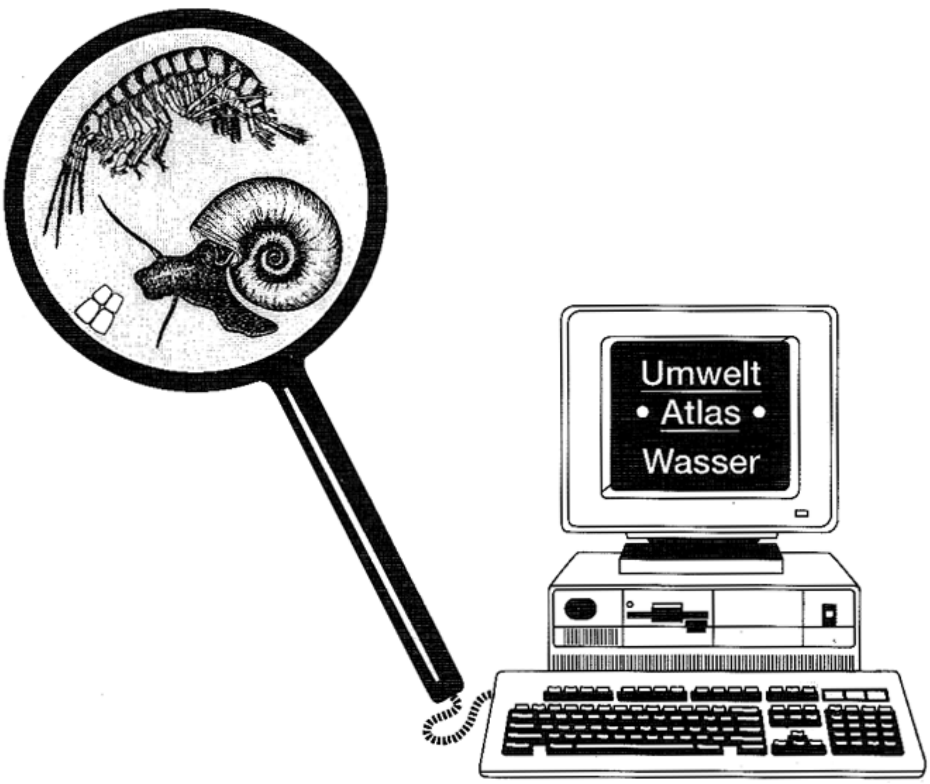
HANDBOOK
BIOLOGY

Reno Graffitti

Biological testing of water quality



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PHYWE – Series of publications

Reno Graffitti

Handbook
Biological Testing of Water Quality

– Methods for testing quality of freshwater with bioindicators –

– Practical procedures for subject and project teaching in general secondary schools –

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Theoretical part

Practical part

1. THE FRESHWATER BIOTOPE

Limnology (Definition: *The science of the life processes, the organisms and their environmental relationships, in standing and running fresh water*) deals with a large number of different freshwater biotopes.

These can be roughly divided into *running water* (the region of the source of running water, brooks, rivers) and *standing water* (lakes, natural and artificial ponds, pools).

In contrast to running waters, in which the waterbody is more or less continually moving in a water bed as a "flowing wave", the waterbody in the restricted water basins of standing waters is still, or only circulates in phases (e.g. the Spring and Autumn circulation of Central European dimictic lakes).

Whereas standing water is bounded on all sides by land, running waters are systems which are open upwards and downwards, and these allow a back and forth transport of dissolved and undissolved substances in the water.

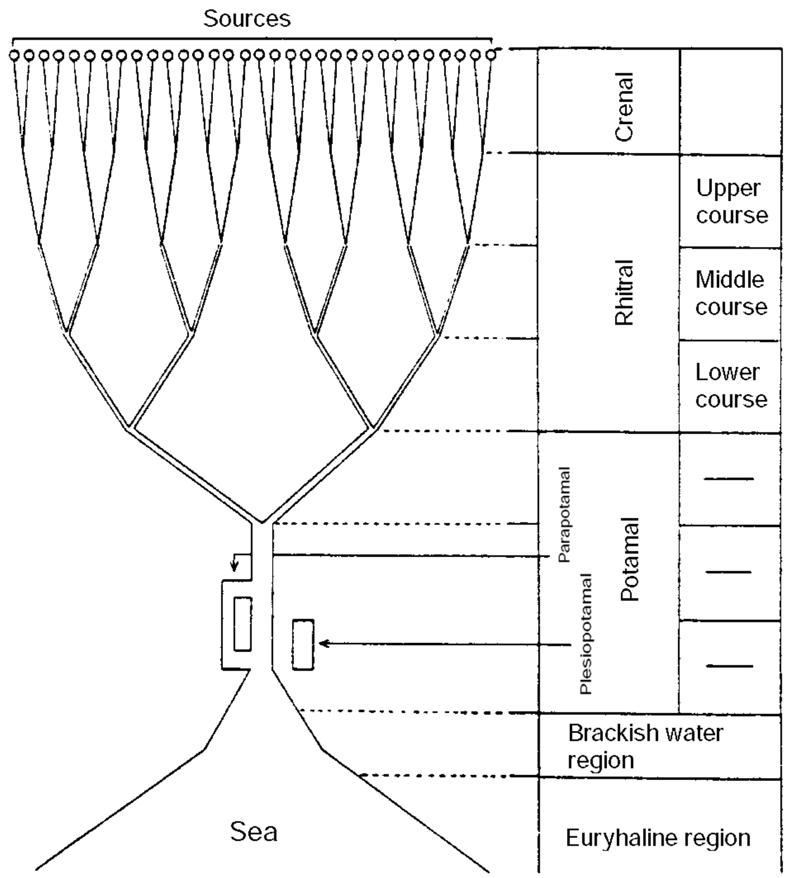
There is no circulation of the water and of nutrients here, but a directed transport towards the mouth or estuary. The milieu factors do not change vertically, as in a lake, but in a downstream direction from the source onwards.

There is a flowing transition between running and standing waters or their segments in the truest sense of the word. With decreasing flow rate, the deeper zones of running water increasingly resemble lakes. The living conditions approach each other, as is indicated by a greater conformity of the life communities. Species are frequently to be found in lower courses, which are also present in standing water.

1.1. Classification of running and standing waters and their biocoenological definition

Running waters are roughly divided into the source, brook and river regions (Fig. 1), which are characterized by different life communities. Those in brooks have been most intensely examined, are most easily reached for examination, and so are also most suitable for examination by students.

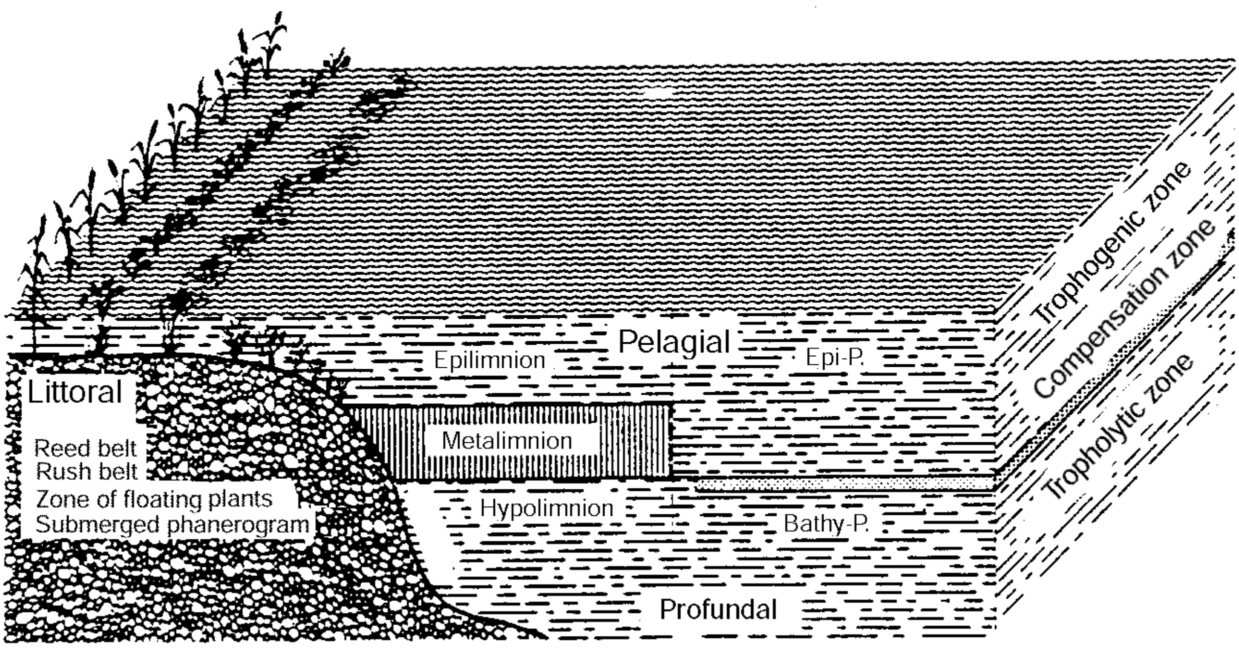
Fig. 1: Regional classification of running waters, as source (crenal), brook (rhitral), river (potamal), brackish water (estuary) and euryhaline (sea).
Parapotamal: Backwater with connection to the main river.
Plesiopotamal: Backwater without connection to the main river = standing water



Usually, about 1/10th of all German plant species can be found among the aquatic, bog and waterside plants in or around running water. On the other hand, almost all running water plant species can be found in other biotopes, such as lakes, ponds or ditches. As a result of the greater diversity of abiotic conditions, however, the species-richness of the macrophytic flora is considerable larger in or around running water, especially in the waterside region, than it is in lakes, for example.
The running water fauna is particularly rich in species, whereby the share of specialized species is exceptionally high. This is shown by a comparison of fresh water habitats, as the number of specialized animal species in running water is about three times higher than that in lakes. This wide variety is primarily conditioned by the large number of ecological niches of the *brook region*. The diversity of the running water specialists in the other regions is far less than that in this specific biotope. The insects are the determining group under the animal species, with more than 3,200 species.
The similarity between the fauna in the waterside regions of running waters and lakes is remarkable.
Standing waters can be divided into those which are permanent or *perennial (e.g. lakes and naturally formed ponds)* and those which are *temporary (periodic; e.g. pools)*.

Lakes which have a depth of a few metres, or up to 1,000 metres, have a relatively large waterbody and a wide variety of biotopes in various areas. The boundaries of these zones in a lake are predominately conditioned by two factors: The irradiation by sunlight and the position in relation to the bottom of the lake. The structure of the lake which results from these basic conditions is shown in simplified form in Fig. 2.
In examinations of waters, two regions of a lake are of great importance: The littoral (lakeside) and the pelagial (open water zone).
The mass of the phytoplankton is in the pelagial, which is primarily responsible for the first-order production, and so determines the trophic level. We are dealing here with plants which form glucose from the inorganic components H_2O and CO_2 with the help of sunlight, by means of photosynthesis. These carbohydrate molecules can now be converted in various metabolic processes to fats and proteins, or be decomposed again by respiratory and fermentation processes, for the purpose of producing energy. For a sound scientific examination of such water and a resulting evaluation of the water quality, therefore, extensive measurements must be made over a longer length of time, mostly in the pelagial but also in other regions.
The *determination of the water quality of standing water* is carried out according to the trophic system.

Fig. 2: Zonation of a lake with the various biotopes



The phytoplankton is to found in the transilluminated, trophogenic part of the pelagial, the so-called epipelagial or (according to thermal currents and the condition with regard to oxygen) also epilimnion. The synthesis processes take place here, in dependence on sunlight.
The phytoplankton has a typical seasonal distribution, which is dependent on various factors (e.g. incidence of light, availability of nutrients, oxygen content, consumption by consumers, Fig. 3).
The mass of the zooplankton (rotifers, small crustaceans) are to be found in the epilimnion, which feeds on the phytoplankton. The dependence of these organisms on the food supply (phytoplankton) can be seen from vertical stratification diagrams (Fig. 4).
When the supply of food decreases, the dead organisms (*detritus*) sink into the depths. Autolytic and bacterial decomposition increasingly take place in the tropholytic zone of the pelagial, the bathypelagial. In a deep, extensively unpolluted lake, the detritus is completely mineralized as it floats down to the aphotic bottom. The oxygen required for this is available in sufficient amounts, despite the typical horizontal stratification in Central European lakes of this quality. In shallow lakes, the mineralization is continued more intensively on the lake bottom. The higher colonization density of the bottom zone results in a correspondingly high consumption of oxygen, and can even lead to a complete exhaustion of it. Replenishment is not possible, because of the horizontal stratification.

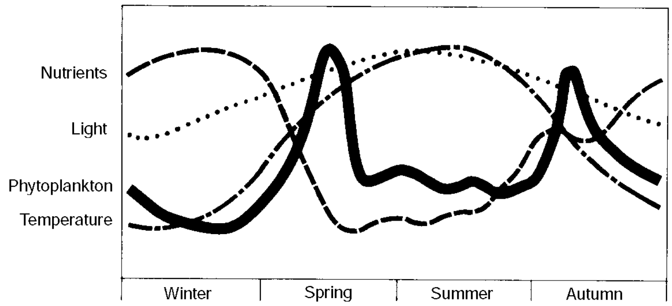
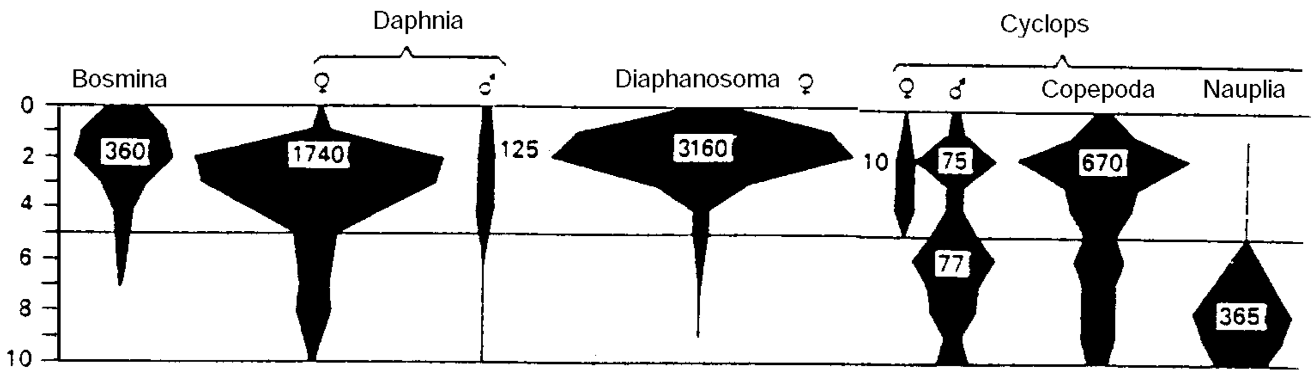


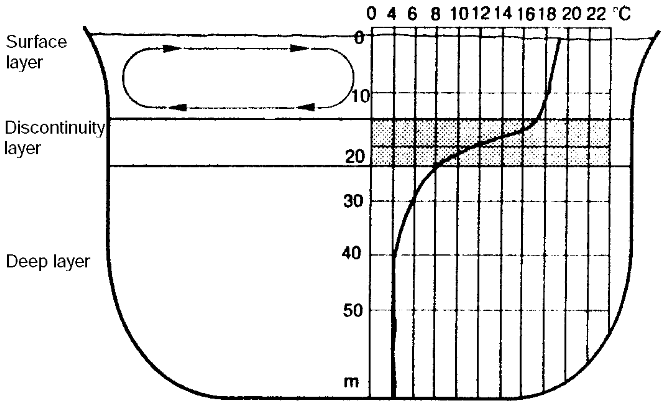
Fig. 3: Seasonal distribution of phytoplankton in a lake

The stratification in Central European lakes is thermally conditioned.
In summer there is a warm upper layer (epilimnion) above a cold deep layer (hypolimnion). In the discontinuity layer between these (metalimnion), the water temperature drops abruptly. Temperature equalization between the layers is not possible, because of the low *heat conductivity of water*.

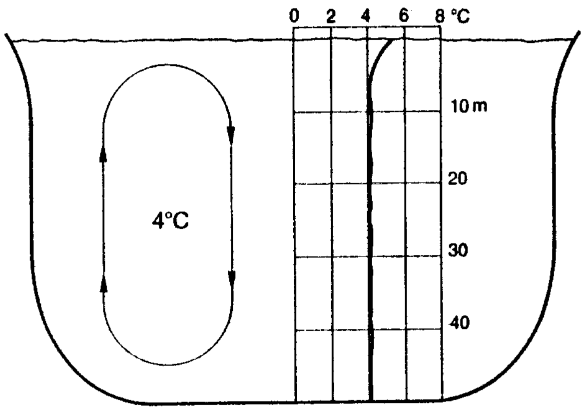
Fig. 4: Vertical stratification diagrams of zooplankton in a lake
Representation of the vertical distribution by "spherical curves"; amount of plankter per litre as 3rd root of the number of individuals divided by 4.19 (spherical radius);



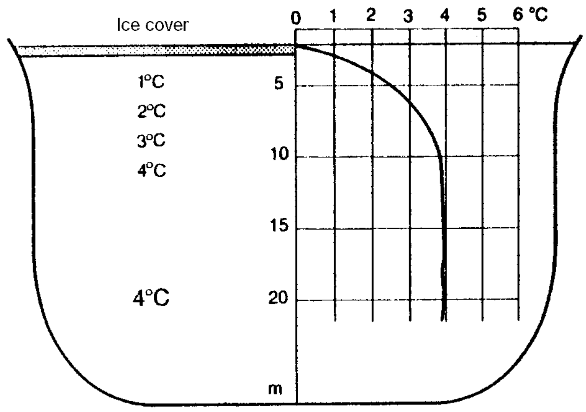
As a result of the so-called density anomaly of water (water has its highest density at a temperature of +4°C; density = 1 g/cm^2), there is in this phase no thorough mixing of the approx. +4°C cold and heavy water of the hypolimnion with the epilimnion (summer stagnation).
There is also, therefore, no possibility of material transport or gas exchange between the layers.
As the air temperature drops with the approach of Autumn, the temperature of the water in the epilimnion layer also drops. The difference in density slowly disappears, so that, under the influence of wind, a complete turnover of the whole body of water can occur. This effects a uniform distribution of the nutrients which were enriched in the profundal and of dissolved gases over the whole body of water.
Towards winter, a new stratification is given as a result of the sinking surface temperature (e.g. as far down as the freezing point of water). The low heat conductivity and the relatively large depth of lakes prevents the freezing of the whole waterbody. After this phase of Winter stagnation, the surface temperature of the water increases again towards Spring, and there is again a complete turnover of the body of water and so a renewed material equilibration (Fig. 5).
Lakes which experience such a complete turnover twice each year are designated dimictic (Lake Constance turns over only once, in Winter, and is therefore said to be warm-monomictic).
The many and diverse, frequently changing conditions for the various life communities of the differing biotopes in the pelagial (and profundal) layers of a lake make clear the differences to shallow stretches of water, as well as to running waters.
The *littoral* is characterized by the presence of many higher plants (reeds, rushes, floating plants). Many points of the habitat conditions are similar to those in comparable zones of running waters. This is also true of the life communities.
Naturally formed ponds, frequently of less than 2 metres depth, are mostly terrestrializing lakes. As shallow waters, they have no differentiation into littoral and profundal. As a rule, sunlight reaches through to the bottom of them, so that aquatic plants can be found everywhere. The habitat conditions are comparable to those of the littoral of lakes. Because of the relatively small mass of waterbody, which is also subjected to large annual and seasonal variations, the natural or anthropogenic input of even only small amounts of nutrients or organic material (e.g. falling leaves in Autumn) can lead to eutrophication.
Man-made ponds are ponds made by hollowing or embanking, or ponds with artificial drainage. They can therefore be allotted to the temporary standing waters.
Pools also belongs to the *temporary standing waters*. They are small, shallow bodies of water without an ephotic deep zone, which dry up at times. In alpine areas they are also known as "Lache", which is equivalent to puddles. Like the naturally formed ponds, they show in principle a remarkable organism-richness in a very small space. The sensitivity to inputs from neighbouring ecosystem is also



Summer stagnation in a lake: Summer temperature profile



Complete turnover in a lake: Autumn-Spring temperature profile



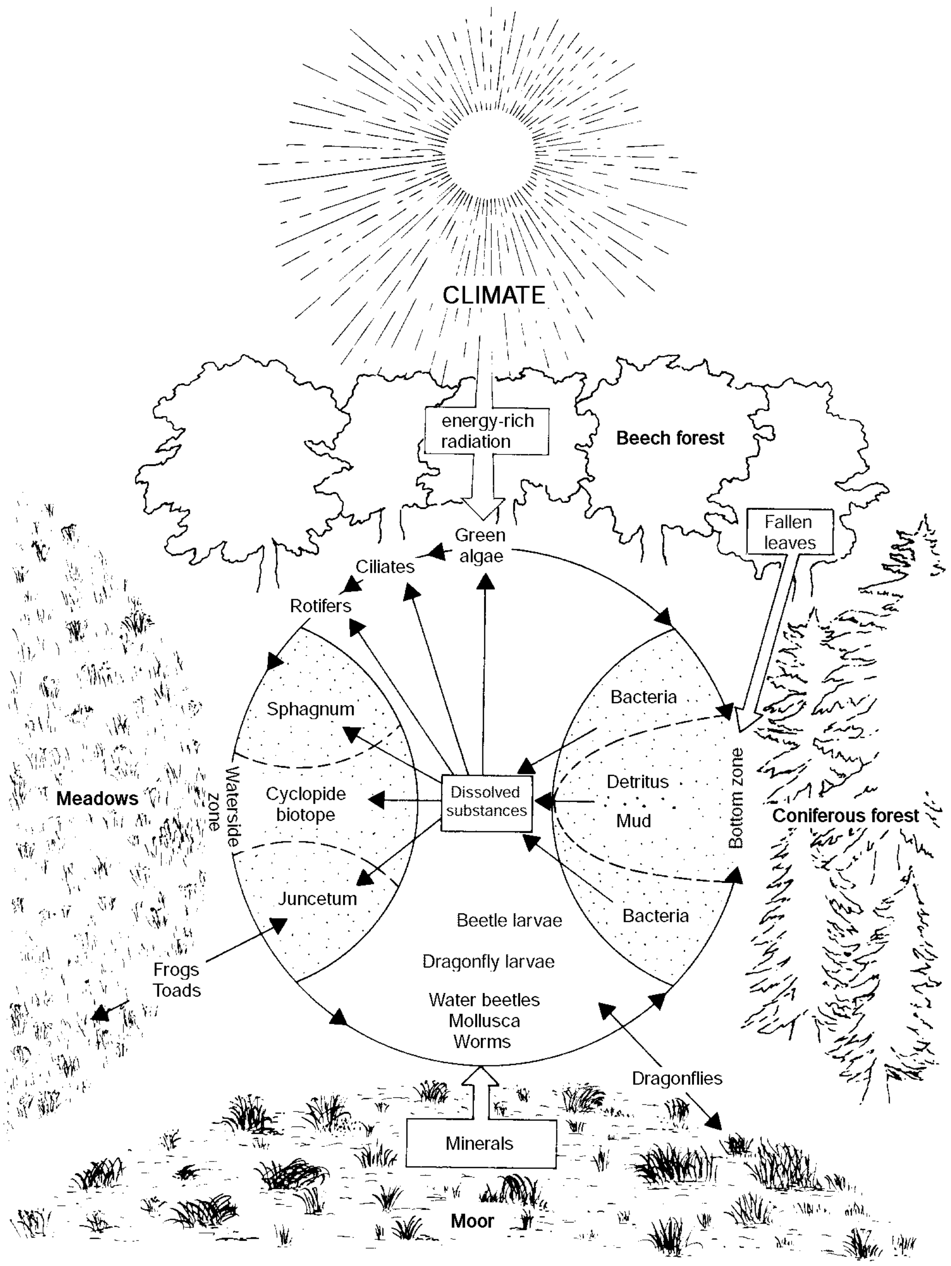
Winter stagnation in a lake: Winter temperature profile

Fig. 5: Seasonal stagnation and circulation phases in a dimictic Central European lake

comparable. The manifold relationships to neighbouring biotopes are shown in Fig. 6.

Characteristic for the organisms of a life community in such periodic waters is their ability to survive drying out in Summer and freezing in Winter. Special adaptation mechanisms are required for this, particularly in development and reproduction. Many of the organisms in these life communities are capable, under optimal conditions, to bring forth an exceptionally large number of progeny at a very early age and in a very short time (e.g. daphnia magna, up to 60 progeny every 3 days from an age of approx. 7 days onwards). Further to this, they are capable of cyst development as a dryness resistant stage, of leaving the habitat when living conditions deteriorate (insects capable of flight, amphibians etc.) or of surviving long dry periods by burying themselves in mud. According to, e.g. the kind of soil, the pH value, the nutrient content, the day-night temperature amplitude (high mountains) and the periodicity of drying out, there is an enormous multitude of types of pools with different species-richness. A classification, as made for lakes, is not possible. Each pool must be treated as an individual case and be monographically described.

Fig. 6: Pools in a deciduous forest: Relationships to the neighbouring ecosystems, material input and course of the food chain



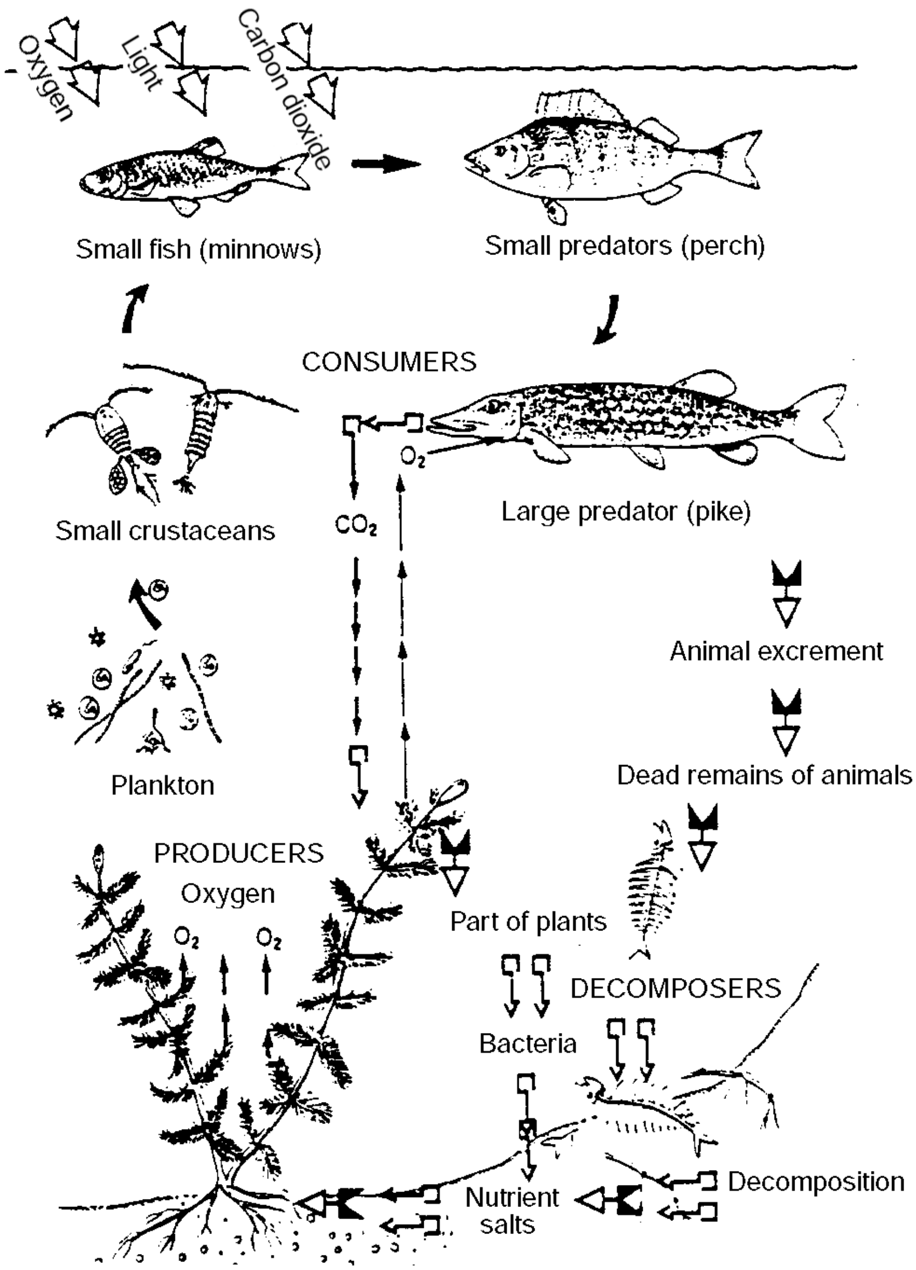
1.2 Energy flow and material conversion in freshwater habitats

Running waters in the vicinity of the source, just as glacial lakes, are characterized by an extreme nutrient deficiency. This was also true for many Central European lakes at the end of the last Ice Age. They were formed in the course of the thawing process of the gigantic masses of ice. Inorganic nutrients, in particular phosphates and nitrates, were and are not present, or only present in very small amounts, in such waters.

The process which has, over thousands of years, formed from the nutrient-deficient (oligotrophic) postglacial lakes the, to a large extent moderately productive (mesotropic) lakes or nutrient-rich, highly productive (eutrophic) lakes, takes place in a principle within a short time during the course of running water from the source to the mouth: *The continual increase in the concentration of nutrients in the water.*

This increase is conditioned by the continual input of biomass into the water and tends to take place naturally (such as by input from feeder streams, inputs of organic substances or minerals blown by the wind, elution from the bedsoil), without human influence. These processes are, however, persistently promoted by anthropogenic influences (such as by domestic wastewater and fertilizers). The organic substances are rapidly decomposed, so that, after their conversion to inorganic nutrients, the basis is given for a continual increase in the production of biomass.

Fig. 7: The food web of a lake



The phytoplankton (green or blue algae, diatoms, autotrophic bacteria) and the higher aquatic plants are thereby the producers (*first-order producers*), synthesizers of energy-rich organic substances: Carbohydrates, proteins, fats. The basic process is *photosynthesis* (or CO_2 assimilation). In this process, under the catalytic effect of chlorophyll, with the help of energy from the sun, and simultaneously with the photolytic splitting of water, the CO_2 dissolved in the water is converted to glucose. Oxygen is a not unimportant by-product of this reaction.

With the production of glucose, conversion to proteins, fats and other organic substances by various further reaction paths is made possible.

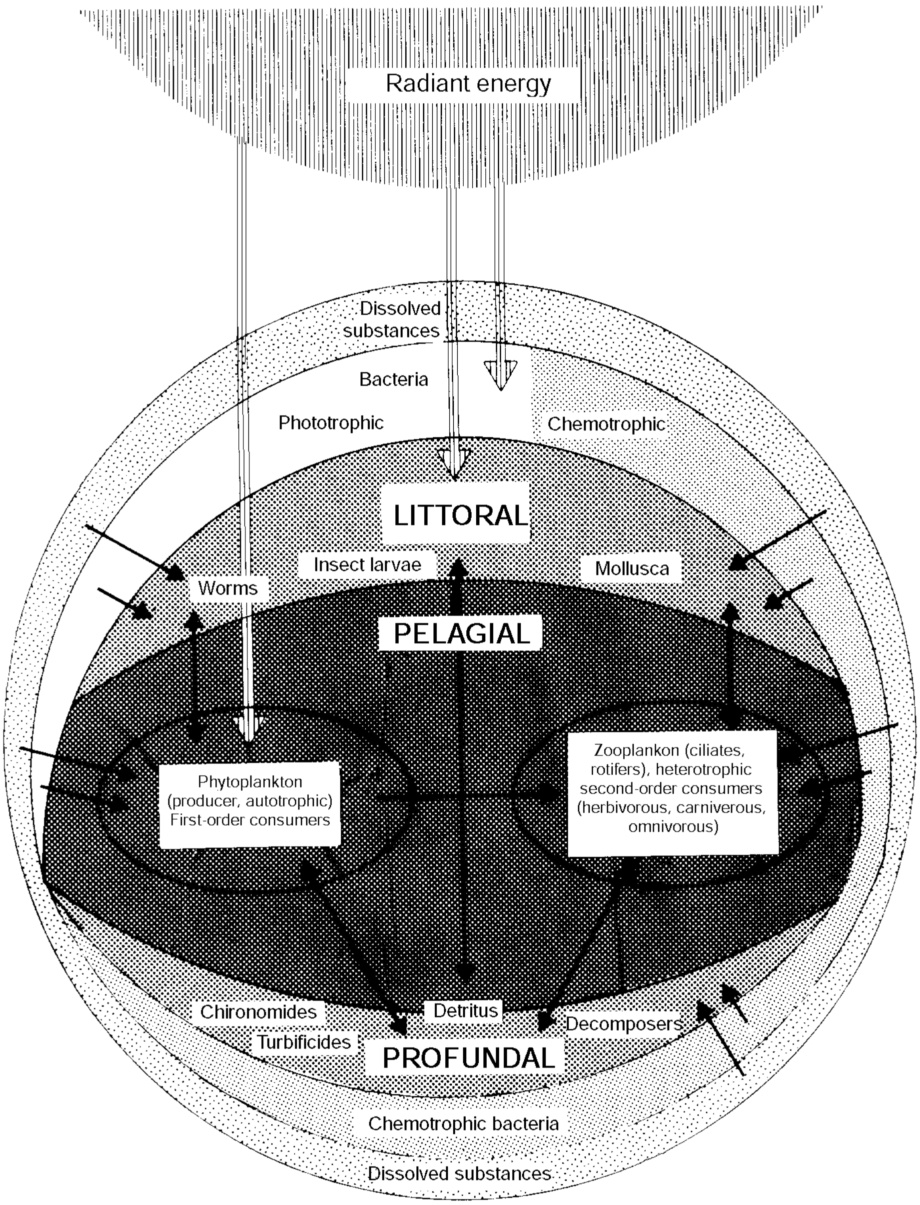
In first-order production of biomass by photoautotrophic organisms, only approx. 1% of the energy radiated by the sun is utilized.

The intensity of the organic photoautotrophic first-order production has been called trophy (gr. trophein = nourish). *Primary producers* are in the 1st trophic level. The organisms of the zooplanktons (e.g. rotifers, water-fleas) feed on the primary producers, and as plant-feeders (herbivore), and so *first-order consumers*, are in the 2nd trophic level. These herbivores are themselves fed on by second-order consumers (e.g. phyllopods, dragonfly larvae) of the 3rd trophic level.

Such a food chain leads finally to the final consumers (e.g. pike, birds of prey; Fig. 7).

The description given here on the relationships between the various trophic levels is highly simplified. As a rule, there are organisms in the various aquatic life communities which, as consumers at a certain trophic level, are at the same time fed on by other organisms of the same trophic

Fig. 8: Energy and material turnover in a lake



level (e.g. phyllopods feed on water-fleas, but both are fed on by dragonfly larvae). For this reason, it is preferable to speak of a *food web*. The smaller the meshes of this network, i.e. the greater the diversity of the food relationships and the larger the number of organisms in the life community of a biotope, the more stable is the biological equilibrium of the corresponding ecosystem.

The nutrients formed or taken in by the organisms serve on the one hand to synthesize endogenous substances and on the other hand as energy depot for the various life processes (e.g. movement, reproduction etc.). The respiratory processes necessary for these result in a loss of part of the energy contained in the nutrients in the form of heat energy.

The flow of energy in an ecosystem is therefore characterized by the fact that between approx. 60% and 90% of the quantity of energy passed on from one trophic level to the next is lost during such processes. In aquatic systems, the loss is relatively low, however, as the life processes take place more economically here than in terrestrial systems (aspects: e.g. movement, transpiration).

With the determination of the biomass of the phytoplankton, in relation to the unit area and volume of the lake, an adequate basis is obtained for a judgement of the total first-order production. The first-order production in a lake results predominately from the pelagial phytoplankton. On exclusively examining the circumstances of the littoral, the share of higher plants in synthesizing first-order production is distinctly higher. Fig. 8 shows an approximation (the real situation is naturally dependent on the size of the particular lake) of the conditions of the energy and material turnover in a lake. The biomass formed as first-order production by the pelagial phytoplankton, and successively to this by the zooplankton, is ultimately a measure of the trophic condition and so of the "burdening" of a standing water with nutrients.

Biological and chemical examinations of vertical profiles, among others, serve to classify the trophic status.

These are carried out at the anticipated end of the summer stagnation, and to determine the oxygen content repeatedly at regular intervals over the whole year.

The flow of energy through the various trophic levels is accompanied by a *circulation of materials* through the food web. The heterotrophic organisms (consumers of various orders) need the amounts of energy taken in with organic material, and available to them, to maintain their life processes. The organic compounds are thereby subject to a constant reduction. The organisms finally even excrete organic substances or come themselves, as dead bodies, into the subsequent mineralization process, at the end of which only the individual elements are left. The individual elements are now available to the photoautotrophic organisms (producers) for the synthesis of new organic materials. Nitrogen and phosphorus compounds play an important role here.

The *mineralization processes*, which are also called *self-purification*, are carried out by the *reducers* (or also *decomposers*). They decompose organic substances to water, carbon dioxide, nitrates, phosphates and sulphates, and in doing so win energy and consume oxygen. These decomposition processes are oxidation processes, in contrast to the synthesis processes of CO_2 assimilation. The decomposition takes place over a long chain of interacting processes, in which, alongside the larger detritus feeders (e.g. insect larvae), above all innumerable bacteria and fungi participate as mineralizers.

The initial condition is again attained when

1. these processes are not continually supplied with additional nutrients or organic compounds, or
2. when sufficient oxygen is available for aerobic decomposition processes and simultaneously the nutrients formed at the end of the decomposition chain are removed from the cycle. This is usually possible in running water by washing away, but is, however, the *great problem* for the self-purication of standing water. The possibilities of removing them are very limited (e.g. the phosphate ions liberated in the decomposition process could, in the presence of oxygen and Fe^{3+} ions, be converted to the sparingly soluble iron-III-phosphate and so be removed from the cycle: "Phosphate trap".

The processes described take place in an unburdened water in biological equilibrium. Here, the relationship between producers, consumers and decomposers is "balanced".

External disturbances (e.g. from natural or anthropogenic inputs) result in a chronologically displaced, interdependent oscillation of the numbers of individuals in the various groups of organisms (a massive multiplication of bacteria leads to phytoplankton growth, which conditions an increase in the zooplankton etc.. Finally, the original condition is more or less reached again by a self-purification).

There, where the disturbances are very great, or exert their influence over a longer period of time, the biological equilibrium of the water is shifted. The nutrients which are additionally formed from the mineralization process increase the circulation of materials. The progressive enrichment with plant nutrients causes luxuriant plant growth, with far-reaching effects on the total balance of the waterbody concerned: The result is eutrophy, the "progressive degeneration" of the body of water.

A comparison of the profiles of oligotrophic and eutrophic bodies of water demonstrates the differences (see Fig. 9). Comparative figures make the difference in productivity in variously burdened waters evident: The 24 hour photosynthesis performance is, for example, 0.065 mg/l CO_2 in oligotrophic lakes, already 0.206 mg/l CO_2 in mesotrophic lakes and finally 7.202 mg/l CO_2 in eutrophic lakes. The biomasses formed can be derived directly from these measurement results. The productivity is therefore approx. 2 powers of 10 higher in strongly burdened (eutrophic) bodies of water than in unburdened, so-called oligotrophic bodies of water. The mineralization processes therefore require a corresponding quantity of oxygen, for the decomposition processes to run under aerobic conditions. When the supply of oxygen is exhausted (e.g. in the hypolimnion

of eutrophic lakes), minerilization is incomplete, reducing processes increasingly occur (activity of the anaerobic organisms). Oxygen is thereby withdrawn from inorganic substances, such as nitrates and sulphates. Carbon dioxide, ammonia, methane and hydrogen sulphide are increasingly produced. This is known as *foulness*. The result is, e.g. with eutrophic and polytrophic lakes, a large muddy zone at the bottom, which finally leads to terrestrialization of the lakes. The entirety of the *heterotrophic bioactivity*, the *saproby*, takes care of the decomposition of the organic substances in the body of water.
Saproby stands in this respect directly opposite to trophy, as complementary phenomenon.
In the self-purification processes, which are primarily carried out by the bacteria, and in the course of time (standing water) or of the purification stretch (running water), qualitatively different water zones (saprobic zones) with characteristic life communities of plant and animal organisms originate. The examination of such life communities allows sure conclusions to be drawn on the quality of the body of water. Whereby the following applies: "The indicator properties of an organism are all the more significant, the higher the degree of contamination which it indicates".
The saprobic classification is the recognized method for determining the water quality of running water.

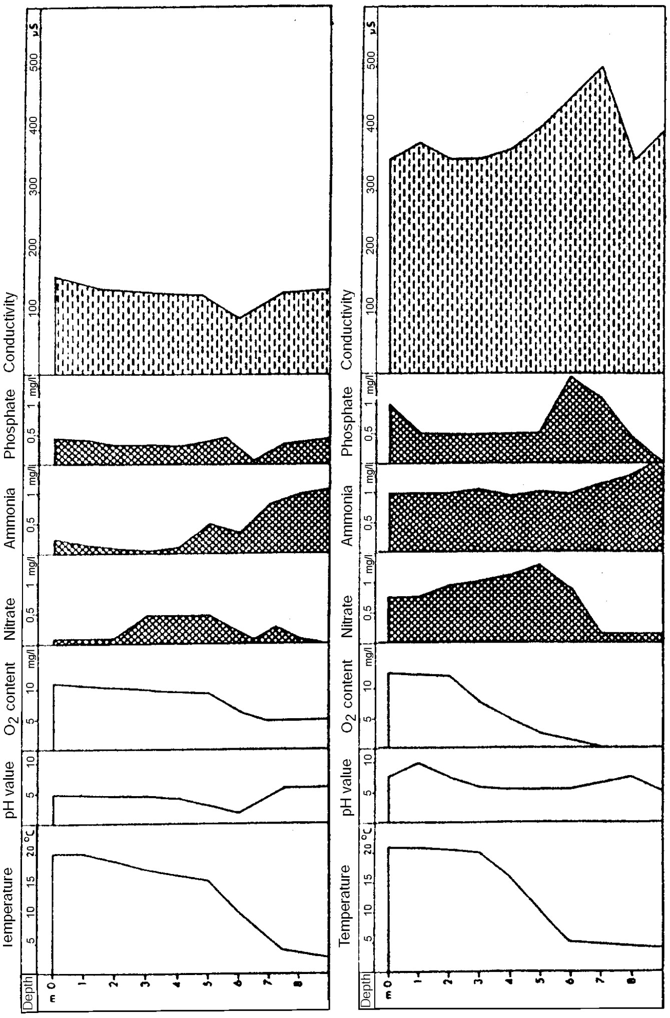


Fig. 9: A comparison of the profiles of a low-nutrient (oligotrophic) and a nutrient-rich (eutrophic) body of water;

2. NATURAL AND ANTHROPOGENIC CHANGES IN BODIES OF WATER – TROPHIC LEVELS AND THE SAPROBIC CLASSIFICATION FOR DETERMINING WATER QUALITY

The lakes which were formed in Central Europe after the end of the last glacial period were in a pronounced nutrient-poor (oligotrophic) condition to start with. Visibility to depths of more than 20 metres and high concentrations of oxygen throughout the whole body of water (at the end of the stagnation phase, deep water is also still saturated with more than 70% oxygen) are already indications of a very low level of plankton production. The cause of this, the nutrient deficiency in such lakes, was changed by natural causes over a period of thousands of years: The supply of nutrients was increased by minerals which were eluted from the soil, and in part also blown in by the wind, and by the organic substances, e.g. fallen leaves, which found their way into the lake.

This increase in the supply of nutrients, which conditioned an increase in the plankton production, and the mineralization processes which occurred later, altered the chemico-physical conditions: The visibility greatly decreased (down to 2 metres) and the concentration of oxygen at the end of the stagnation phase was now only 30% to 70%. The way in which such a mesotrophic lake (low-burdened body of water) is formed can, however, still be explained by *natural lake senescence*.

Another dimension of the deterioration of water quality is conditioned by anthropogenic pollution.

The *water pollution caused by man* has various causes and lasting consequences for the habitats of many biotopes. The discharge of organic wastes, the increased entry of inorganic fertilizers and animal manure and the entry of detergents containing phosphates, have radically changed the nutrient conditions in many Central European lakes in a relatively short time: *The lakes eutrophicate.* In these nutrient-rich lakes, the production of plankton increases dramatically (visibility in part far less than 2 metres), The remineralization processes consume the deep water oxygen supplies (at the end of the stagnation period, the saturation in such lakes is between 0% and 30%), and anaerobic putrefactive bacteria almost exclusively take over the decomposition work. Alongside the liberation of putrefactive gases (hydrogen sulphide, methane), anaerobic sludge remains on the lake bottom. The nutrient salts which are formed, together with newly entered substances, lead to an increased bio-production in the next vegetation period.

These processes, which took on particularly catastrophic dimensions in the sixties and seventies, had the result in Hamburg, for example, that all of the lakes there are now either eutrophic or polytrophic. In polytrophic lakes, there is always a large supply of nutrients and so mass development of phytoplankton. This leads to a supersaturation with oxygen and a very limited depth of visibility. The deep water is already free from oxygen in Summer and shows a distinct development of hydrogen sulphide.

As a rule, anthropogenic pollutions of standing waters have longer lasting effects than in running waters. The waste water effluents discharged into them remain in the system, in contrast to running waters. Even when discharge into them is completely stopped, eutrophication continues when they have been highly polluted. This is primarily due to the availability of the *minimum factor phosphate*: With increasing poorness in oxygen in the layers of the hypolimnion near to the lake bottom, phosphate ions dissolve out of the difficultly soluble iron-III-phosphate ($FePO_4$), which was formed under aerobic conditions and deposited in the sediment, reach the trophogenic zone (epilimnion) during the next complete turnover and so continually augment phytoplankton growth.

The characterization of the water quality of standing waters by the trophic level:

Preliminary remark: The term "water quality" is commonly used in the characterization of bodies of water which are classified by means of their chemical and physical parameters. It must be realized hereby, that the term "quality" can in many cases be misleading, as it implies in principle anthropogenic influences. Many bodies of water are, however, "burdened" in the conventional sense, without having been subjected to a lasting influence by human activity, and are given a higher water quality index only because of this. Nevertheless, we will also adhere here to the term water quality.

The *trophy* as "the intensity of the organic photoautotrophic first-order production" is particularly high when the supply of nutrients for plants is particularly large. It drops with the reduction in these substances when they are used in the synthesis of biomass.

The *saproby*, i.e. the "entirety of the heterotrophic bioactivity", then increases. With the decomposition of organic substance and increasing mineralization, the saproby decreases and the trophy increases again. This complementary pair of terms, saproby and trophy, characterize the condition of a body of water, but with different approaches.

The trophic levels serve to classify standing waters.

Running waters are separated into five load groups with respect to their anthropogenic burdening:

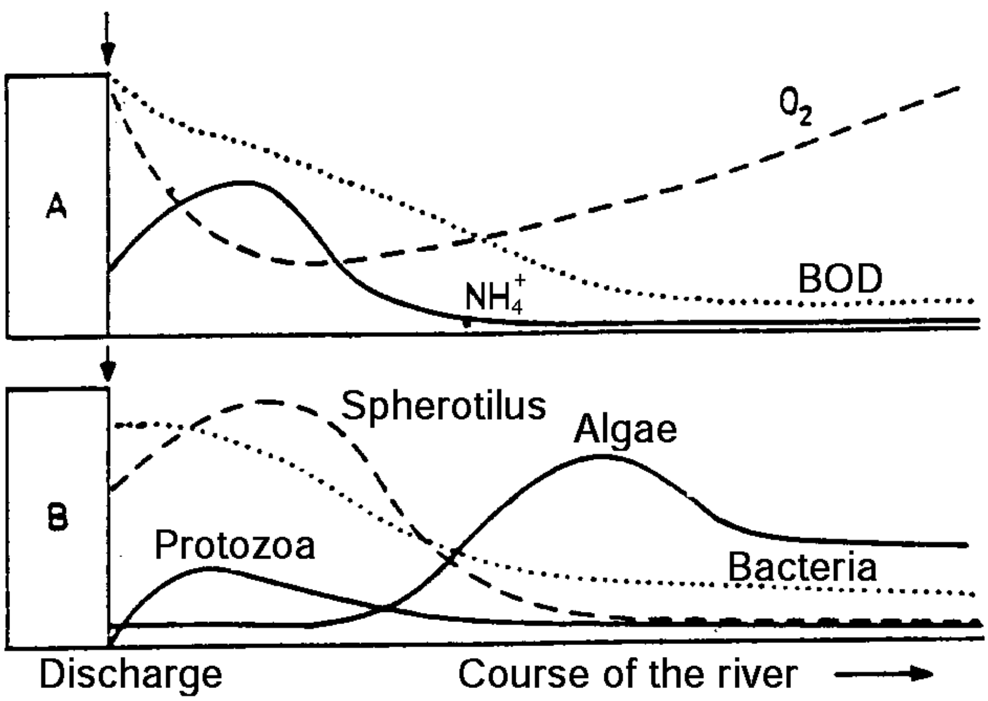
1. Organic, putrefiable contamination (e.g. faecal wastewater from sewage systems, liquid manure, wastewater from breweries etc.), which are more or less easily decomposable.
2. Complicated organic compounds (e.g. halogenated hydrocarbons, polycyclic aromatic substances), which can also be decomposed by microorganisms, but whose decomposition takes place in many steps and so takes longer. These substances are mostly very poisonous even in low concentrations.
3. Salty wastewater, e.g. from inorganic fertilizer factories or coal mines, which lead to life communities poor in species (here: haline life communities).

4. Heavy metal compounds (lead, cadmium, chromium, copper, nickel, mercury, zinc) from alloy-works, steel-works, ore mines, are as a rule highly toxic even in low concentrations, accumulate to a great extent in the nutrient cycle, and act cumulative and mutagenic.
5. Warming up from cooling water discharge, e.g. from nuclear power plants or factories, leads to a shortage of oxygen and so to the interconnected eutrophication process.

With respect to the *self-purification of running waters*, we will only deal here with the first group, i.e. organic, putrefiable contamination.
All bodies of water contain a multitude of organisms (primarily bacteria) which are capable of decomposing these organic compounds to inorganic substances (CO_2, water and minerals). The rate of this decomposition process mainly dependent on two factors:
– on the intensity and concentration of the substances which are brought in, and
– on the availability of oxygen (a high flow rate and a low water temperature increase the take up of oxygen by water).

After a heavy pollution, under optimal conditions, clean water can already be found after a few kilometres of the self-purification stretch.
Various water quality classes take over from each other "*flowingly*" over this *self-purification stretch*.
The polysaprobic zone (water quality class IV):
In this zone of greatest pollution, the organic substances are almost exclusively decomposed by bacteria (more than 1 million bacteria per cm^3 of water), which propagate on a massive scale and consume a large amount of oxygen. The various decomposition processes are carried out by many different species of bacteria. The high oxygen consumption leads to zones which are without oxygen (in particular in the deeper water layers), in which anaerobic microorganisms liberate hydrogen sulphide, methane and ammonia during their decomposition processes. As a rule, therefore, one can "smell" the condition of such a segment of water. The bacterium Sphaerotilus natans ("sewage fungus") develops under these conditions in large numbers and is easily recognizable with the naked eye as a slimy object formed by a chain of cells. Many bizzare-shaped ciliates are found along with only a few multicellular animals, e.g. along with tubifex worms or rat-tailed larvae.

Fig. 10: The development of chemical parameters and the frequency succession of some groups of organisms subsequent to an entry point of organic wastewater effluent and over the further course in the self-purification stretch.
The BOD value describes the biochemical oxygen demand, and is higher, the more oxygen-consuming decomposition processes which occur in the nutrient cycle



The α-mesosaprobic zone (water quality class III):
In this zone, the oxygen taken in from the atmosphere is already no longer completely consumed. A large portion of the organic burden is already decomposed. The number of aerobic bacteria is, however, still quite large (about 100,000 bacteria per cm^3 of water). There is a massive appearance of blue and green algae, and of diatoms. The number of ciliates, which feed on the bacteria, is particularly large. Bloodworms and bladder snails (Physidae acuta) can be named as representatives of multicellular animals.

The β-mesosaprobic zone (water quality class III):
The water in this zone contains only relatively few bacteria, and is clear and rich in oxygen. The variety of species (plant and animal life) has reached its highest stand here.
The development of the self-purification processes , from the polysaprobic stage through to the β-mesosaprobic stage, is shown in Figure 10 (summarizing representation of the changes in the colonization).
(It must be emphasized here, *that the various organisms of the different saprobic stages are not responsible for the self-purification of a body of water, but only document the stage of the self-purification processes. The "purification processes" themselves are almost exclusively carried out by bacteria.* The best water quality class is found in Central Europe only in brooks, after their emergence from a spring, and in mountain streams. As a rule, therefore, the self-purification processes only progress up to the water quality class II.

The oligosaprobic zone (water quality class I)
The water is very rich in oxygen and low in nutrients, there is hardly any dead organic matter in it. Only a few species and a low density of individuals are additional characteristics.

Classifying the quality of running waters according to the saprobic classification:
Table 1 presents the essential characteristics for a description of the quality classes of running waters in comparison with the experimental microbiological and chemical criteria.
The representation of the composition of bodies of water in Germany resulted from a standard regulation according to the evaluation criteria of running water quality issued by a State Working Group Water (LAWA). These criteria are based on examinations of the burdening of bodies of water with substances which are biologically degradable under the consumption of oxygen (primarily household and industrial wastewaters containing easily decomposable substances). The regularly issued map of water quality also contains a detailed description of the "*Characteristics for the evaluation of the quality classes of running waters*". This detailed list is very helpful for a comprehensive orientation and as a help in the identification of corresponding water quality classes, also, because of the *list of characteristic species and in particular also the species grouping*. The usage of this aspect, however, usually requires a sound background knowledge and practical determinative experience: A summary is given in the following list, whereby the classification is reduced in each case to just a few examples of species and also contains chemical factors as supplementary information:

CHARACTERISTICS FOR A DESCRIPTION OF THE QUALITY CLASSES FOR RUNNING WATERS

Table 1: The essential characteristics for a description of the quality classes of running waters in comparison with the experimental microbiological and chemical criteria.

Quality class	Identifying colour	Degree of the organic burdening	Biological characteristics	Saprobity index	Saprobic count/ml	Colony (mg/l)	BOD_5 (mg/l)	NH_4-N (mg/l)	O_2 minimum
I	blue	unburdened to very low	moderately densely populated; algae, mosses, free living flatworms, insect larvae	oligo saprobic	1.0-1.5	100	1	traces at most	>8
I-II	light blue	low	densely populated; great species diversity, salmonid water	transition	1.5-<1.8		1-2	around 0.1	>8
II	green	moderate	very large species diversity and density of individuals; algae, snails, small crustaceans, insect larvae, fish, luxuriant aquatic plants	ß-meso-saprobic	1.8-<2.3	10000	2-6	<0.3	>6
II-III	light green	critical	regressive number of species of macro-organisms, partly with mass development	transition	2.3-<2.7		5-10	<1	>4
III	yellow	highly polluted	threadlike colonies, wastewater bacteria and ciliates, few macro-organism species,: leeches, water slaters, partly periodic mass death of fish	a-meso-saprobic	2.7-<3.2	100000	7-13	0.5 to several	>2
III-IV	orange	very highly polluted	anaerobic sludge deposits, colonization by bloodworms and tubifex worms, fish population regionally limited	transition	3.2-<3.5		10-20	several mg/l	<2
IV	red	excessively polluted	primarily populated by bacteria, flagellates and free living ciliates, fish are completely lacking	poly-saprobic	3.5-<4.0	>1000000	>15	several mg/l	<2

Quality class I: Unburdened to only very slightly polluted

Occurrence: Mostly in the region of the source and in the upper courses of running waters which are cold in summer, stony bed
Water: Clear and poor in nutrients
Bed: Stony, gravelly or sandy, mud only present when of a mineral nature
Colonization: Moderately dense; red algae (Batrachosperma), diatoms, mosses, free-living threadworms, stonefly larvae, caddis worms, beetles, salmonides (spawning area)
Saprobic index: < 1.5
O_2 content: Approx. 95%-105% saturation (not below 8 mg/l)
BOD_5: Around 1.0 mg/l
NH_4-N: Traces at most

Quality class I-II: Only slightly polluted

Occurrence: Upper courses of bodies of water
Water: Clear, low nutrient content
Colonization: Dense; algae (Ulothrix), mosses, flowering plants (Berula, Callitrichacea), free-living threadworms, stonefly larvae, mayfly larvae, caddis worms, beetles (Elminthidae, Hydraenidae); salmonides, groundfish (Cottus gobio) as characteristic fish
Saprobic index: Between 1.5 and 1.8
O_2 content: Approx. 85%-95% saturation (usually not above 8 mg/l)
BOD_5: Between 1.0 and 2.0 mg/l
NH_4-N: Low concentration, on average 0.1 mg/l

Quality class II: Moderately polluted

Occurrence: Regions of bodies of water stony, gravelly, sandy or also muddy
Water: Slightly turbid
Colonization: Very dense with algae (all groups), flowering plants (often complete coverage), snails, small crustaceans and insects/insect larvae, many fish
Saprobic index: Between 1.8 and 2.3
O_2 content: Greatly variable because of wastewater burdening and algae development, but always above 6 mg/l
BOD_5: Between 2.0 and 6.0 mg/l
NH_4-N: Frequently below 0.3 mg/l

Quality class II-III: Critically polluted

Occurrence: see above
Water: Always slightly turbid, anaeobic sludge locally
Colonization: Dense with algae (colony-like mass development of many species), in part with wastewater fungi and flowering plants (Potamogeton, Nuphar), sponges, moss animalcules, small crustaceans, mussels, leaches, insect larvae, a great species-richness of ciliates
Saprobic index: Between 2.3 and 2.7
O_2 content: Approx. half of the saturation value
BOD_5: Between 2 and 5 mg/l
NH_4-N: Frequently below 1 mg/l

Quality class III: Highly polluted

Occurrence: The bottom of the body of water is frequently blackened by iron sulphide (with stony-sandy bottoms)
Water: Turbid from wastewater discharge, anaeobic sludge in parts where there is little current
Colonization: Comparatively little algae and flowering plants, complete coverage by colonies of wastewater bacteria (sphaerotilus) and sessile ciliates, few macroscopic animal species, which however in part develop massively (water slaters, lice, sponges), little fish population, periodic death of fish because of lack of oxygen
Saprobic index: Between 2.7 and 3.2
O_2 content: Sinks at times to about 2 mg/l
BOD_5: Between 7 and 13 mg/l
NH_4-N: Mostly above 0.5 mg/l, not seldom around a few mg/l

Quality class III-IV: Very highly polluted

Occurrence: The bottom of the body of water is usually sludgy (anaerobic sludge)
Water: Turbid from wastewater discharge
Colonization: Almost exclusively by microorganisms, particulary ciliates, flagellates and bacteria, macroorganisms: only bloodworms and tubifex worms (but in very large amounts), fish only present locally and in phases
Saprobic index: Between 3.2 and 3.5
O_2 content: Sometimes below 1 mg/l, usually only a few mg/l
BOD_5: Between 10 and 20 mg/l
NH_4-N: Mostly several mg/l

Quality class IV: Excessively polluted

Occurrence: The bottom of the body of water is usually characterized by large anaerobic sludge deposits (also smells of hydrogen sulphide then)
Water: Very turbid because of wastewater discharge
Colonization: Almost exclusively by bacteria, fungi and flagellates, some free moving species of ciliates (partly in very large amounts)
Saprobic index: Above 3.5
O2 content: Very low to 0 mg/l
BOD_5: Mostly above 8 mg/l
NH_4-N: Mostly several mg/l

3. DOCUMENTATION OF ANTHROPOGENIC POLLUTION USING BIOLOGICAL INDICATORS

A multitude of bacteria, plants and animals, as individuals or in complex communities of organisms, have a relationship to certain environmental factors, so that their presence and their concentration can supply information on the corresponding environmental factor, in quality and quantity.

The life functions of such *"Indicator organisms"* or *Bioindicators* closely correlate with the environmental factors which are identified by them.

Bioindicator performance

Bioindicators are used in various ways.

In the scope of this theme, we will only discuss and utilize them in their role as indicator of changes in certain biotopes, which were or are polluted by anthropogenic influences (*pollution indicators*).

The complex ecological damage can thereby make itself noticeable in the population or biotic community in various ways:

— in a contraction of area
— in a decrease in productivity
— in a reduction of the density of individuals
— in a change in the natural age structure, and finally, by
— the species composition.

A possible method for examining the changes in a biotope caused by anthropogenic influences could be to concentrate on the development of the individuals of a single indicator population (e.g. green algae as bioindicators of water quality).

Another approach takes a *whole series* of different "indicator populations" from the biotic community of a biotope into account in the examination procedure. This principle will be applied in the procedure described here.

Using bioindicators in school water analysis

One should not conceal the fact, that working with indicator forms at a correspondingly high standard as a rule necessitates a determination right down to the species.

It makes sense, however, for the practical work in a school to be didactically reduced.

This means the use of a higher taxonomic unit, at the cost of a lower technical quality, i.e. the method used could be called into question by competent specialists. One should be aware of such specialists objections when using common examination methods.

The following is an example: In an examination of the river Fulda and its tributaries, one was able to detect different amphipoda species in dependence on the stages of pollution in the various sections of the river. Thereby, it was shown that it would have been possible to carry out the water quality determination *alone* by the appearance of individuals of the genus Gammarus (Gammarus pulex, G. fossarum, G. roeseli). To suffice scientific demands, the indicator form should have been clearly defined as species. The Gammarus species named were found (in increasing sensitivity to the total factor wastewater: Gammarus roeseli – G. fossarum – G. pulex in various water quality classes, but with distinct overlapping.

The determination methods of which are used in schools, do not differentiate in their determination key in the area of the genus Gammarus, or only refer to the different species (G. pulex and G. roeseli), which place similar life demands on the water quality. This shows the difference in requirements between the school method and the procedure used by the State Water Laboratories or the State Working Group Water : Whereas in the first case *the* (brook) freshwater shrimps or also the (river) freshwater shrimps can be roughly positioned in water quality class II, in the second case, for example, there is a clear differentiation to be seen between Gammarus fossarum (saprobic value 1.3) and Gammarus roeseli (saprobic value 2.3, or 2.0).

This demand for exactness is relativized in our example "Gammarus", however, by the fact that differing quality class characterizations are used in the various German States, and that thereby differences from half a quality class can occur with a specific indicator species.

In the context of the mapping of the water quality, the Water Conservation Society pleads for *one or two biological analyses per year per examination site*. One examination should be carried out in the months April to June a second one after June. It is also recommended, that "supporting chemical values" (oxygen, BOD and ammonia) be determined.

The school water analysis (brook sponsorship) could also be orientated to the recommended schedule. In this, the use of a computer with appropriate software (e.g. Environmental Atlas Water), which is used and further developed by all colleagues concerned, should belong to the concept of long-term acquisition of measurement data within the framework of caring for a body of water in the town area or in the countryside.

Significance and limitations of the use of bioindicators within the context of macroscopic water analysis:

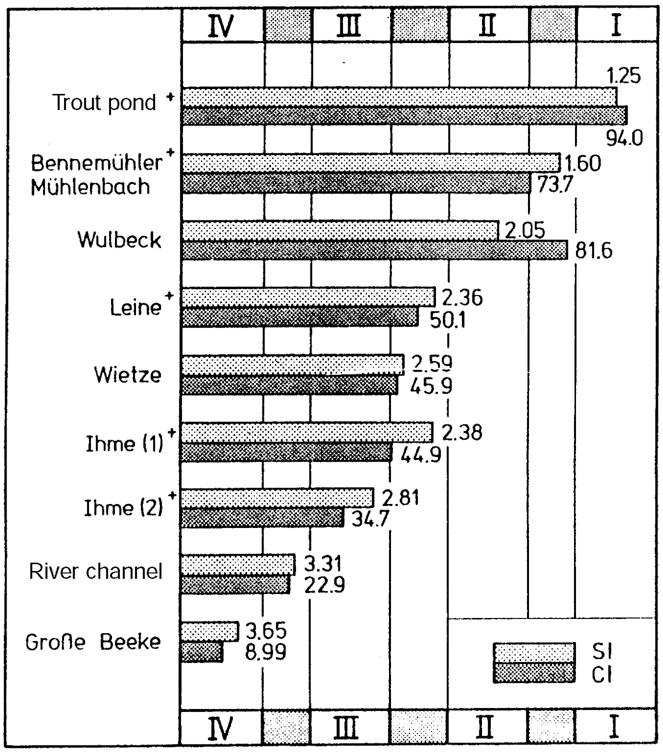
Anthropogenic pollution can also be detected by *chemico-physical methods* (see Handbook 30837.22). It is indeed a fact that herewith more exact, quantitative measurements of individual pollutants at a certain time are possible, but on the other hand, damage to individual organisms or disturbances in the complex interplay of each of the components of the food web over a certain time span cannot be documented. The chemical water analysis is indispensible when the type of damaging substance, or the composition and the concentration of it, as well as its point of entry, are to be determined. The bioindicator method can only be supplemented with chemico-physical analyses, and not be replaced by them.

The predominant reason for this is that, in biological analyses, the individuals of a life community which live over a longer time span in the water under examination are observed. They are generally not driven out of their biotope by a single or brief contamination. The examination principle allows the determination of an "average value". Just a single examination can *very quickly* give a good average

value. Short-term deterioration in the living conditions, which can be very exactly determined by chemical water analyses, can with this method of only a few sample takings not be identified as a limited-time disturbance. In the same case, when using the biological analysis, the short-term change in the milieu would not deceive the examiner as to the "normal" condition of the biotope in question.
Extensive comparative examinations of running waters in Lower Saxony have demonstrated, that for all quality classes (I to IV), the chemical index (CI) is subject to considerably larger variations than the saprobic index. In the biological analyses, 98% met the "average quality" according to the saprobic index, but only 66% in the BACH chemical analyses. The biological and chemico-physical examinations in this series were carried out together monthly from April to Septembe,. As can be seen from Table 2, the results obtained from each of the two methods are very close to one another. The two methods are therefore independent of each other, both qualified water quality analysis procedures.
Among other reasons, the biological method is so attractive for school use because it is very much cheaper and quicker. In contrast, at least 6 examinations are needed for the determination of the CI.

Supplementing water analyses with bioindicators
The determination of water quality by use of saprobic indices can be with good reason combined with corresponding measurements of O_2 content, the O_2 reduction in 2 days and the BOD_5 value. This form of parallelism of different examination methods, not only increases the accuracy of the examination, but also supplements the biological method while doing without the more time-consuming or costly procedures of, for example, the BACH and G.R.E.E.N. chemico-physical water quality determination. Comparisons with other attempts to parallelize between the saprobic value and, for example, the BOD values, demonstrate the difficulty generalizing.
The cost of the oxygen determination set required is comparatively low.

Table 2: Comparison of saprobic index (SI) and chemical index (CI) for 9 running waters in the Hanover area; average values after 6 (+ or 5) months;



PARALLELISM OF QUALITY CLASSES, SAPROBIC VALUES AND OXYGEN CONDITIONS IN RUNNING WATERS
Table 3: Saprobic indices and oxygen contents in running waters
(Further data, such as BOD values, O2 content and toxicity, are often used alongside the saprobic indices to determine water quality, particularly according to the so-called "Munich Method". Roman numerals = quality classes; arabic numerals = corresponding saprobric indices; oxygen supersaturation is taken into consideration in column 2b

Column	1	2a	2b	3	4	5
Quality class (saprobity levels)	O_2 content			O_2 reduction (in 48 hours)		BOD_5
	mg/l at 20°C and 760 mm	% saturation	% saturation	mg/l at 20°C	%	mg/l at 20°C
I (1.0)	8.45-8.84	95-100	100-103	0.0-0.3	0-5	0.0-0.5
I-II (1.5)	7.5-8.45	85-95	103-110	0.3-1.1	5-10	0.5-2.0
II (2.0)	6.2-7.5	70-85	110-125	1.1-2.2	10-20	2.0-4.0
II-III (2.5)	4.4-6.2	50-70	125-150	2.2-3.8	20-40	4.0-7.0
III (3.0)	2.2-4.4	25-50	150-200	3.8-7.0	40-70	7.0-13.0
III-IV (3.5)	0.9-2.2	10-25	200	7.0-12.0	70-95	13.0-22.0
IV (4.0)	0-0.9 poss. H_2S	10		12.0	95	22.0

4. METHODS FOR THE BIOLOGICAL EXAMINATION OF RUNNING WATERS AND CALIBRATION PROCEDURES

The population density in Central Europe is relatively high. The pollution of bodies of water with organic matter is therefore correspondingly high.
As early as the beginning of the 20th century, the first investigators described the different sapriotic zones in variously polluted waters, and so provided the basis for a classification of running waters with indicator organisms.
Nowadays, there is a multitude of biological examination methods, which can be derived from this work. The differences in the versions are to be found in the species listing used, the saprobic index or quality class formula and the form of the graphical presentation.
The species listing attracts most attention. Whereas the first investigators talked of about 700 "key saprobic forms", it very quickly became clear from practical usage, that it is only possible for a group of specialists to have so much and so accurate specific taxonomic knowledge. The present method, is distinguished not only by a considerably shorter species listing, but also, at least in part, a refrainment from determining species.
What is true for the development of recognized and official examination methods, must also be valid, to an even greater extent, for pedagogic work in the scope of environmental education in schools.
Too elaborate examination procedures quickly overtax the ability and the patience of students. Frustration can result. Working with enjoyment, being open to perceive ecological problems, and the fostering of a readiness to react in the sense of independently standing up for an improvement in environmental conditions have a higher importance than obtaining scientifically sound experimental results. These facts, and the selection of subjects in the successive classes, explain the various methods presented here in the practical part are explained by this.

Calibration:
The calculation of the individual saprobic indices is an essential prerequisite for the determinative method. This can be done in various ways:

1. In laboratory experiments, the reaction of the possible indicator species to wastewater or to certain wastewater ingredients is examined, under consideration of the natural decomposition conditions for these substances.
2. From field results, it is determined how saprobic levels and quality classes correlate (species and species communities) to other data (biochemical, chemical and toxicological).
3. In statistical surveys, the spreading of the individual indicator species within the spectrum of the saprobic system is determined.

In the *quality classification according to biological methods*, a series of insect genera are of importance. In the course of Spring and summer, entire insect genera leave the water as a result of the metamorphosis of insect larvae to winged adult animals. As the eggs and young larvae which are later present cannot be found or identified, these genera are at this time completely absent from a saprobic determination. The consequence would appear to be, that either the insect genera concerned should be excluded from examinations during this time, or that examinations should not be caried out during this time. On taking a closer look at the insect genera, however, it can be seen that their detraction from the examination method is unimportant. In principle, the genera concerned all represent lower quality classes. The number of species in these quality classes is so high, however, that even when certain forms are absent, the total calculation is not falsifed.
"*The life community determines the quality class, not the individual*".

5. A METHOD FOR THE MACROSCOPIC-BIOLOGICAL EXAMINATION OF STANDING WATERS

The determination of the trophic level:
To classify a body of water, it is necessary to carry out relatively extensive examinations of the various regions of the body of water according to chemico-physical and biological criteria. These also include *depth profile examinations*. These require, alongside examinations of plankton (density, sociology), measurements of the contents of the important plant nutrients nitrogen and phosphate (minimum factors), as well as the chlorophyll concentration as measure of the algae density and production potential, oxygen content, pH and acid binding capacity (carbonation system).
The sense of a classification of still waters is seen by the Environmental Department in Hamburg, for example, to be the observation of the changes in the body of water over time (aging of lakes). The official opinion is that the measurement procedures required for a *direct measurement of the production performance* would require an enormous expenditure and so, because of cost, are out of the question for routine State water control.
But the registering of parameters in the different sections of a standing body of water for *the indirect method* to determine the trophic level is also, in comparison with the methods for the determination of the quality of running waters, relatively expensive.
Investigators differentiate 4 trophic levels according to the phosphate-phosphorus content. From this, the following 4 trophic levels are given for lakes:

1. *Ultra-oligotrophic to oligotrophic lakes*:
   < 8 µg/l P
2. *Oligotrophic to mesotrophic lakes*:
   8-18 µg/l P
3. *Mesotrophic to eutrophic lakes*:
   18-84 µg/l P
4. *Hyper-eutrophic lakes*:
   > 84 µg/l P

Meyer added a further trophic level to these four. A simplified formulation is that the eutrophic level is separated into eutrophic and strongly eutrophic (refer also to 6.4).

Classification of lakes according to their phosphate-phosphorus content:

Oligotrophic:	5-14 µg/l P
Mesotrophic:	14.0-49 µg/l P
Eutrophic:	38-84 µg/l P
Strongly eutrophic:	84-189 µg/l P
(exceptions up to approx. 420 µg/l P)	
Polytrophic or hypertrophic:	>420 µg/l P

Note: According to this, there is overlapping of the values for the mesotrophic and eutrophic levels. Further measurement factors (e.g. O_2) must therefore be brought into consideration here for an effective evaluation.

Educational use of the waterside zone of standing waters:
With the introduction of the BACH examination parameters at the beginning of the eighties, teaching work in biology and environmental education was greatly enriched.
With the help of data acquisition and evaluation of 8 chemico-physical parameters, there was, alongside the customary biological determinative methods, a practical alternative for the *determination of the quality of running water*.
The circle of interested people increased considerably with the introduction of the G.R.E.E.N. parameters, as well as the computer supported evaluation ("Environmental Atlas Water"), the interlinkage possibilities established for this, and the basic idea behind the G.R.E.E.N. philosophy of an inter-disciplinary, project and action orientated schooling in the environmental education field.
As these examination methods for the determination of the water quality without doubt not only suffice for school use, but also fulfil higher requirements (official establishments also use the BACH or saprotic system to determie a quality index), there were hardly any problems from the technical side.
I know from my experience in the continuing education of teachers, that many colleagues have applied the customary methods for examining running waters to the measurement and characterization of still water. This has no doubt been done mostly in those areas where, because of a lack of suitable running waters, a nearby lake has been used as an adequate substitute. There are doubtless reasons for this which are understandable in the sense of a didactic reduction in the technical requirements. Prerequisite for this is, in any case, a corresponding indication of the simplifications and problems involved. For example, examinations of the waterside region of a lake which is subject to a seasonal waterbody stratification do not allow a conclusion to be drawn on the trophic level of the entire lake. With still water it is possible that good water organisms feel at home at the water surface, but that there are only "dirty brats" on the lake bottom, because there the condition is either poor in oxygen, or no oxygen at all.
For these reasons, one finds oligosaprobic harmoniously alongside polysaprobic key forms in such waters. In very shallow standing waters, however, a judgement of the quality in the lakeside region may also have a limited meaning for the entire body of water.
The interest in utilizing comparable possibilities for the evaluation of the water quality to the running water examination within the scope of environmental education in schools is only too understandable. No further reasons are required.
Thereby it is absolutely necessary, however, to limit yourself to what can be done at your school and simultaneously to ensure that the technical requirements are met.
For *examinations of standing water with the aim of determining the quality*, one should usually concentrate on measurements and observations in the lakeside area, and accordingly limit statements on the water quality exclusively to this area. This is valid for both chemico-physical and biological examination methods.
When working with students, the examination of the lakeside is the easiest to organize, and in addition, the macroscopic flora and fauna are particularly species-rich and comparatively easy to examine.
A comprehensive examination of a lake, for example by means of the numerous chemico-physical and biological parameters in the various zones and at different times, with the aim of an ambitious determination of the quality of the entire body of water, can as a rule not be afforded within the scope of a normal instructional treatment.
We shall therefore limit ourselves here to the *biological examination of water in the lakeside region of standing waters*.
In order to be able to work with the indicator organisms of the saprobic system here, it is necessary:
— To check the possibility of applying the saprobic system to standing waters.
— To emphasize biotope similarities and thereby use comparative examinations of indicator organisms in both areas.
— To carry out a parallelization of the customary trophic system for standing water with the saprobic system for running water.

Usage of the saprobic system for the examination of standing waters:
One finds among the species in standing water many saprobes, which are arranged in the trophic levels just as

in the quality levels of running water. This is not to be wondered because in many other publications the flowing transition between running and standing waters has been emphasized. Why should then in general the differences in the organisms between running waters and lakes, for example, be greater than those between the source and mouth regions of big rivers, or in comparison with ditches which by definition should be considered to be running waters?

The cardinal question which must be answered to apply the saprobic system to the examination of standing waters is:

Are the same indicator organisms (even possibly down to the identification of the species) also to be found in standing waters?

Is there a solid data base for possible comparative examinations?

Are the methods on which comparative examinations based proven in practice and commonly accepted?

Let us start with the final question. The macroscopic-biological field method for the evaluation of the water quality of running waters is – even in the "slimmed" variation with 46 indicators for teaching purposes – a proven and accepted system in practical examinations of water. It is used, among others, by the Study Group Limnology and Water Protection (SGLW). The chosen form of the procedure is substantiated, a comparison of chemico-physical with biological parameters adequate. All available parameters of importance (O_2 content of the water. O_2 reduction, BOD value, toxicity, saprobic index) are also used in the determination of the quality of running waters by the so-called "Munich method", for example.

The data basis on which the application of the saprobic index system to standing waters is founded is indeed still quite restricted. It has been tested exclusively in lakes, gravel pits and rainwater catchment basins. The quality of these bodies of water fluctuates between eutrophic and strongly eutrophic.

In every case, and also in standing waters which were examined, *all the indicator organisms included in Meyer's system were found*.

<u>Evaluation of the SGLW data material for standing waters:</u>

The immediate waterside zones of running waters, with their fullness of forms, most closely resemble the shallow water regions of lakes, or their surf zone.

In 1995, at my request and despite being sceptical at first, Detlef Meyer undertook the task of attempting to prepare a list, comparable to the saprobic system for running water, for the examination of the waterside areas standing waters, and to substantiate it for the determination of a corresponding trophic level, by evaluating the available SGLW data according to the Meyer list and comparison with the chemico-physical procedures for the determination of the trophic level (prerequisite: modified trophic level division).

Result: Of the 24 standing waters examined, 19 gave a remarkable congruence in the results of the evaluations by the two procedures (= 79%). Only with 5 of the waters were the individual results a trophic level apart (whereby in one case, the "correct" trophic level was only "missed" by 1/100.

Meyer pointed out, that merely an additional depth of visibility test would have been needed to correct the five cases of disputable biological determinations.

Conclusion: The results of this investigation is an encouragement for the use of indicator organisms for the evaluation of waterbodies, including standing waters. According to Meyer, the method is already "a win, when one can also acquaint students with standing waters and the fullness of forms living in them".

<u>Parallelization of trophic levels to saprobic levels:</u>

In a comparison of the two quality levels, the wastewater-biology designations oligosaprobic (oligos = little) and polysaprobic (poly = much) correspond in meaning to the limnological designations oligotrophic and polytrophic. Contrary to this, the limnological designation eutrophic (eu = good) does not cover any special wastewater-biology saprobic level.

Whereas the limnologist, at the time when the 3-level trophic system was introduced, used the designation eutrophic for a nutrient-rich, and so also species-rich, waterbody, the wastewater biologist was naturally primarily interested in designating the various levels of decomposition of organic substance as an indicator of the degree or pollution. In dependence on the degree of eutrophication, therefore, various segments in this area must be differentiated.

For a long time, a further level has been inserted between *oligotrophic* and *mesotrophic*, namely the *mesotrophic* level, which describes a low nutrient burdening. As there is a considerable difference between standing waters with a moderate or a large supply of nutrient, however, Meyer recommended that the remaining eutrophic level be divided into *eutrophic* (= moderate supply of nutrient) and *strongly eutrophic* (= high supply of nutrient). Further to this, the *polytrophic* level (= excessive supply of nutrient) is maintained.

Herewith, the comparibility of trophy and saproby determinations is attained by the introduction of two further trophic levels (mesotrophic and strongly eutrophic). According to Meyer, the following division is given for parallelity of the saprobic index (SI) with the trophic levels described:

SI	Trophic level
1.0–1.5	Oligotrophic
1.5–2.0	Mesotrophic
2.0–2.7	Eutrophic
2.7–3.2	Strongly eutrophic
3.2–4.0	Polytrophic (hypertrophic) level

PRACTICAL PART

6. THE MACROSCOPIC-BIOLOGICAL EXAMINATION OF RUNNING WATERS AND WATERSIDES OF STANDING WATERS

Two examination methods, designed at very different levels for different user groups, are to be presented here:
The methods of Xylander/Naglschmid and Meyer.

6.1 Two different examination methods for teaching purposes

The system of Xylander/Naglschmid uses exclusively higher taxonomic categories (taxa).
With the animal groups found, differentiation is exclusively on the basis of *numbers of distinguishable forms*. Abstaining from the use of lower taxa naturally lowers the technical standard. Experience with this method shows, however, that the results of the determination of quality are comparatively good.
The advantages of this method are:

- The number of organisms is manageable.
- The determination is not very time-consuming.
- Even teachers and students not practised in determination procedures mostly get on well with it and as a rule obtain usable results.

The method of Xylander/Naglschmid has for many years been included in the "Environmental Atlas Water" software, which is specially designed for schools.
The determination method should primarily be used in secondary level I, but can also be used in secondary level II.

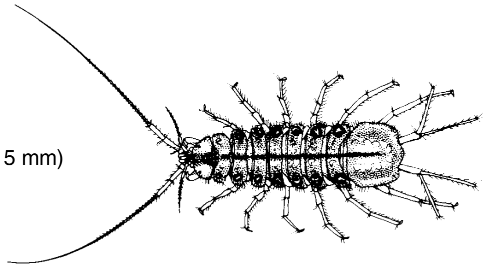
The system developed by Meyer demands much more of the user, whereby it is a field method for which a 10x magnifying glass is sufficient for determination. In my opinion, the list of the 46 indicator species (the author propagates parallel to this a list of 76 indicators for the "practised examiner") is optimal for the "beginner", with respect to the demands and the readiness of the students to "work", in the scope of secondary level II environmental education. The saprobic list leans extensively towards the list of the State Working Group Water, which is binding for the water resources administration. Accordingly, 80% of comparable indicators are covered by a same, or at least nearly same, saprobic index.
The determination method is as a rule used in secondary level II. The decision on this is dependent on the composition of the examining group/learning group and the time available for the entire examination of the water.
Quite a number of the 46 indicators with very low saprobic values will, because of the condition of many bodies of water, not or only seldom be met. This is particularly true for standing waters. In this much, when one takes a closer look, it can be seen that Meyer's list relativizes itself.

6.2 Introduction to forms of animals with indicator function

In Table 4, forms of indicators which are included in both systems are depicted in an exemplary fashion.

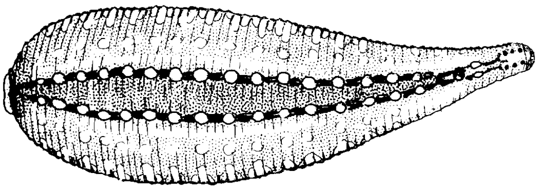
Table 4, Indicator forms for the macrosopic-biological determination of water quality
(Examples of frequently occurring forms of the various groups)

SLATERS/Crustaceans

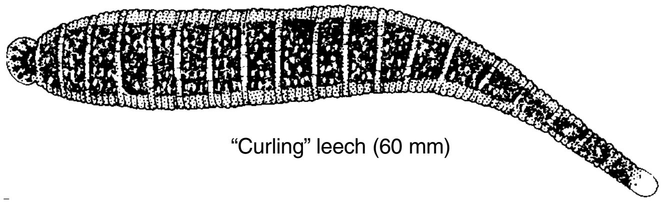


Water slater (15 mm)

LEECHES/Segmented worms

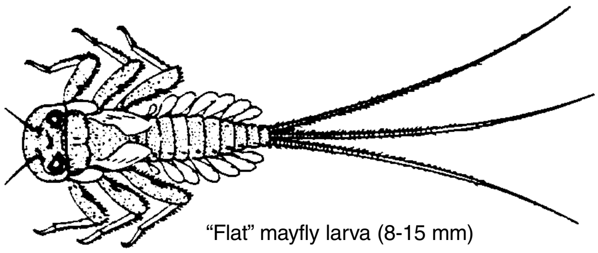


Large snail leech (30 mm)

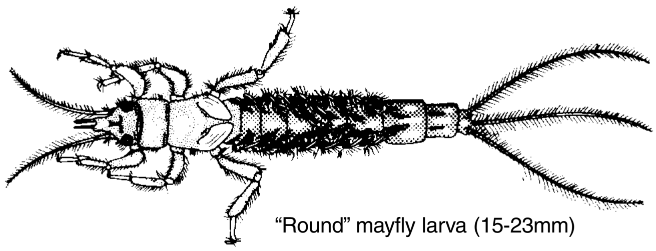


"Curling" leech (60 mm)

MAYFLY LARVAE/Insects

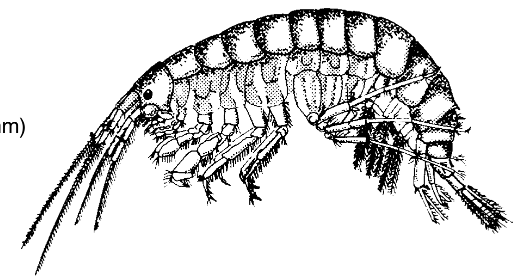


"Flat" mayfly larva (8-15 mm)



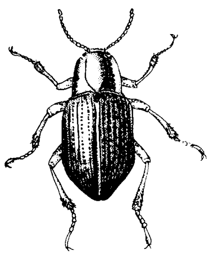
"Round" mayfly larva (15-23mm)

BEACH HOPPERS/Crustaceans

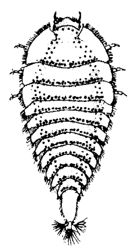


"Brook" freshwater shrimp (15-20 mm)

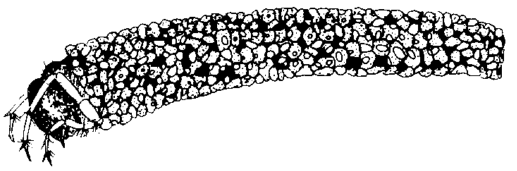
BEETLES/-LARVAE/Insects (here, not actually an indicator but important for the number of forms: Xylander)



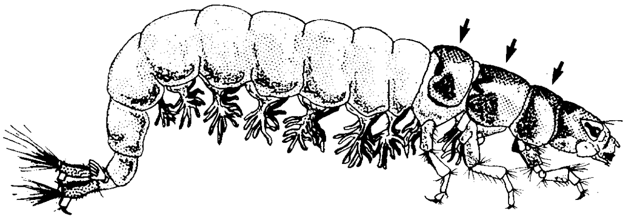
"Hook" beetles and their larva



CADDIS WORMS/Insects

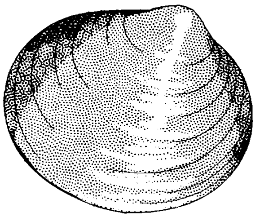


Cased caddis worm (15-20 mm)

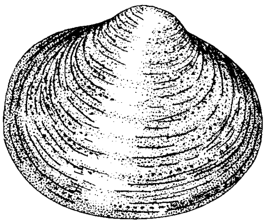


Caseless caddis worm (10-20 mm)

MUSSELS/Mollusca

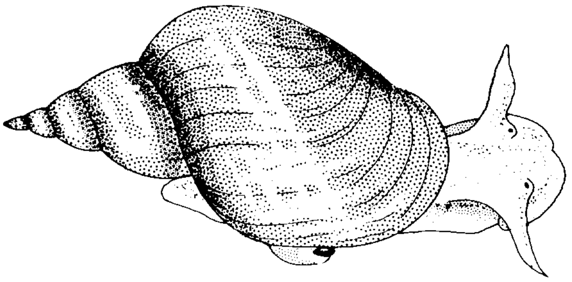


Pea mussel (10 mm)

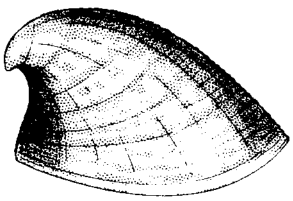


Orb mussel

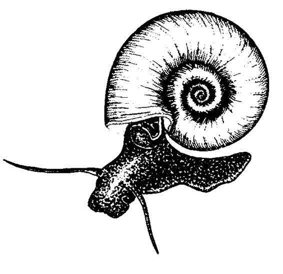
SNAILS/Mollusca



Pond snail (50-60 mm)



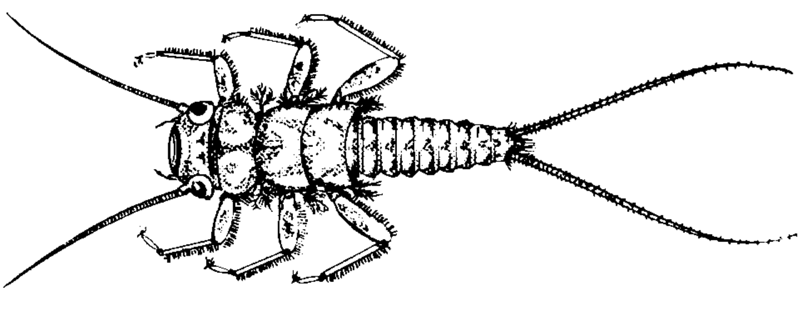
River limpet (5-6 mm)



“Saucer” snail (10 mm)

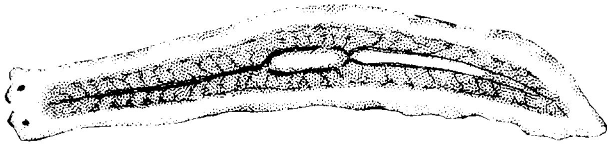
STONEFLY LARVAE/Insects

Stonefly larva (7-10 mm)



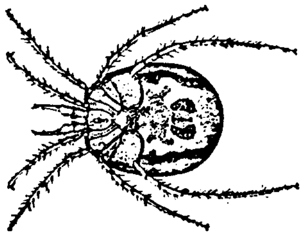
FREE-LIVING FLATWORMS/Flatworms

Gray flatworm (25 mm)

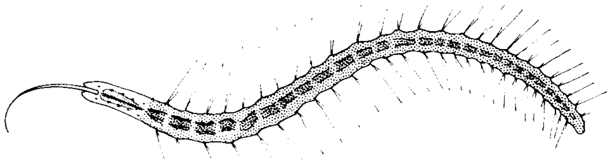


White flatworm

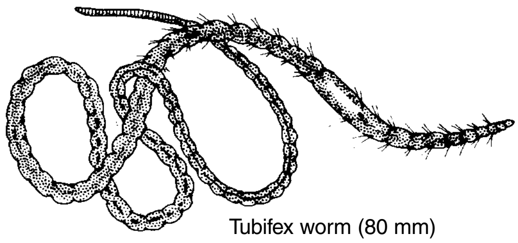
MITES/Spider-like (here, not actually an indicator but important for the number of forms: Xylander)



OLIGOCHAETA/Segmented worms

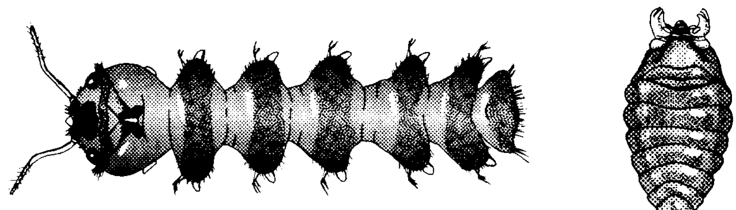


Pond snake (20 mm)

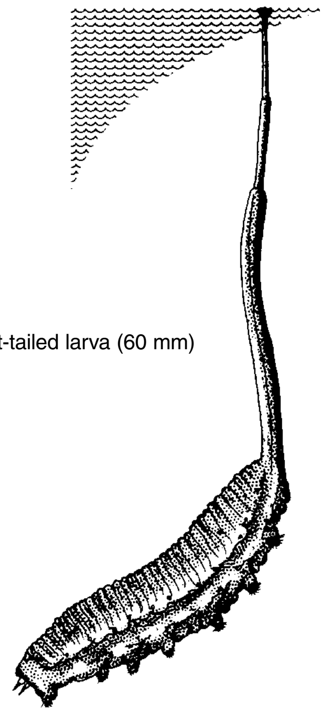


Tubifex worm (80 mm)

TRUE FLY LARVAE/Insects

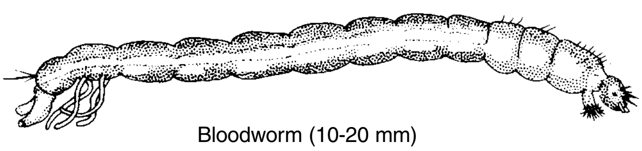


Larva of the eye gnat (10 mm) and pupa of the eye gnat (6-8 mm)



Rat-tailed larva (60 mm)

“Soldier” fly larva (40-50 mm)



Bloodworm (10-20 mm)

6.3 Examination method acc. to Xylander/ Naglschmid

6.3.1 Description of the method

1. Catching and registering organisms

All substrates at the examination site (freewater, stones, plants, branches in the water, waterbed) are to be examined for their particular share of the total substrate:

— Sift through freewater with a fishing-net, and among the plants with a fine-meshed sieve. Sieve out animals from the waterbed and from the mud there.
— Lift up and turn over stones which are on the waterbed and on the waterside region. Use tweezers or a brush to remove the organisms.
— Collect from washed-up material (branches and foliage)
— Collect from aquatic plants

Collect the organisms in a bucket or in large light-coloured or transparent plastic dishes.

2. Catching time/sampling position

Approx. 30 minutes for the whole of the substrates at the sampling position.

3. Determination

Transfer the animals to a magnifying glass or onto a flat, white lid (plastic lid with low rim) using tweezers or a brush. Use an additional magnifying glass for the determination.
The Wassmann/Xylander determination key (6.3.2) can be of assistance to unpractised examiners, as can another Guide.

4. Collecting

After determination, collect the animals separately in extra bottles (for a possible post-examination at school).

5. Evaluation

This is carried out using the evaluation sheet (6.3.3).
The chronological listing of animal groups from stonefly larvae to tubifex sludgeworms is according to increasing saprobic value*.

— Tick off the *animal groups found* in column 1.
— Enter the *number of different forms within an animal group* in column 2
— Add up the numbers of the different forms and enter this *total number of forms* in the thickly bordered box.
— Determine the decision class from the number of forms of the uppermost animal group (lowest saprobic value, the first tick from the top in column 1).
— Conclude the quality determination by appropriate use of the second (bottom) part of the Table.

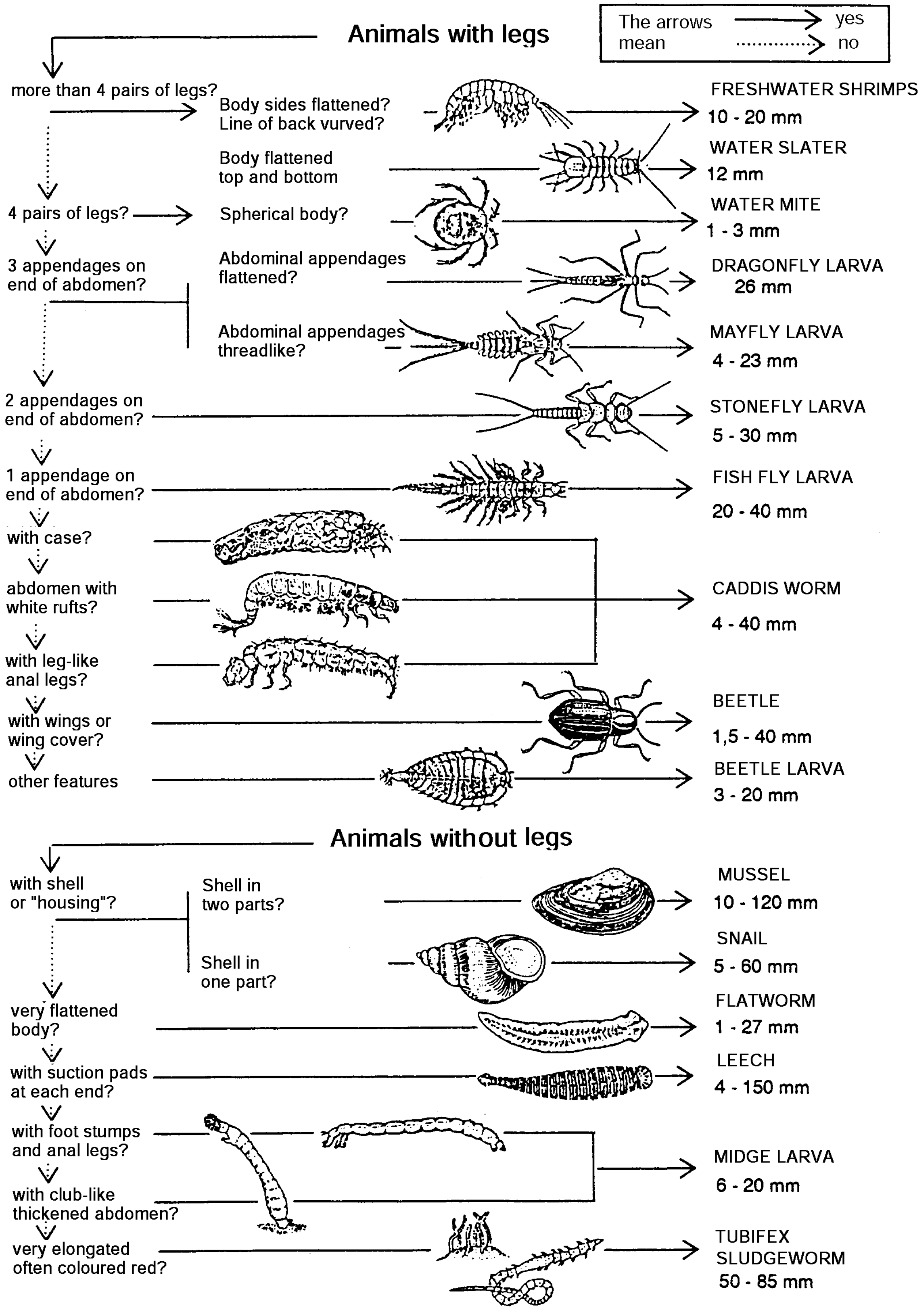
The particular water quality is determined by the total number of forms found in the animal group taken as decision class.

6. Returning the animals

Put the animals back into their biotope after the evaluation at the latest.

**Saprobic value: According to the diction of the State Working Group Water (DIN 38 410), in grading indicator organisms, the term saprobic value should be used, and no longer the term saprobic index. The saprobic index is now understood to be that value which determines the quality of the body of water (total sum: total frequency = saprobic index).*

6.3.2 DETERMINATION KEY FOR MACROSCOPIC ANIMAL GROUPS IN BODIES OF WATER



6.3.3 DETERMINATION TABLE FOR THE EVALUATION OF ANIMAL GROUPS FOUND

(Xylander/Naglschmid method)

Animal group	Animal group found **1**	Number of distinguishable forms **2**	Evaluation Number of forms **3**	Evaluation Decision class **4**
Stonefly larvae			2 or more 1	A B
Mayfly larvae			3 or more 2 (see caddis worm) 1	B C no significance
Caddis worms			4 or more 1-3 1-3	B C
Beach hoppers			2 or more 1	C no significance
Fish fly larvae				D
Water slaters				D
Leaches				D
Tubifex sludgeworms				E
Mussels			Of no significance for the decision class	
Snails				
Flatworms				
Midge larvae				
Water mites				
Beetles or beetle larvae				
Total number of forms (TNF):			Decision class	

Decision class \ Total number of forms	0-1	2-8	9-15	16 or more
A	–	II	I-II	I
B	III	II-III	II	I-II
C	II-IV	III	II-III	II
D	IV	III-IV	III	II-III
E	IV	IV	III-IV	III

6.4 Examination method according to D. Meyer

Preliminary note:

Although Meyer only considers his modified method described here as suitable for "beginners", it is relatively demanding compared with the Xylander/Nagelschmid examination method.

From my experience, the definition of the indicator form as species (as a rule) and the compexity of the determination method represent an optimal sophistication for teaching (also in secondary level II).

The procedure combines elements of classical biological examination methods with the characteristic features of meticulous identification and comparison with ecological aspects in a cross comparison. This "puzzle-like" elimination procedure has the elements of a game, and is so very attractive, not only for "puzzle freaks" but also for a large proportion of the students, after a successful introduction. The certainty of obtaining reliable results on correct usage certainly serves to increase this attractiveness even more. The characteristics of the required way of working; the patient determination, the comparison, the consideration (with the experience component, which changes with repeats) and finally the decision (with the consciousness of, under some circumstances, going the wrong way) have a high standing in connection with an orientation towards an educational aim. The basic method of proceeding which is essential to be able to overcome future tasks of complicated nature is "trained" here.

6.4.1 Description of the method

1. Catching and registering

A representative examination must be carried out at a position which is typical for the segment of the waterbody which is to be evaluated.

For each examination, harvest the animals from 10 hand-sized stones (substitutes; washed-up branches, bark of trees etc.; in each case with a brush/tweezers), in addition use a household sieve to sift intensively through the plants growing there (e.g. Canadian waterweed; substitute; washed-up foliage) and also sieve along the waterbed and through the mud 5 times.

Should not all of the substrates named be present, then examine the other characteristical small biotopes more intensively, according to their relation to each other.

Ensure that only "stationary or substrate-bound organisms" are collected.

2. Catching time: Approx. 10 minutes for each sampling position.

3. Determination

Transfer the animals to a magnifying glass or onto a flat, white lid (plastic lid with low rim) with tweezers or a brush. Additionally use a magnifying glass for the determination.

For the determination, use:

— The list of 10 different forms of animals with a total of 46 organisms.
— The description and determination lists of the individual indicators (from Meyer, modified).
— Additional literature on determination.

4. Collecting

After determination, collect the animals separately in extra bottles (for a possible post-examination either at the site or back at school).

5. Evaluation

Each indicator has a certain saprobic value, which can be taken from the list. The **frequency value** for this indicator is derived from the number of individuals (counted or estimated). Use Table 5 to determine the frequency value.

Table 5: Determination of the frequency value

Frequency value (abun-dance number + abundance)	Number of individuals in the biotope examined
1 = single find	not more than 2 animals
2 = few	3-10 animals
3 = few to average	11-30 animals
4 = average	31-60 animals
5 = average to many	61-100 animals
6 = many	101-150 animals
7 = huge numbers	more than 150 animals

After having determined the *frequency value*, multiply this with the corresponding *saprobic value of the bioindicator*. The result is the *individual sum*.

Add all of the individual sums of the bioindicators together to obtain the *total sum*. Also add up the *frequency values* to obtain the *total frequency*.

Finally divide the total sum obtained from the individual sums by the total frequency to obtain the *saprobic index for the body of water examined*. Read off the appropriate quality class directly from Table 6.

6. Returning the animals

Subsequent to determination, collect the animals separately in extra bottles (post examination/evaluation). Put the animals back into the water they were taken from after the evaluation.

Table 6: Relationship between saprobic index and quality class

Quality class	Saprobic index
I	1.0-<1.5
I-II	1.5-<1.8
II	1.8-<2.3
II-III	2.3-<2.7
III	2.7-<3.2
III-IV	3.2-<3.5
IV	3.5-4.0

Use the Examination and Evaluation Worksheet as protocoll of the examination results obtained, and either file these or calculate and store them in a computer using suitable software at school. The possibility of long-term acquisition and display of changes in various sections of a running water, as well as the fascinating aspect of graphical documentation, can, as continuum over many school years, result in a strong connection between the school and a nearby running water (sponsorship).

6.4.2 Examination and Evaluation Worksheet

for the macroscopic-biological examination of running waters acc. to Meyer
– Page 1 –

Name of the waterbody: . . . .

Description of the measurement site (name/topographical position/distance from the mouth, river kilometre/altitude in m above sea level):

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....

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When examined (date/time): . . . .

Weather: . . . .

Water temperature: . . . .°C

Current/turbulence . . . .

Substrate relationship at the shore and at the bed:

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....

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Characterization of the waterside zone:

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Characterization of the body of water (turbidity/colour/smell):

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....

....

Further remarks:

....

....

Examiner/examining group:

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....

6.4.2 Examination and Evaluation Worksheet

for the macroscopic-biological examination of running waters acc. to Meyer
– Page 2 –

INDIVIDUAL SAPROBIC VALUE (ISV), NUMBER (N), FREQUENCY (F), INDIVIDUAL SUM (IS), TOTAL SUM (TS), TOTAL FREQUENCY (TF), TOTAL SAPROBIC INDEX (TSI), QUALITY CLASS (QC) ( ) = mark with a cross

HIGHER TAXA	INDICATOR ORGANISMS	(ISV)	( )	(N)	(F)	(IS)
FLATWORMS (TURBELLARIA)	Polycelis felina/Crenobia alpina	1.0	( )			
	"Triangular head" flatworm/Dugesia gonocephala	1.5	( )			
	Other planarians + Dendrocoelum i., each	2.2	( )			
OLIGOCHAETA	Red tubifex worm/Tubificidea sp.	3.8	( )			
LEECHES (HIRUDINEA)	Common fish leech//Piscicola geometra	2.0	( )			
	All "flat" leeches/Fam. Glossiphoniidea	2.5	( )			
	"Curling" leech/Erpobdella octoculata	3.0	( )			
SNAILS (GASTROPODA)	"Cup-like" and "cap-like" river limpets/Ancylus fluv.	1.8	( )			
	Large pond snails/Lymnae stagn.	1.9	( )			
	Ramshorn snail/Planorbius corneus	2.0	( )			
	"Longhorn snouted" snail/Bithynia tent.	2.3	( )			
	all other pond snails/Lymnaeidea	2.5	( )			
MUSSELS (BIVALVIA)	Pea mussels/Pisidium sp.	1.8	( )			
	River mussels/Fam. Unionidea	2.0	( )			
	Migratory mussel/Dreissena polymorpha	2.2	( )			
	Orb mussel/Sphaerium sp.	2.5	( )			
BEACH HOPPERS (AMPHIPODA)	Freshwater shrimps/Gammarus fossarum	1.3	( )			
	Beach hoppers/Gammaridea (fossarum) pulex;					
	a) predominately in life communities of < 1.6	1.6	( )			
	b) in other life communities (except: G. roeseli)	2.0	( )			
	Freshwater shrimp with dorsal thorns (G. roeseli)	2.3	( )			
SLATERS (ISOPODA)	Water slaters/Asellidae aquaticus	3.0	( )			
MAYFLY LARVAE (EPHEMEROPTERA)	Flat larvae without active movement of gill lamellae					
	a) with 2 tail filaments/Epeorus sp.	1.0	( )			
	b) with 3 tail filaments/Rhottrogena sp.	1.0	( )			
	Flat larvae with active movement of gill lamellae and 3 tail filaments/Ecdyonurus sp.	1.5	( )			
	Stocky larvae, very hairy and mud covered/Ephemerella major	1.6	( )			
	Round larvae with 7 pairs of "tree-like", not "leaf-like", gills/Habrophlebia sp.	1.6	( )			
	Burrowing larvae, size 15-23 mm, "feather-like" gills on the back/Ephemera sp.	1.7	( )			
	Round larvae, size 5-9.5 mm, with 7 pairs of "egg-shaped" gill lamellae, in part doubled, middle tail filament shorter	2.0	( )			
	Other larvae only help in decision for QC II in deciding between II and II-III	2.0	( )			

SUBTOTAL: FV..... IS......

6.4.2 Examination and Evaluation Worksheet

for the macroscopic-biological examination of running waters acc. to Meyer
– Page 3 –

INDIVIDUAL SAPROBIC VALUE (ISV), NUMBER (N), FREQUENCY (F), INDIVIDUAL SUM (IS), TOTAL SUM (TS), TOTAL FREQUENCY (TF), TOTAL SAPROBIC INDEX (TSI), QUALITY CLASS (QC) ( ) = mark with a cross

HIGHER TAXA	INDICATOR ORGANISMS	(ISV)	( )	(N)	(F)	(IS)
STONEFLY LARVAE (PLECOPTERA)	Large larvae > 16 mm (without tail filaments) vivid bright colouring, gills in breast region/Fam. Perlidae	1.3	( )			
	Large larvae > 16 mm (without tail filaments), without gills/Fam. Perlodidae	1.3	( )			
	Smaller larvae < 16 mm (without tail filaments), mostly 12 mm, only one species determinable/Leuctra sp.	1.5	( )			
	Smaller larvae < 16 mm (without tail filaments), various species	1.4	( )			
	Small larvae < 12 mm calculated w.o. tail filaments, with egg-shaped marginal wing pad lines/Chloroperlidae	1.0				
	Small larvae < 12 mm calculated w.o. tail filaments, stocky shape, uniformly brown, with 6 "tube-shaped" neck gills/Protonemura sp.	1.0	( )			
CADDIS WORMS (TRICHOPTERA)	Larvae in housings like "heaps of stones", size < 10 mm/Agepetus sp.	1.0	( )			
	Larvae in bent, thin-walled and smooth sand casings, not > 15 mm long case/Sericostoma sp.	1.2	( )			
	Larvae in tube-shaped sand casings with side-loading stones, which are a) about as wide as the casing/Silo sp.	1.2	( )			
	b) either narrower or wider than the casing /Lithax and Goeridae	1.5	( )			
	Larvae without cases, at most web dwelling, without gills on abdomen only in brook biotope /Plectocnemidae	1.2	( )			
	Larvae without cases, with gills on abdomen, a) but only 1 breast segment chitinous on top /Rhyacophilidae	1.4	( )			
	b) all 3 breast segments chitinous on top /Hydropschidae	2.0	( )			
	Remaining cased caddis worms	2.0	( )			
TRUE FLIES (DIPTERA)	"Soldier" fly larvae/Stratiomys sp.	3.0	( )			
	Bloodworms/Chironomus sp.	3.6	( )			
	Rat-tailed larvae/Eristalis sp.	3.8	( )			
				TOTAL SUM:	**FV.....**	**IS......**

EVALUATION

$$\frac{\text{TOTAL SUM OF THE INDIVIDUAL SUMS}}{\text{TOTAL FREQUENCY}} = \text{SAPROBIC INDEX}$$

The quality class can be directly derived from the saprobic index (Table 6)

Example: TOTAL SUM: 48.5
TOTAL FREQUENCY 14 ⇒ SAPROBIC INDEX: 48.5 : 14 = 3.46
⇒ QUALITY CLASS III-IV

6.4.3 DESCRIPTIONS and DETERMINATION LIST of INDICATOR ORGANISMS

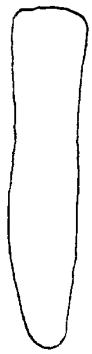
Page 1: **FREE-LIVING FLATWORMS**/TURBELLARIA

Only the group of the Tricladida (generalized: Planarians) is of importance in the determinations. They are indicators of the quality classes from I to II.

Description:
Body oblong, posterior tapered, flat front head part recognizable, eyes numerous or binary; undersurface lies flat on underground, colour; dark (gray, brown, black)

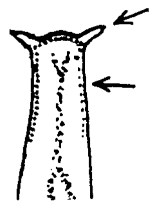
Locomotion:
Even, calm movement, whereby the whole undersurface glides over the underground. (Leeches, on the other hand, move looplike, by alternately releasing the front and back suckers).
Planarians turn like a corkscrew when they come to lie on their back during determination.

Occurrence:
In places averted from sunlight; under stones, branches, leaves. Mostly recognizable as small, "lifeless" jellylike clumps, which move when touched.



prototype of Planarians

"Many eyed" flatworm*/Polycelis felina*

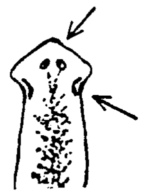


Determination attributes:
Size 18 mm; variously coloured; subulate tentacles at the corners of the frontal margin; many eyes on the margins of front and neck.

Occurrence:
In springs and brooks having a constant low temperature.

Saprobic value: 1.0

"Triangular head" flatworm*/Dugesia gonocephala*



Determination attributes:
Size up to 25 mm; brownish or dark; triangular, almost arrow-tip shaped head with small "ears" which can be moved sideways.

Occurrence:
In the middle courses of clean running water (in mountains or on plains).

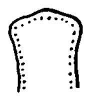
Saprobic value: 1.5

Other flatworms

With the exception of the alpine flatworm/Crenobia alpina (up to 16 mm), which occurs in cold, clear mountain brooks (ISV: 1.0), all other planarians show a great tolerance to pollution (with high salt contents: ⇒ Dendrocoelum l. and Planaria t / with high organic loads: ⇒ Dugesia l. and Polycelis n.).

Determination attributes:

Polycelis nigra: Up to 12 mm long:



Planaria torva: Up to 20 mm long:

Dugesia lugubris: Up to 20 mm long:

Dondrocoelum lactean ("milk-white" flatworm: Up to 26 mm long.

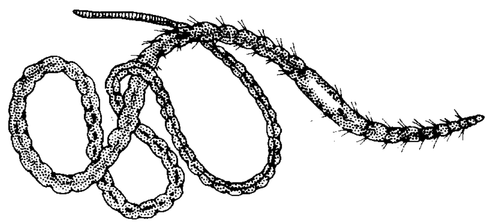
Saprobic value: 2.2 for all of them

DESCRIPTIONS and DETERMINATION LIST of INDICATOR ORGANISM

Page 2: **WORMS**/OLIGOCHAETA

Description:
Worms with elongated body and mostly round cross-section, without parapodia.

Red tubifex worms, *Tubificidae (here: Tubifex tubifex)*
Occurrence:
In mostly large colonies in mud and sandy bottom of polluted standing and running waters; frequently associated with other "red tubifex worms"; Tubifex stick in vertical tubes coated inside with slime with the front part in mud, consume mud and thereby utilize the richly present organic components in it, the rear ends stick out and carry out pendular movements to support the intake of oxygen in the usually extremely oxygen-poor mileau. Some hundreds of thousands of tubifex worms can be present per square metre (⇒ reddish shimmer of the mud surface). When vibrations occur, however, they immmediately draw themselves back into their tubes.



Determination attributes: Approx. 85 mm long, diameter approx. 1 mm; reddish colour (translucent dorsal blood vessels); with bristles.

Saprobic value: 3.8

Notes on the saprobic value:
Because of their association with other red tubifex worms, it is easily possible to confuse them.

- ⇒ *Mix-ups with Limnodrilus hoffmeisteri are of no consequence, because each have about the same saprobic value.*
- ⇒ *Mix-ups with Stylodrilus heringianus are a problem, as these occur in a completely different life community (quality classes I-II). Differentiation in the field is not possible, as there is no appropriate method for this.*

Recommendation:
- ⇒ *Do not use red tubifex worms in the determination when the other indicators belong to a great extent to the quality classes I-II.*
- ⇒ *Use red tubifex worms in the determination with the saprobic value 3.8, when bloodworms, water slaters, "roll" leech etc. are also detectable, even when the same number of indicators of a saprobic value of 2 or better are present. This is of great importance in the last case, as otherwise, in a biotope with different oxygen conditions, the average quality value would be falsified.*

DESCRIPTIONS and DETERMINATION LIST of INDICATOR ORGANISMS

Page 3: **LEECHES**/HIRUDINEA

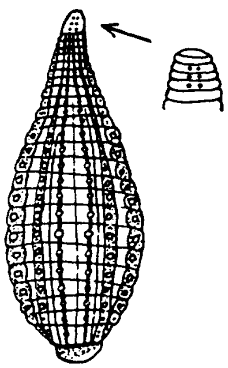
Description: Leeches have suckers
The outlines of the diagrams of the bodies show the differences between "fish", "flat" and "curling" leeches at a glance.
Further attributes:
- ⇒ "Flat" leeches do not *completely* stretch out their hind body in the resting position, nor in the searching or locomotive movement. The hind body is also rounder than that of other leeches.
- ⇒ "Flat" leeches roll themselves into a ball on shock movement (in comparative situations, however, "curling" leeches lie only slightly curled up on the bottom)
- ⇒ "Curling" leeches and "flat" leeches stretch themselves out completely
- ⇒ "Fish" leeches have anterior and posterior suckers as "shields".

Occurrence: Shallow, plant-rich bodies of water; mostly beneath stones, in cracks in branches or between leaves of aquatic plants, without particularly high oxygen demand.

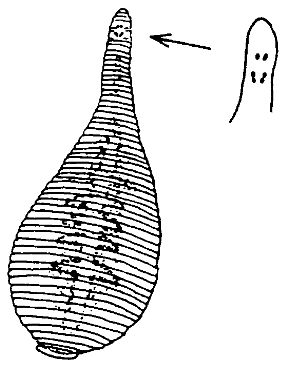
Common fish leech*/Piscicola geometra*
Occurrence: Running and standing bodies of water; on aquatic plants
Determination attributes: Up to 10 cm long, very slender, terete; greenish brown variegated; posterior suction disc conspiuously marked, oral disc with 4 circularly arranged eyes.
Saprobic value: 2.0

"Flat" leeches*/Fam. Glossiphoniidae*
The large "snail leech" (a) is up to 30 mm long, the small "snail leech" (b) and the "two-eyed flat leech" (c) each up to approx. 10 mm long.
Determination attributes: Among others, the position of eyes, see the diagrams.

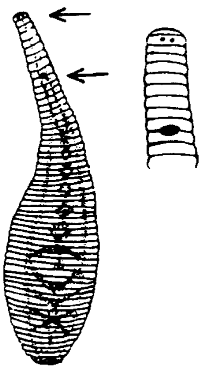
a)



b)

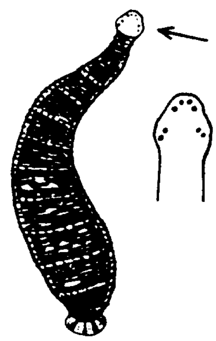


c)



Saprobic value: 2.5 for all of them

"Curling" leech*/Erprobdella octoculata*
Occurrence: In polluted bodies of water (e.g. harbour water); can temporally exist anaerobically
Determination attributes: Up to 60 cm long, mostly brown with lighter spots; frequently curls itself up; very good swimmer; characteristic positioning of the eyes (see diagram).
Saprobic value: 3.0



DESCRIPTIONS and DETERMINATION LIST of INDICATOR ORGANISMS

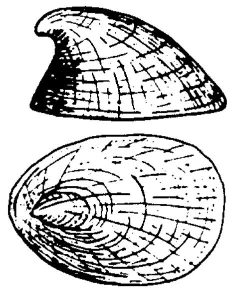
Page 4/1: **SNAILES**/GASTROPODA

Occurrence:
Snails occur in both mesosaprobic zones. They make only small demands on the oxygen content of the water. Plants as basic food and an optimal movement of the water are the decisive factors for the particular preference. Snails with large area shells (pond and saucer snails) are hardly to be found in biotopes exposed to strong currents, whereas forms which are "streamlined" are found there (e.g. water limpets). In standard water segments with marked plant growth, a number of species are to be found which indicate the various stages of pollution.

Note:
Difference between terrestrial and aquatic snails: Aquatic snails have eyes at the base of a pair of feelers (horns), terrestrial snails have two pairs of feelers and eyes on the larger pair of feelers (terrestrial snails have apparently been known to "go for a swim").

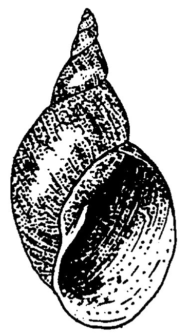
Occurrence:
On plant stalks and leaves as well on poles and stones.

River limpets (cap-like)*/Ancylus fluviatilis*
Determination attributes:
Length 4-9 mm long, width 3-7 mm, height 2-5 mm; shell pointed hood-shaped; aperture egg-shaped.
Occurrence:
Mostly in slightly polluted running waters.
Saprobic value: 1.8



Notes on the saprobic value:
The water snail requires oxygen-rich water because, as its pulmonary chamber is regressive, it depends on respiration through the skin. When the pollution of quickly running water is not too high (tolerance even up to quality class II-II), the oxygen content is usually still sufficient. The saprobic value given by Meyer represents a compromise here.

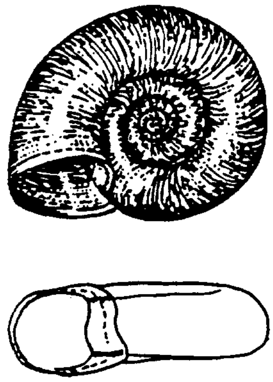
Pond snail*/Lymnaea stagnalis*
Determination attributes:
Length 40-60 mm long, width 20-30 mm; horn coloured shell with long drawn out sharply tipped spiral (almost as high as the aperture), shell with 7-7.5 whorls, the last whorl swollen belly-like.
Occurrence:
Mostly in slightly polluted bodies of water.
Saprobic value: 1.9



DESCRIPTIONS and DETERMINATION LIST of INDICATOR ORGANISMS

Page 4/2: **SNAILES**/GASTROPODA

Ramshorn snail (large, thick, plate snail)*/Planorbarius corneus*
Determination attributes:
Disc-shaped, hard-walled shell:
Shell diameter 27-30 mm, height 10-14 mm;
5.5 (spirals) whorls, which quickly increase in size; olive to brown coloured.

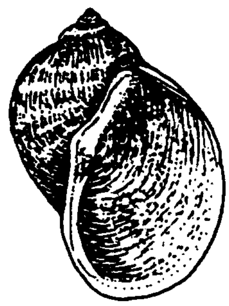


Occurrence:
Frequently found in North Germany, scattered in South Germany; in slowly flowing bodies of water rich in plant life, partly also in standing waters.
Saprobic value: 2.0

"Longhorn snouted" snail*/Bithynia tentaculata*
Determination attributes:
Conically pointed, egg-shaped shell:
Height 10-12 mm, width 6-7 mm,
5-5.5 whorls, with distinct separating seam;
aperture pointed oval and operculum with almost concentric core.

Can easily be mistaken for Bithnia leachi, but this has a circular aperture and a very deep seam.
Saprobic value: 2.3

All other pond snails*/Lymnaeidae*
e.g. Lymnea peregra f. ovata ⇒ diagram
Saprobic value: 2.5

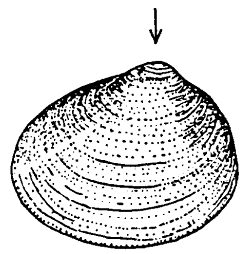


DESCRIPTIONS and DETERMINATION LIST of INDICATOR ORGANISMS

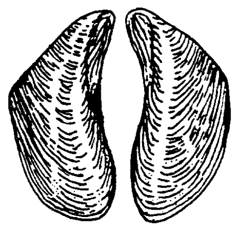
Page 5: **MUSSELS**/BIVALVIA

Mussels are of great importance in the self-purification processes of bodies of water. They extract a considerable amount of the suspended matter. Measurements of the quantity of water which was caused to flow through, and be filtered by, a single mussel in one hour by means of gills and mantle ciliation, have given values of more than 40 litres of water. The excrement which is formed is passed out through the upper mantle opening into the mud on the bottom. The organic components are further decomposed there by microorganisms. Mussels are often found in mesosaprobic zones.
Description:
Like the snails, mussels belong to the mollusks. They are bilateral symmetrical animals. They have no head, and their body is surrounded by a shell consisting of two lateral parts, which are held together at the back by an elastic ligament and closed by very strong adductor muscles.

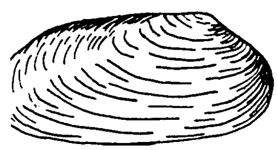
Pea mussels*/Pisidium sp./Fam. Sphaeriidae*
Determination attributes: Very small, i.e. almost always < 10 mm in size, shell oblique, whirl thereby not medial; colour; whitish-yellow, horn-coloured or brown, not possible to be mistaken for Sphaerium sp. as there the whirl is medial and the species is larger.
Saprobic value: 1.8



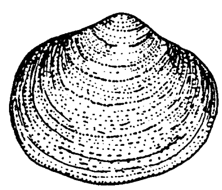
"Migrating" mussels*/Dreissena polymorpha*
Determination attributes:
Height 15-18 mm, length 30-40 mm, width 20-25 mm, shell firm-walled, three-sided, boat-shaped; colour yellowish-gray with dark brown waves and zig-zag lines; pointed, strongly standing out whirl on the front end of the shells.
Can be confused with Congeria cochleata (⇒ brackish water form); this is slimmer and has no zig-zag marking.
Saprobic value: 2.2

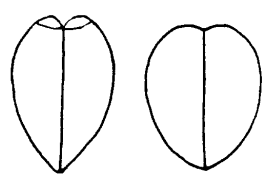


River mussels*/Fam. Unionidae*
Determination attributes:
All species with long shells; longer than 4 cm (adult animals).
Mix-up; not possible because of their size, ⇒ example of the shape on the right:
Occurrence:
In brooks, rivers, lakes and ponds.
Saprobic value: 2.0



Orb mussels*/Fam. Sphaeriidae*
Determination attributes:
Size about 20 mm, whirl of the shell medial (see arrow); yellowish or grayish-brown (not belonging here: "bonnet mussel"/S. lacustre; here the whirl is tube-shaped and different side view; see comparison diagrams of the side views ⇒ left: S. lacustre.
Occurrence:
In standing and slowly flowing waters, mud
Saprobic value: 2.5

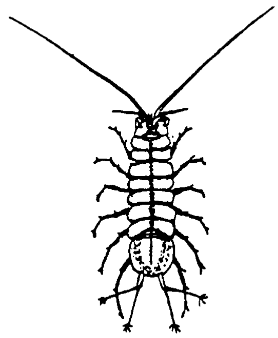




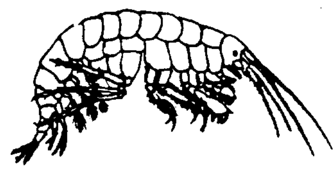
DESCRIPTIONS and DETERMINATION LIST of INDICATOR ORGANISMS

Page 6: CRUSTACEANS/CRUSTACEA here: **SLATERS**/ISOPODA and **BEACH HOPPERS**/AMPHIPODA

The **slaters** primarily populate slowly flowing water. In contrast to the **beach hoppers** (gammarides), they make no great demands on the oxygen and lime content, and also tolerate higher salt concentrations. The gammarides are present the whole year round and in great numbers. They are considered to be good bioindicators.



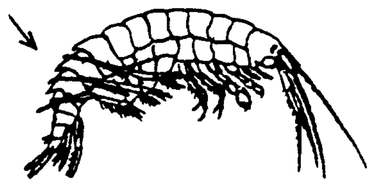
Ware slaters/*Asellus aquaticus*
Determination attributes:
Size, 8-12 mm; dirty-brown, light spots, pigmented, has eyes
Occurrence:
Mostly between foliage and dying plants.
Possible to be cofused with A. coxalis, but this has been taken into account in the saprobic value.
Saprobic value: 3.0



"Brook" freshwater shrimps/*Gammarus fossarum*
Determination attributes:
Looks like G. pulex (common hopper) ⇒ diagram is the same for both!
The attribute is the occurrence: G. fossarum is to be found at altitudes above 450 m above sea level, alone or also with G. pulex.
Occurrence:
In clean, cold mountain waters and in clear brooks on plains.
Saprobic value: 1.3

Common hopper/*Gammarus pulex*
Determination attributes:
Size, up to 20 mm; colour, light brown to gray; movement; sideways forward.
Saprobic value: on occurrence in life communities of ISV of up to 1.5: **1.6**
in all other life communities of higher ISV: **2.0**

Note on the saprobic value:
Below 450 m above sea level, both gammaride species (G. fosserum and G. pulex) are found. G. pulex is mostly found alone below 100 m. In life communities of ISV up to 1.5, it can therefore be expected that both gammarus species are present, so that a differentiation should be made here. Confusion with G. roeseli is possible, but can, however, be avoided by observation of the dorsel spines (⇒ see G. roeseli diagram); with G. tigrinus less probable, as it has a "tiger colouration". G. tigrinus also tolerates higher salt concentrations, as it is a naturalized brackish water form.



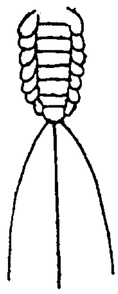
"River" freshwater shrimp/*Gammarus roeseli*
Determination attributes:
Keeled segments on the back dorsal area (⇒ see diagram). Colour, mostly olive-green.
Occurrence:
In standing and slowly flowing bodies of water, tolerates an oxygen minimum of 4 mg/l.
Saprobic value: 2.3

DESCRIPTIONS and DETERMINATION LIST of INDICATOR ORGANISMS

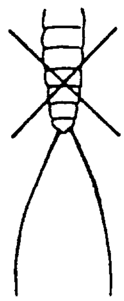
Page 7/1: **MAYFLY LARVAE**/EPHEMEROPTERA

Mayfly larvae are often mistaken for stonefly or dragonfly larvae. They are recognizable by the difference in the hind bodies:

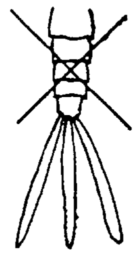
Mayfly larvae with 3 cerci and gill lamellae



Stonefly larvae with 2 cerci, without gills



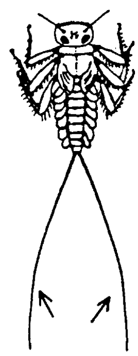
Dragonfly larvae with 3 tail lamellae, without gills



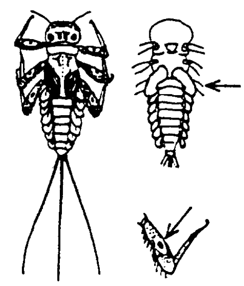
All mayfly larvae have a relative large oxygen demand. They are indicators for the quality class from I up to and including II. Their body-build allows four groups of species to be differentiated. They enable conclusions on the particular mode of life, and as a rule also on the type of body of water which they live in.
"Flat" mayfly larvae are found in quickly flowing mountain brooks and in plains. Their flattened body shape protects them – pressed against stones – form the strongest currents (water flow rates up to 1.3 m/s). Their zig-zag movements in all directions can be observed when a stone is taken out of the water.
"Burrowing" mayfly larvae are found in slowly flowing water or in the waterside zone of standing waters. Prerequisite is a sandy or muddy soil base, in which they can build mole-like tunnels with their dagger-like mandible and flattened front legs. **"Swimming (round)" mayfly larvae** are also found in slowly flowing water or in ones with little current in small streams, in the region of the plant belt. Their hair-covered cerci serve as swimming organs. **"Crawling" mayfly larvae**, which are very hairy, mostly covered in mud (and therefore difficult to recognize) are found in the region of the beds of various bodies of water.

"Flat" mayfly larvae

Epeorus sylvicola: Flat larvae with only two tails (the middle one is missing); no active movement of the gill lamella, eyes on the top side of the head
Occurrence:
In quickly flowing, cold mountain streams.
Saprobic value: 1.0



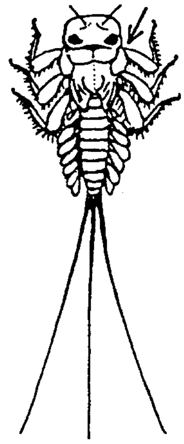
Rhitrogoena sp.: Flat larvae with three tails; no active movement of the gill lamella, eyes on the top side of the head; greatly enlarged 1st pair of gill lamella on the underside of the body, as well as light marks with a dark point on each femur ⇒ diagram
Occurrence:
In quickly flowing mountain streams, seldom in plains.
Saprobic value: 1.0



DESCRIPTIONS and DETERMINATION LIST of INDICATOR ORGANISMS

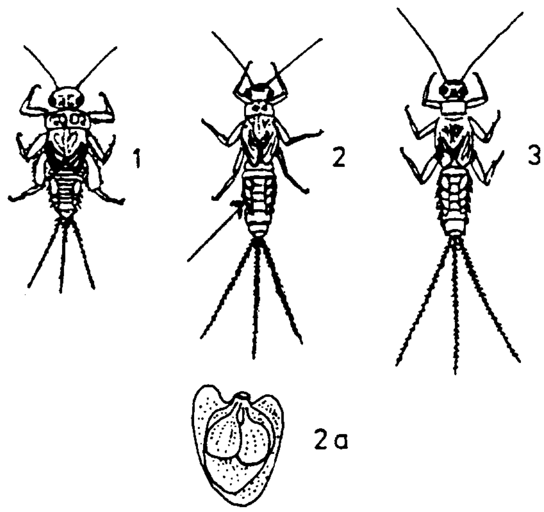
Page 7/2: **MAYFLY LARVAE**/EPHEMEROPTERA

"Flat" mayfly larvae (continued):
Ecdyonurus sp.
Determination attributes:
Flat-shaped larvae with eyes on the top side of the head; yellowish-brown to dark gray, now and again brown with lighter markings; gill lamella more egg-shaped, active movement of the gill lamella can be observed; front thorax prolonged disc-like from the corners along the sides of the middle thorax ⇒ diagram
Occurrence:
Mostly in mountain brooks, less seldom in the lower courses of waters of average quality.
Saprobic value: 1.5

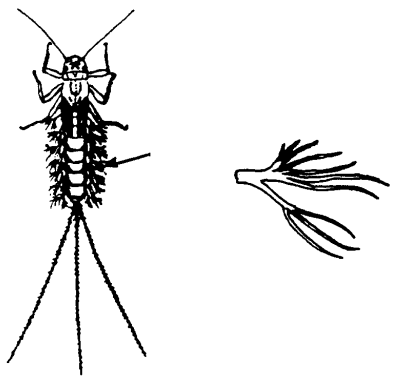


"Crawling" mayfly larvae
Ephemerella sp.
Determination attributes:
Size, 6-11 mm; yellowish-brown; eyes diected towards the sides; 5 pairs of tracheae gills on the top side of the abdomen, tiled one on the other, whereby the 5th or 4th pair is covered by the others, diagram 2a (type 2). Diagrams 1 to 3 show different types.
Occurrence:
Frequently in mountain brooks, E. major (1; very stocky shape) usually covered with mud particles and very inconspiuous.
Saprobic value: 1.6

Note on the saprobic value:
This is a mixed value for the whole family (the saprobic values are very different, but a differentiation between them in the field is very difficult).

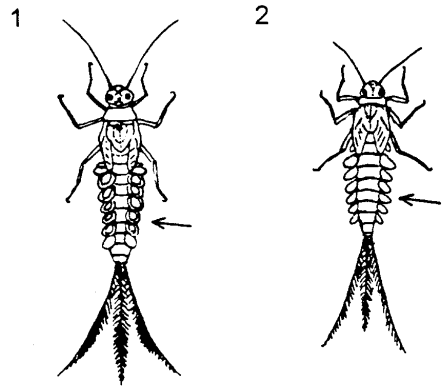


"Round" mayfly larvae
Habrophlelbia sp.
Determination attributes:
Size, 5-6 mm; brown; 7 "tree-like" (not "leaf-like") pairs of gills.
Occurrence:
In slowly running waters.
Saprobic value: 1.6



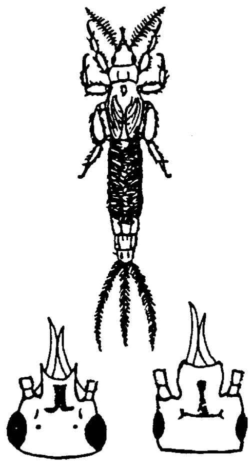
DESCRIPTIONS and DETERMINATION LIST of INDICATOR ORGANISMS

Page 7/3: **MAYFLY LARVAE**/EPHEMEROPTERA"Round" mayfly larvae" (continued):



Fam. Baetidae
Determination attributes:
Size, 5-10 mm; 7 pairs of gill lamella on the abdomen (doubled, diagram 1, or single, diagram 2); head is held vertically to body posture ("locust-like"); outer caudal filaments only with hair in the inner side.
Occurrence:
In standing waters as well as in slowly running waters.
Saprobic value: 2.0

Note on the sapropic value:
An **ISV of 1.5** is used in mountain brooks down to 200 m above sea level with extensive indicators up to quality class 1.

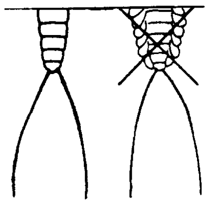


"Burrowing" mayfly larvae
Ephemera sp.
Determination attributes:
Size, 15-23 mm; yellowish; 7 pairs of tracheae gills on the back of the abdomen, two-branched, feather-shaped lamella (not recognizable in the diagram); differences on the top of the head of E. vulgata (⇒ diagram a) to E. danica (⇒ diagram b) only shown here as a matter of interest.
Occurrence:
Waterside zones of brooks in uplands and plains, lakes.
Saprobic value: 1.7

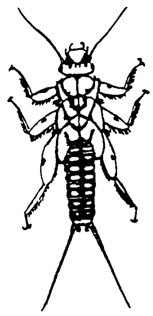
Remaining mayfly larvae
⇒ only as a help in reaching a decision for quality class II, when they are determined without a limiting value between II and II-III, then:
Saprobic value: 2.0

DESCRIPTIONS and DETERMINATION LIST of INDICATOR ORGANISMS

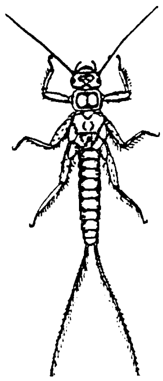
Page 8: STONEFLY LARVAE/PLECOPTERA



Stonefly larvae always have only two tail bristels or cerci. The differences in this determinative criterium to mayfly larvae and small dragonfly larvae are shown on page 7/1. One can, however, confues stonefly larvae with mayfly larvae Epeorus sp., which also have only 2 cerci, but in addition gills on the side of the abdomen (⇒ diagram). Stoneflies have a higher oxygen demand and are therefore found almost exclusively in quickly running, extensively unpolluted waters. They react very sensitively to pollution. They are almost exclusively indicators for water qualities of I and I-II.
Occurrence:
Predominately at the underside or the current leeside of stones, between washed-up vegetation and branches, or among aquatic plants and moss carpets.
Nutrition:
Young larvae feed on detritus, otherwise herbivorous (small forms) and carniverous.



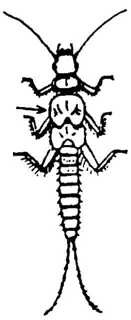
Large larvae > 16 mm (measured without the tail filaments), brightly coloured; *Gills in the thorax region* ⇒ **Fam. Perlidae** (representatives Perla sp., Perla marginata and Dinocras sp. here with a mixed index of 1.3; diagram shows Perla sp. as example)
Occurrence:
All in brooks and upper courses of rivers in mountians.
Saprobic value: 1.3



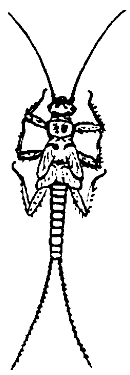
Large larvae > 16 mm (measured without the tail filaments); body somewhat flattened and yellowish-dark brown in colour, head with vivid markings *without gills* ⇒ **Fam. Perlodidae**
Occurrence:
In springs, cold brooks and rivers in the uplands and the Alps, partly also in plains.
Saprobic value: 1.3

Small larvae < 16 mm (measured without the tail filaments); **mostly < 12 mm**, only one species determinable, very slender, 5-12 mm long body of uniform yellowish to light brown colour, and regular parallel wing pads directed backwards: Leuctra sp. (not depicted here)
Saprobic value: 1.5

Small larvae < 16 mm (measured without the tail filaments); **mostly < 12 mm**, several species can be differentiated.
Saprobic value: each 1.4



Small larvae < 12 mm (measured without the tail filaments); with egg-shaped marginal lines of the wing pads; yellowish; larvae without gills.
Occurrence:
Brooks and rivers in the uplands and the Alps ⇒ **Chloroperla sp**.
Saprobic value: 1.0



Small larvae < 12 mm (measured without the tail filaments); stocky shape, monotonous brown, 6 *tubular* neck gills ⇒ diagram ⇒ **Protonemura sp**.
Occurrence:
Brooks and rivers in the mountains and uplands, hardly in plains.
Saprobic value: 1.0

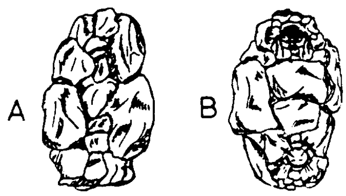
DESCRIPTIONS and DETERMINATION LIST of INDICATOR ORGANISMS

Page 9/1: **CADDIS WORMS**/TRICHOPTERA

From their appearance and mode of life, two basic forms can be distinguished:

Non-campodeiform larvae (A) (caterpillar-shaped, eruciform)	**Campodeiform larvae (B)**
The *longitudinal axis* of the head is at a *right angle* to the axis of the body	The *longitudinal axis* of the head is in a *straight line* with the axis of the body
Many forms have *lateral lines*	*No lateral lines*
Gills in individual or multiple threads and rows (ventral, dorsal or lateral rows)	*Gills not so* formed
Frequently with *hump* on the first abdominal segment	No hump
All with transportable housing (case)	*Only few have a case*, and this is mostly not transportable
Pytophagous	*Frequently* predators
Usually in *rapidly running water*	*Slowly running water* and *standing water*
Indicators of *quality classes I-II and II*	Indicators of *quality classes I and I-II*

Larvae in housings which look like "heaps of stones" and are < 10 mm long, width approx. 4-5 mm, height approx. 3 mm; housings semi-ellipsoidal, bent top side (A) with coarse material, flat or concave underside (B) covered with small stones and with two holes, for the head and front legs and for anal claws.
Occurence: Fast running brooks in mountains and uplands, seldom plains
Saprobic value: 1.0

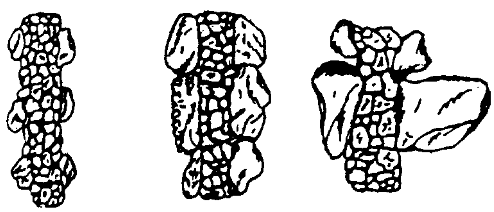


⇒ ***Agapetus sp.***

Larvae in curved, thin-walled, smooth housings of sand; see diagram (⇒ not > 15 mm long cases, width 2-3 mm; shaped like a horn of plenty; back end with a circular hole in the secreted membrane; larvae not campodeiform, and with dark head; mesothorax often membranous on top and with some chitinous spots.
Occurrence: Mountain and upland brooks or fast running brooks in plains
Confusion possible with Notidobia, which is up to 18 mm long ((⇒ S.V. 1.5).
Saprobic value: 1.2

⇒ ***Sericostoma sp.***

Larvae in tube-shaped cases of sand, which are side-loaded with stones of about the same width as the cases (compare with Lithax and Goeridae); length 10-12 mm, width 2-3 mm (measured without the loading stones); larvae not campodeiform, head and thorax reddish-brown, otherwise blackish-brown.
Occurrence: Fast running brooks in mountains and plains
Confusion possible with Lithax and Goeridae (see diagram).
Saprobic value: 1.2



Lithax Silo Goera

⇒ ***Silo sp.***

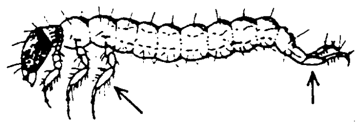
DESCRIPTIONS and DETERMINATION LIST of INDICATOR ORGANISMS

Page 9/2: CADDIS WORMS/TRICHOPTERA

Larvae in tube-shaped cases of sand, which are side-loaded with stones which are either much smaller (Lithax) or much wider (Goera) than the cases, see the diagrams under Silo sp.; larvae not campodeiform, colour of head and back part yellowish-brown (Goera pilosa), black (Lithax) and reddish-brown to blackish-brown (Silo sp.).
Occurrence: Goera pilosa: Brooks on plains and surf zone of lakes. *Lithax obscuras*: Fast running brooks, mainly in plains
Saprobic value: 1.5

⇒ ***Lithax and Goera***

Larvae without housing, at most web dwelling, campodeiform larvae, up to 22 mm long and 3.5 mm wide, no gills; head and first breast segment chitinous, mostly with point markings; legs with long bristles (not with P. montanus); anal prolegs are leg-like and haired.
Occurrence: Mountain and upland brooks or in the upper courses of running waters in plains
Confusion possible: Therefore only to be used as indicator of water quality when it is not found in still water regions and channels, as well as in upper and middle courses of running waters. The biotope is the determinative feature here.
Saprobic value: 1.2



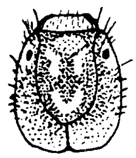
⇒ ***Plectrocnemia sp.***

Larvae without housing, campodeiform, up to 25 mm long and 3.5 mm wide, relatively small egg-shaped head; larvae swarm freely (without web dwelling) with tufted gills on the abdomen; only 1st breast segment chitinous.
Occurrence: Mountain and upland brooks as well as in rapidly running brooks in plains (e.g. heath brooks).
Confusion: Eventually with larvae of the Fam. Hydropsyschidae (with these, all 3 breast segments are chitinous on top).
Saprobic value: 1.4

⇒ ***Rhyacophila sp.***

Larvae without housing, with web dwelling tightly anchored to stones etc.; campodeiform, up to 20 mm long, all 3 breast segments chitinous on top, Mostly grayish-brown; branched tufted gills; bright (yellow) markings on the head shield.
Occurrence: Mostly in rapidly running water in plains and mountains.
Saprobic value: 2.0

⇒ ***Hydropsyche sp.***

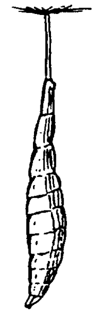


Further caddis worms with housings: Because of the abundance of further forms and the difficulty in their determination, it appears to be practical to use an ISW of 2.0 when a quality class II decision with a limiting value between II and II-III is to be substantiated, as there are no caddis worms with an ISW worse than 2.0.
Saprobic value: 2.0

DESCRIPTIONS and DETERMINATION LIST of INDICATOR ORGANISMS

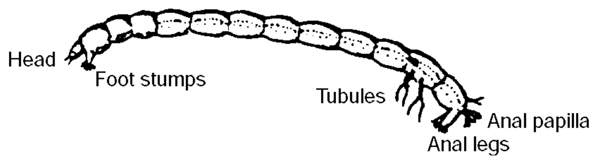
Page 10: TRUE FLIES/DIPTERA

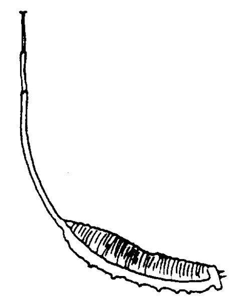
There is an extraordinarily large number of dipterous insects. They are found in biotopes of various quality classes. There are, for example, alone in the Chironomidae family (bloodworms, with about 1000 species no doubt the most species-rich insect group in Central Europe), representatives in all types of waters, from mountain streams to sewers. There are, however, only relatively few forms which are suitable for our purpose as indicator organisms. They indeed fulfill the most important requirements of an indicator, but either cannot be identified, or only with great difficulty, by macroscopic field methods. In addition, in most cases not only larva, but also pupa and imago, are required to determine the species.



"Soldier fly" larvae*/Stratiomys sp.*
Determination attributes:
Larvae are about 40-50 mm long; grayish-green in colour; also recognizable by the long, extended abdominal segment (resembling a breathing tube) with a wreath of bristles at the end, with which the larvae can hang onto the water surface.
Occurrence: Slowly running or standing waters, in tangles of dense algal tufts; frequently in saline water.
Saprobic value: 3.0

Bloodworms*/Chionomus thummi or Ch. plumosus groups*
Determination attributes:
Larvae are about 10-20 mm long; small head, 12 cylindrical segments; a pair of foot stumps on the first segment, two pairs of longer appendages (tubules) on the next to last segment, a pair of anal legs on the last segment; around the anus, anal papilla; body coloured red by haemoglobin.
Occurrence: In the upper mud layers of strongly polluted running waters and wastewater ditches; up to 3,000 or more animals per m2.
Confusion between the two groups is possible, but insignificant, as both are key types of quality class IV.
Saprobic value: 3.6 (only when tubules are present).





Rat-tailed larvae*/Eristalis sp.*
Determination attributes:
Larvae about 20 mm long; appear to be fat; whitish-gray; locomotory warts on the underside; 3 section, telescope-like breathing tube is about 35 mm long.
Occurrence: In standing or slowly running, nutrient-rich waters, wastewater ditches, liquid manure reservoirs and cess pits.
Saprobic value: 4.0.

6.5 Introduction to the Eco-Kit "Biological Testing of Water Quality"

The Eco-Kit is designed to enable examinations to be carried out by large groups (up to the size of a school class). The individual examination tasks necessitate that the work be split up within the group: Some group members use the fishing net to comb through the plant belt by the waterside, while some other small groups search for organisms under stones, leaves or submerged branches, determine the animals first found, measure the temperature of the water or note the initial data in the Examination and Evaluation Worksheet. The Eco-Kit case contains the following equipment and materials for the diverse tasks:

Contents of the Eco-Kit for Biological Testing of Water Quality 30834.77

Sieve, d = 160 mm, fine-meshed	65854.00	6
Fishing net for aquatic insects	64576.00	1
Dish, plastic, 150x150x65 mm	33928.00	6
Tweezers, curved, pointed 100 mm	64608.00	6
Brush, fine	64702.00	4
Painters brush, hard	40979.00	2
Pipette with rubber bulb, 10 pcs	47131.01	1
Weighing dishes, 80 x 50 x 14 mm, 12 off	45019.05	1
Magnifying glass, small	64599.00	6
Magnifying glass, large	64600.00	6
Snap-cap vials, 15 ml, 10 pcs	33621.03	
Snap-cap vials, 50 ml, 10 pcs	33623.03	1
Petri dishes, plastic, d = 9 cm, 6 off	64709.03	1
Vernier caliper, plastic	03011.00	1
Rule, plastic, 200 mm	09937.01	2
Handbook Biological Testing of Water Quality	30834.02	1

7. THE PHYWE TEST-KIT 30837.77 FOR CHEMICO-PHYSICAL EXAMINATIONS OF RUNNING AND STANDING WATERS

It is recommended that, when examining bodies of water, not only the biological parameters be measured, but also the chemico-physical parameters. The parallel results enable the results to be better substantiated.
The handbook for the PHYWE Test-Kit 30837.77 contains a presentation of the examination procedure according to the method of BACH and G.R.E.E.N. which has already proved its worth in school use. The chemico-physical parameters can also be entered in the "Environmental Atlas Water" software and be evaluated by it.