERTES
ÖSTERREICH

FAUNA AQUATICA AUSTRIACA

Part VII

Sensitive taxa

FAA

BOKU

IHG

MINISTERIUM
FÜR EIN
LEBENSWERTES
ÖSTERREICH

FAUNA AQUATICA AUSTRIACA

Part VIII

Aquatic Invertebrate Neozoa

MINISTERIUM
FÜR EIN
LEBENSWERTES
ÖSTERREICH