

3.A. WATERSHED

WHAT IS A WATERSHED?

Rivers can be seen as veins of a leaf, extending all over a drainage basin up to their divides. When rain falls on a watershed it finally ends up in a river system. A river channel is the lowest point in the surrounding landscape. Its purpose is to convey excess water from a drainage basin, which will include the products of weathering and additional loads of solutes produced by man. This property makes a drainage basin an integrator and its operation is reflected in the quantity and quality of the river run-off.

Drainage basin (catchment area) is the area which supplies a river system, lake or reservoir with water. The whole area consists of **smaller sub-catchments** supplying tributaries of the main river and **direct catchments**, which drain straight into a lake or main river (Box 3.1).

The purpose of the river system is to drain catchment areas. Surplus water in the drainage area forms **river run-off**, which is conveyed by a river system. Products of weathering (sediments and solutes) as well as man-generated pollutants, are transported with the water.

WHERE ARE THE BOUNDARIES OF A WATERSHED?

The boundary line separating catchments is called a **drainage divide** or **watershed divide**.

A watershed divide is delineated on a topographic

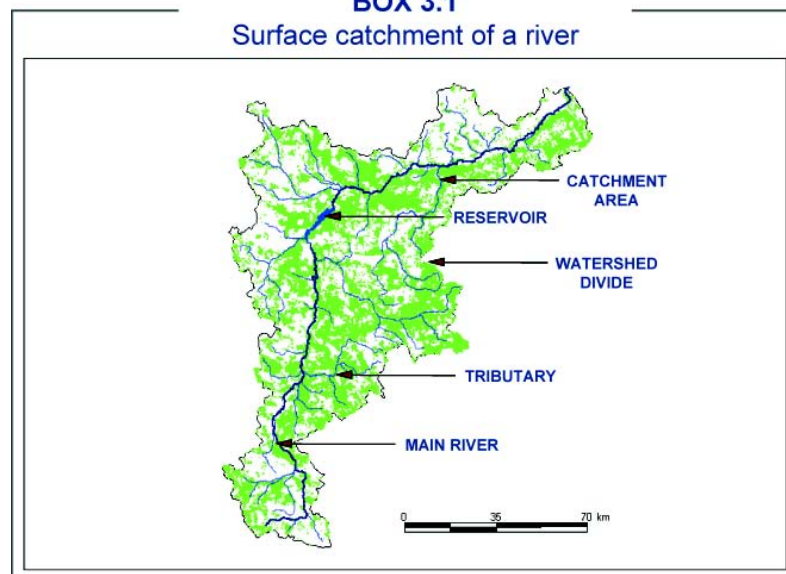
map according to the relief of the landscape. This method helps to determine the **surface catchment**.

In many catchments the area which supplies a river system with groundwater is not coincident with the surface catchment. Ground water may flow from a distant area. In such a case a **groundwater catchment** should be delineated based on an analysis of the groundwater contour lines or piezometric surface.

WHY IS A WATERSHED A BASIC UNIT IN IWM?

A drainage basin is the primary unit for water and matter circulation, analysis and planning. In this unit mesoscale water circulation is created from a random and temporally uneven field of atmospheric precipitation. According to the first principle of ecohydrology, which defines the **framework for ecohydrological processes** in IWM, energy flow, water and matter circulation are integrated at a basin scale, as a major unit, and function as a single entity. The mesoscale cycle of water circulation within a basin regulates the coupling of terrestrial and aquatic ecosystems, provides a template for the quantification of ecological processes and creates the template for the application of **ecohydrology and phytotechnologies** in management practices.

BOX 3.1
Surface catchment of a river





■ 3.B. CLIMATE

WHAT IS CLIMATE?

- ▶ **Climate** is defined as the average of weather variables over relatively long periods of time.
- ▶ **Climate variability** is defined as the range of values that the climate can take over time in a given area.
- ▶ **Climate change** means an alteration of atmospheric processes attributed to human activity, in addition to natural climate variability.

DOES CLIMATE CHANGE?

According to the most recent assessment of the Intergovernmental Panel on Climate Change (2001), the global surface temperature may increase by between 1,4°C and 5,8°C over the 21st Century as a result of human activities. Not only air **temperature**, but also **precipitation**, **evapotranspiration**, **wind speed** and **solar radiation**, are likely to be perturbed due to changes in the chemical composition of the atmosphere. Climate changes are likely to exaggerate **extreme weather fluctuations**.

HOW DOES IT CHANGE?

The impacts of climate change on hydrology and ecology are usually assessed by defining scenarios for changes in climatic inputs to physical and biological processes. There is a growing demand for credible regional-scale climate scenarios, which are reliant on techniques to downscale from **Global Climate Models (GCMs)** - the principal tools for climate change research.

There is much uncertainty implicit in the choice of GCM, further complicated by the variety of downscaling methods. One of the major policy implications of climate change is that it may no longer be assumed that the future aquatic resources base will be similar to that of the present.

HOW CAN CLIMATE CHANGE IMPACT ECOHYDROLOGICAL PROCESSES?

Global climate change is expected to affect directly both the **quantity** and **quality of water resources**.

It will affect particular elements of the hydrological cycle, changing river discharges, and hence also water retention times in reservoirs and water levels in lakes. It is predicted that the timing and intensity of **floods and droughts** will also change, which can have serious economic and sociological effects. Since water is the main medium responsible for the export of nutrients and pollutants from catchments, the above processes will alter **nutrient transport patterns** to fresh waters, and hence their physical and chemical parameters. Due to predicted air **temperature increases**, water temperature and the number of ice-free days will also change. The rate of all physical, chemical and biological processes could be accelerated. Some **species may disappear** or the boundaries of their range could be shifted. All the above processes may seriously affect ecosystem functioning and structure, especially in the case of degraded ecosystems.

3.C. HYDROLOGICAL CYCLE

WHAT IS THE HYDROLOGICAL CYCLE?

The hydrological cycle is a process of water circulation between the atmosphere, hydrosphere, and lithosphere (Box 3.2). It can be considered at two major scales:

- ▶ **global scale**, where the major elements are the oceans (97%), continents (0,02% as inland waters), and atmosphere (0,001%); and
- ▶ **basin scale (mesoscale)**, where the major elements are water fluxes between the atmosphere, biosphere and lithosphere. Mesoscale water circulation can be considered as the **template for the quantification of fundamental ecological processes**.

WHY IS AN UNDERSTANDING OF THE HYDROLOGICAL CYCLE IMPORTANT FOR IWM?

Water quantity...

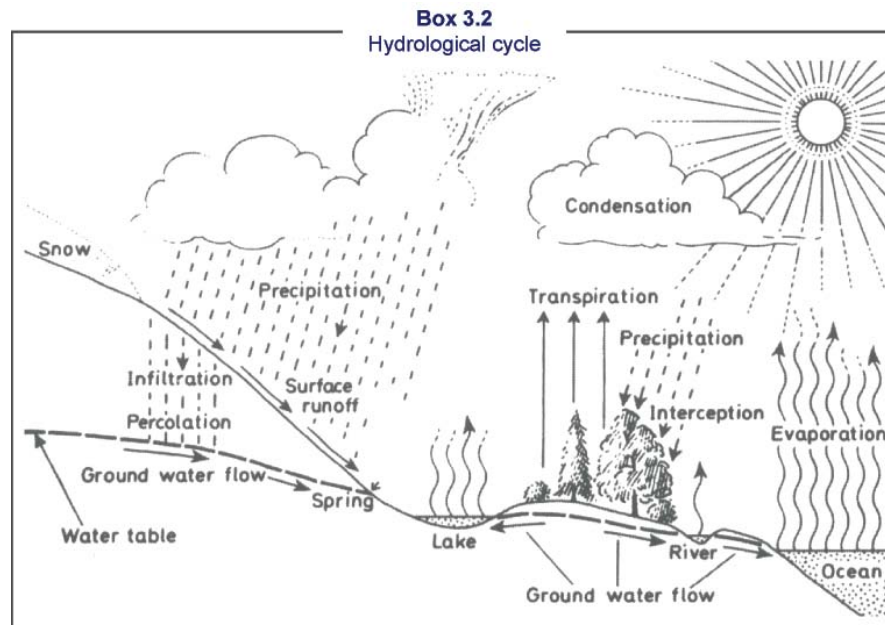
Sustainable water management should take into account the natural water balance that determines the amount of water resources and their availability in time. Hydrological cycle dynamics regulate **the amount of water** in freshwater ecosystems and the **availability of water** in terrestrial ecosystems, which is potentially a limiting factor for primary productivity and hence vegetation development. Therefore, water is one of the major driving forces for ecological processes at

the catchment scale. On the other hand, biological processes can also regulate the hydrological cycle, especially at the mesoscale, by influencing evapotranspiration, evaporation, and the heat and water balances. Therefore, application of phytotechnologies (e.g., increase of water retention in a catchment by management of vegetation cover) can be a useful tool to regulate water circulation in a basin and, consequently, to increase the quantity of water.

From a socio-economic perspective, stabilization of the hydrological cycle by using ecohydrological and phytotechnological measures may reduce the risk of **floods and droughts**.

Water quality...

The hydrological cycle forms a template for biogeochemical cycles in a catchment and is linked with processes of **erosion** and **sedimentation**. Water is one of the most important driving forces for material circulation and the primary medium by which nutrients and pollutants flow within landscapes and into most terrestrial and water ecosystems. Therefore, without an accurate estimate of the hydrological cycle elements in a catchment, it is not possible to estimate biogeochemical cycles, the control of which is fundamental for the application of **ecohydrological and phytotechnological measures in IWM**.



3.D. BIOGEOCHEMICAL CYCLES

WHAT ARE BIOGEOCHEMICAL CYCLES?

Biogeochemical cycles are the characteristic routes between **abiotic elements** of the environment and its **biotic components** through which **matter circulates**. Matter circulates as particular elements and occurs in the form of **continuously transformed organic and inorganic compounds**. Living organisms need 40 elements to sustain growth and reproduction. The most required **nutrients** include such elements as: carbon, phosphorus, nitrogen, oxygen and hydrogen, of which the last two are usually readily available in most environments.

HOW ARE NUTRIENTS TRANSFORMED?

Nutrient transformations in biogeochemical cycles are controlled by two groups of processes:

- ▶ **Abiotic** - geochemical cycles such as: precipitation, diffusion, dissociation and redox reactions.
- ▶ **Biotic** - resulting from the activity of live organisms such as: incorporation of inorganic and organic nutrients into the biomass of plants, grazers and predators or liberation of nutrients in microbiological decomposition.

All the above processes in both terrestrial and freshwater ecosystems are strongly controlled by **solar energy, water and temperature**. Solar energy is assimilated by plants and flows through trophic levels and back to decomposers. Water serves as a medium determi-

ning the «routes» of the nutrients in biogeochemical cycles (e.g., the rate of erosion and nutrient availability for vegetation). Temperature determines the rate of both abiotic and biotic process.

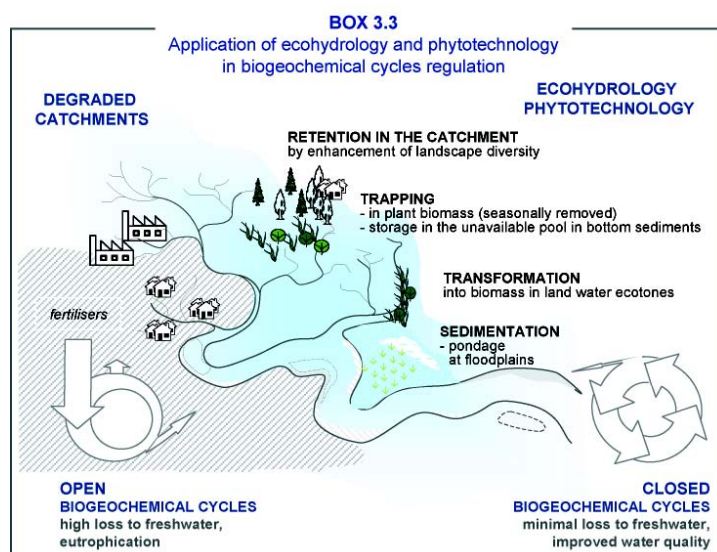
Degradation of biogeochemical cycles

Anthropogenic pressure results in degradation of landscapes (e.g., deforestation, unsustainable agriculture and urbanization) and the biotic structure of fresh waters (e.g., river regulation), and thus leads to modification of evolutionarily established biogeochemical cycles.

The above processes open nutrient cycles that results in their increased export from the landscape to fresh waters and diminish the ability of freshwater ecosystems to self-purify, while nutrient enrichment will lead to eutrophication.

Role of ecohydrology and phytotechnology

Proper functioning of biogeochemical cycles determines water quality. The main role of **phytotechnology** is to reverse the effect of their degradation by retention of nutrients in vegetation. **Ecohydrology** defines how to optimize the assimilation processes by use of hydrological processes, e.g., for precise distribution of vegetation in a catchment. Therefore, understanding the functioning and factors regulating biogeochemical cycles is fundamental for application of ecohydrology and phytotechnology in IWM.



■ 3.E. LANDSCAPE STRUCTURE AND VEGETATION COVER

WHAT IS A LANDSCAPE?

A **landscape** is the total human environment including the geosphere, biosphere and technosphere. From an **ecological point of view**, it should be considered as a group of biotopes, which are the smallest spatial units of homogenous abiotic conditions (**physiotope**) with a related natural combination of **biota**.

This imposes the approach for **landscape analysis**, which requires a holistic and integrative approach focused on the entirety of biogeochemical processes, such as proposed in the concept of ecohydrology.

WHAT ARE LANDSCAPE FUNCTIONS?

- ▶ accumulation of material and dispersion of human - induced energy;
- ▶ receptacle of unsuitable wastes from populated areas and their rendering;
- ▶ filtration of energy, matter and organism flows;
- ▶ resource regeneration and recycling;
- ▶ provision of wildlife refuges; and
- ▶ support for regional settlement and recreation (Mander et al., 1995).

WHAT DECIDES LANDSCAPE STRUCTURE?

A landscape is a complex system of elements, which are **static** or **dynamic** in time and space.

- ▶ static elements include forms that are structural in character - **point, line and area elements** distributed homogeneously, heterogeneously or in a patchy way;
- ▶ dynamic elements consist of **biota** reflecting relationships between biotic and abiotic components.

UNBALANCED AND BALANCED LANDSCAPES

The **elements** in each class consist of primary or **natural**, and secondary, or **human-made or man-modified**, structures. The unsustainable interaction between these two groups may create an **unbalanced** situation leading to devaluation of landscape processes.

The effect of this interaction is degradation of landscape structure, its fragmentation or homogenization (depending on the land - use system).



Fig. 3.1
Representation of a tropical Landscape,
Bogor, Indonesia
(photo: V. Santiago-Fandino)

Both situations may lead to:

- ▶ increased leak of toxic substances and nutrients to waters;
- ▶ decrease of water retention in river catchments;
- ▶ changes in solar radiation balance; and
- ▶ decline of biodiversity.

Freshwater ecosystems, which are located in land depressions, are good indicators of the quality of neighbouring terrestrial systems.

ECOHYDROLOGY & PHYTOTECHNOLOGY IN LANDSCAPE MANAGEMENT

Vegetation is one of the most important factors **protecting landscapes** and, at the same time, the most sensitive element affected by man's activities. Its role is influenced by: the reduction of forests, changes in species composition and quantitative properties of vegetation cover, land drainage or irrigation, and the degradation of land - water ecotone zones.

Therefore, sustainable **landscape management**, as well as management of **ecotone zones** between a landscape and water, requires a better understanding and regulation of hydrology - biota interactions as proposed in the **ecohydrological** approach and put into practice through the application of **phytotechnologies** as one of major biotic tools.

The goal of sustainable management is to maintain the ecological functions of landscapes under increasing human aspirations and pressures.

3.F. STREAMS AND RIVERS

WHAT ARE THE STRUCTURAL COMPONENTS OF A RIVER ECOSYSTEM?

Streams and rivers are integrated flowing systems that create and maintain aquatic habitats within the structure of their flow as well as on and below their wetted boundaries.

Natural channel evolution is governed by climate, geology, topography, soil and vegetation conditions of a watercourse and watershed. The characteristic regime, or geomorphology, of a natural channel can be defined in terms of the maximum water level contained between its banks, channel width to depth ratio, occurrence of an active floodplain, meander pattern, slope, bed material and bank material.

Streams and rivers are thus open systems characterized by a high level of heterogeneity across a range of spatio-temporal scales (Ward, 1989). Four dimensions are recognized:

- ▶ longitudinal dimension: along the direction of flow from source to estuary;
- ▶ lateral dimension: the system composed of the main channel and floodplain;

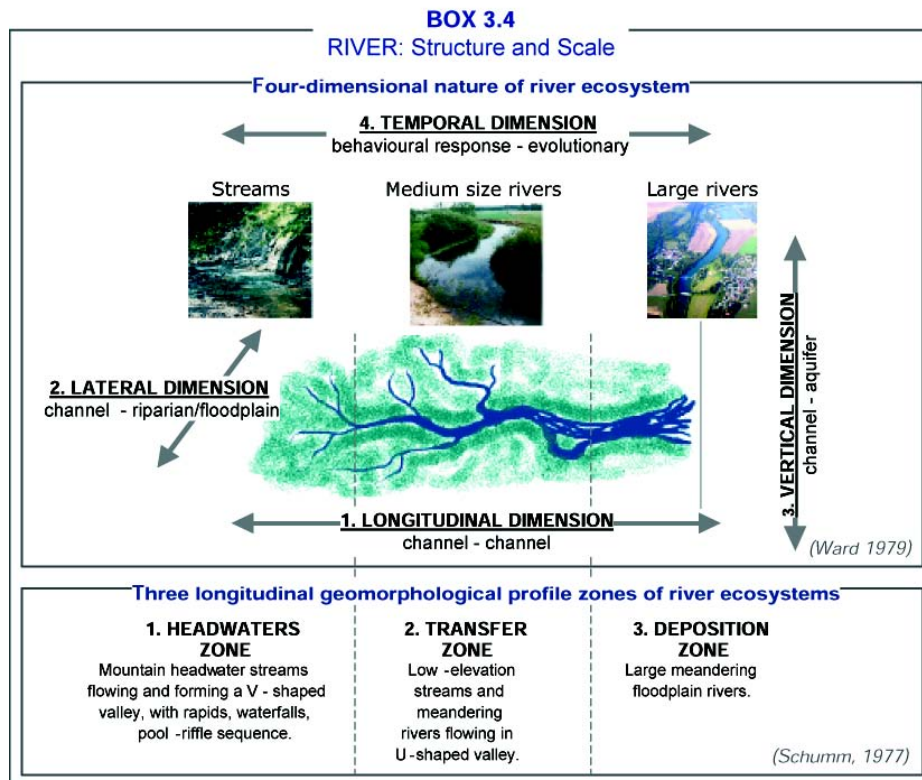
- ▶ vertical dimension: the interactions between river water and groundwater in the surrounding area; and
- ▶ temporal dimension: processes such as succession and rejuvenation.

Longitudinally rivers are divided into three zones:

- headwaters;
- transfer; and
- deposition zones (Schumm, 1989).

Riverine habitats are organized hierarchically in a basin context (Frissell et al., 1986) and should be especially considered during restoration projects. The broad spatio-temporal scale of river ecosystems, especially their links and interactions with landscapes, determines the need to view and understand its processes in the larger scale and holistic context proposed, e.g., by ecohydrology concept.

The simplest way to estimate the size of a river is with the stream-order conception (Strahler, 1964). In this system, channels with no tributaries are numbered as order 1. Two channels of order 1 create a channel of order 2, etc.



■ 3.G. LAKES AND RESERVOIRS

WHAT ARE THE DIFFERENCES AND SIMILARITIES BETWEEN LAKES AND RESERVOIRS?

A **lake** is a natural, standing, freshwater or saline water body found on the Earth's continental land masses (Table 3.1) .

Man-made **reservoirs**, also called „artificial lakes”, are water bodies with different shapes and sizes that have been constructed by humans by damming a river.

Reservoirs that have been formed by diverting water from a river to an artificial basin are called **impoundments**.

FUNCTIONS OF LAKES AND RESERVOIRS

The functions of lakes and reservoirs usually includes:

- production of drinking water;
- fisheries and aquaculture; and
- recreation.

Additionally, reservoirs may also be used for:

- flood prevention;
- retention of storm waters; and
- production of electricity.

Some of the functions require maintaining high water quality.

MAN-MADE RESERVOIRS - MANAGEMENT ISSUES

Freshwater management strategies for dams have usually been focused on issues such as flood protection, drought relief, and energy generation. However, catchment degradation resulting in lowering of water quality in reservoirs has lately become an emerging problem. River damming intensifies sedimentation of particular matter and thus nutrient retention within a reservoir. Subsequent recirculation of the matter by the biota and increased productivity leads to so called „secondary pollution”. The worst of these impacts are blooms of cyanobacteria that may produce carcinogenic toxic substances.

WHY RESERVOIRS ARE SUSCEPTIBLE TO WATER QUALITY DEGRADATION?

Limnological characteristics of reservoirs make them especially susceptible to the processes of eutrophication. This is because of:

- the high ratio of catchment to reservoir area resulting in high nutrient input;
- high suspended matter sedimentation;
- increase of water retention time; and
- lack of a littoral zone as a consequence of water level changes.

TABLE 3.1
General characteristics of lakes and reservoirs on a global scale

CHARACTERISTICS	LAKES	RESERVOIRS
location	especially abundant in glaciated areas	worldwide, often in areas with a scarcity of natural lakes
shape	generally circular	elongated and dendritic
drainage: surface area	ratio usually <10:1	ratio usually >10:1
shoreline	Stable (except for shallow lakes in semi-arid zones)	usually changing (artificially regulated water level)
water level fluctuation	generally small (except for shallow lakes in semi-arid zones)	can be high
water flushing time	long in deeper lakes	often short
rate of sedimentation	usually slow under natural conditions	often rapid
nutrient loading	variable	usually large
ecosystem succession	slow	often rapid
flora and fauna	relatively stable	variable
water outlet	at surface	variable
water inflow	typically from multiple, small tributaries	typically from large rivers

modified from UNEP, 2000

3.H. FRESHWATER BIOTA

PHYTOPLANKTON

Freshwater phytoplankton is the algal component of plankton, which are free-living organisms within aquatic environments. Phytoplankton is represented by prokaryotic cyanobacteria and several groups of eukaryotic algae.

Phytoplanktonic organisms are autotrophs, i.e., they fix solar energy by photosynthesis using carbon dioxide, nutrients and trace metals. They comprise the major portion of primary producers in most fresh waters. Like plants on land, they provide basic food for higher trophic levels such as zooplankton and fish.

Nutrients are necessary for algal development, however, their surplus (especially phosphorus) due to catchment degradation, for example, may lead to formation of blooms that degrade water quality.

Cyanobacteria

- filaments or round 3-4 μm diameter prokaryotic cells that can build large dense colonies, 100 to 500 μm in diameter (Fig. 3.2);
- they often form seasonal blooms in late summer in temperate lakes, reservoirs, and seas.
- produce toxic compounds that pose a health hazard to people and animals;
- colonies are not easily ingested by aquatic fauna due to their large size;
- destabilization of a reservoir's hydrological characteristics may reduce cyanobacterial growth.

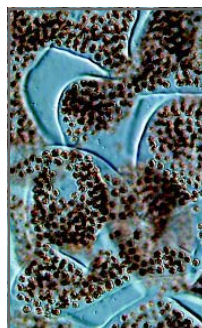


Fig. 3.2
Microcystis wesenbergi
(photo: P. Znachor)

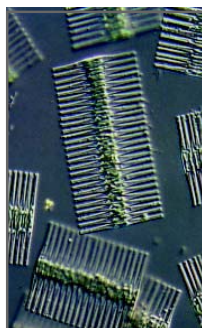


Fig. 3.3
Fragilaria crotonensis
(photo: P. Znachor)

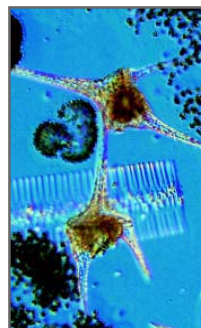


Fig. 3.4
Ceratium hirundinella
(photo: P. Znachor)

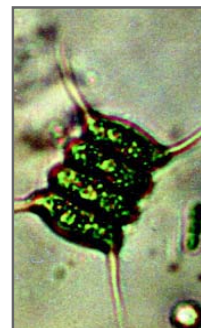


Fig. 3.5
Scenedesmus quadricauda
(photo: M. Tarczynska)

Diatoms

- the most morphologically varied group, including single-cell and colonial species (Fig. 3.3);
- the cells are covered with a cellular membrane hidden inside box-shaped silicate shell;
- unable to move actively, they may have a problem keeping suspended in the water column and that is why they prefer turbulent mixing conditions;
- The dominant group in spring-early summer and in autumn.

Phytoflagellates

- possess flagella, which enable migration through a water column;
- some taxa, especially dinoflagellates, cryptomonads and euglenoids, can be temporarily heterotrophic (Fig. 3.4);
- can dominate throughout the year, especially in winter (some dinoflagellates and cryptomonads), or early summer (chrysophyceae);
- may form blooms that sometimes can be toxic, e.g., *Peridinium* sp.

Green Algae

- characterized by their grassy green colour, they are among the main sources of food for filtering fauna (Fig. 3.5).
- high diversity of cell size and cellular organization (single cells, colonial and filamentous) and may be both motile and non-motile.
- in fresh water they are dominant, especially during the second half of summer-autumn. Sometimes they may reach bloom density.

ZOOPLANKTON

Zooplankton occupy a key position in the food webs of lakes and reservoirs, transferring algal primary production to higher trophic levels. Filtering algae and suspended detritus, zooplankton strongly determine the amount and composition of organic matter in the water column.

Rotatoria

- small organisms (body length <0,2 mm) characterised by different body forms (Fig. 3.6). Among them one can find planktonic, crawling or sedentary genera, while a few are parasites. Rotatoria occur in lakes of different trophic status. Most rotatorians have a carapax, a taxonomic feature;
- they feed on algae, bacteria and detritus while some forms are predatory, e.g., *Asplanchna* sp. (Fig. 3.7). They are characterized by sexual reproduction - they may be partenogenetic or may have separate sexes. In lakes of temperate regions, Rotatoria peak in early spring and/or during autumn.

Cladocera

- they are the dominant mesoplankton (200 μm - 2 mm in length) in many lakes but are represented by only three genera in the sea (*Evadne* sp., *Podona* sp., *Penilia* sp.);
- herbivorous cladocerans are filter feeders and form the most studied group of zooplankton;
- especially the genus *Daphnia* spp (Fig. 3.8), which is characteristic of mesotrophic lakes;
- small species of Cladocera, like *Bosmina* sp. (Fig. 3.9), may control the microbial food web as top predators;
- very large predatory cladocerans (8-16 mm in length), like *Leptodora kindtii* (Fig. 3.10) or *Bythotrephes* sp., can significantly reduce zooplankton population biomass by 50-60% due to their intensive consumption rates;
- Cladocerans have simple life cycles with partenogenetic reproduction through most of the year with no larval stages. Neonates are morphologically similar to adults.

Copepoda

- pelagic copepods belong to the two suborders Calanoida and Cyclopoida and occur both in the sea and in fresh waters. Most of the species are herbivorous (mainly Calanoida), although there are also some predatory and parasitic Copepoda.
- different dominance patterns are often observed along trophic gradients: calanoid copepods reach their highest biomass levels in oligotrophic lakes and cyclopoid copepods in eutrophic lakes.
- they are characterized by a complicated life cycle: obligate sexuality, larval nauplius stages and subadult copepodid stages.



Fig. 3.6
Keratella taurocephala
(photo: A. Wojtal)



Fig. 3.7
Asplanchna sp.
(photo: A. Wojtal)

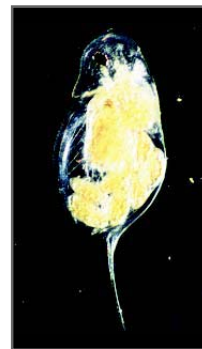


Fig. 3.8
Daphnia longispina
(photo: A. Wojtal)



Fig. 3.9
Bosmina coregoni
(photo: A. Wojtal)



Fig. 3.10
Leptodora kindtii
(photo: A. Wojtal)



FISH

Teleost fish are represented by about 20 000 species, which means that nearly half of all vertebrate species are fish. Fresh waters are inhabited by approximately 41% of all fish species (Wootton, 1990). Freshwater fish show multi-adaptations for living in highly variable habitats, utilizing all available food sources by means detritivory via herbivory to insectivory and piscivory (Box 3.2). Many are key major species in lakes and reservoirs, influencing their functioning and dynamics.

In many countries freshwater fish are of great importance as a source of food, but in recent years they also serve as a biomanipulation tool for improving water quality by changing the biotic structure of ecosystems. To achieve this goal, proper fish stock management based on a thorough knowledge of fish biology and ecology is required.

Depending on the position of a given fish species in the trophic structure of a ecosystem, it may play a positive or negative role in regulating water quality. Many piscivorous fish control zooplanktivorous fish reducing grazing pressure on zooplankton, thus can indirectly reduce algal blooms. On the other hand herbivorous fish by consumption



Fig. 3.11
Pikeperch
(photo: Z. Kaczkowski)

of macrophytes and algae return readily available nutrients (up to 90%) to water and intensify algal blooms.

To promote a strong and vital population of fish species favourable for lakes and reservoirs, one can utilize the inherent properties of the ecosystem, e.g., the dependence of spawning success of given fish species on the availability of spawning grounds, which in nature is highly influenced by the hydrological regime. Water level manipulation in a reservoir in order to regulate fish spawning success is a good example of an activity based on this principle (Zalewski et al., 1990).

TABLE 3.2
Major trophic categories in fishes

DETRITIVORES	e.g., <i>Tilapia</i>
SCAVENGERS	e.g., <i>Anquilla</i>
HERBIVORES	Grazers (e.g., <i>Plecostomus</i>) Browsers (e.g., <i>Ctenopharyngodon</i>) Phytoplanktivores (e.g., <i>Tilapia</i>)
CARNIVORES	Benthivores Selecting relatively small prey (e.g., <i>Gasterosteus</i>) Disturbing and then selecting prey (e.g., <i>Sufflamen</i>) Picking up substrate and sorting prey (e.g., <i>Lethrinops</i>) Grasping relatively large prey (e.g., <i>Balistes</i>) Zooplanktivores Filter feeders (e.g., <i>Engraulis</i>) Particulate feeders Aerial feeders (e.g., <i>Toxotes</i>) Piscivores Ambush hunter (e.g., <i>Cottus</i>) Lurers (e.g., <i>Lophius</i>) Stalkers (e.g., <i>Esox</i>) Chasers (e.g., <i>Salmo</i>) Ectoparasites (e.g., <i>Exodon</i>)

modified from Wootton, 1990



3.1. ESTUARINE AND COASTAL AREAS

WHAT ARE ESTUARIES AND COASTAL AREAS?

Estuaries are commonly defined as areas where rivers discharge into the sea. Based on Pritchard's (1967) definition, Day (1980, 1981) considered „an estuary as a partially enclosed coastal body of water which is either permanently or periodically open to the sea, and within which there is a measurable variation of salinity due to the mixture of sea water with fresh water derived from land drainage”. However, this „hydrological” definition must include the more „biological” approach suggested by Perillo (1995), that also considers estuaries as being responsible for „sustaining euryhaline biological species for either part or the whole of their life cycle”.

According to water circulation patterns, estuaries can be classified as salt wedge estuaries, partially mixed estuaries, well-mixed estuaries, and fjord - type estuaries (Box 3.5). Salt wedge estuaries occur when circulation is controlled by a river that pushes back the seawater. Partially mixed estuaries, usually deeper estuaries, have a tidal flow: salt water is mixed upward and fresh water is mixed downward. Well-mixed estuaries are frequently shallow, have strong tidal mixing and reduced river flow resulting in vertical homogeneous salinity. Fjord-type estuaries are deep and have moderately high river input and little tidal mixing. Estuaries are commonly subdivided into upper,

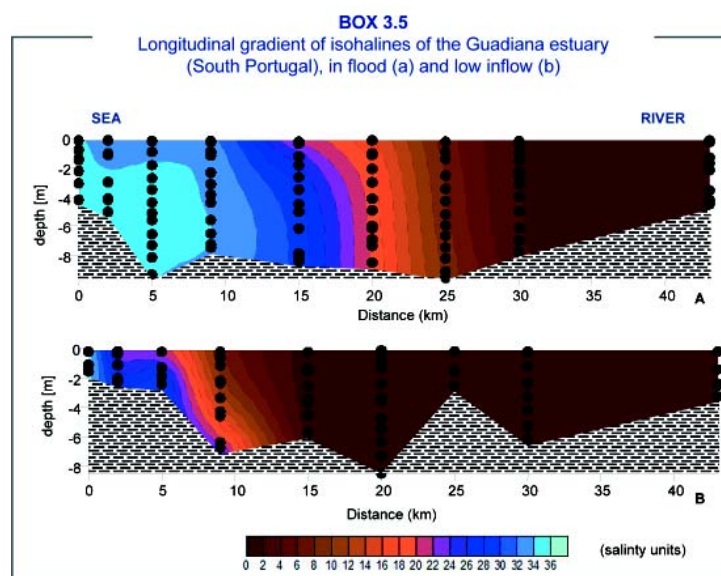
middle and lower areas. The upper estuary includes most of the freshwater section, although the effects of tides are still observable. It is an area where riparian vegetation is abundant. This vegetation constitutes a buffer zone, „controlling” nutrient inputs into an estuary, thus representing a particularly important target for application of phytotechnology. The middle estuary is a transition area in terms of salinity (mainly brackish water) and vegetation. The lower estuary is characterized by a marine influence.

The coast is where land meets the sea. However, as in estuaries, land and ocean processes change this line over time and space, affecting the area considered as coastal.

WHY ARE ESTUARIES AND COASTAL AREAS IMPORTANT?

The dynamic nature of estuaries forms the basis of a very complex food chain based on high primary and secondary productivities

Estuaries are perceived as highly productive ecosystems because they are often nutrient rich and have multiple sources of organic carbon to sustain populations of bacteria and other, heterotrophs. These sources include riverine and waste inputs and autochthonous primary production by vascular plants, macroalgae, phytoplankton and benthic microalgae (Cloern, 1987).





Sediments in the water column, of organic and inorganic origins, can be trapped in a strong upstream bottom flow and forced into the Maximum Turbidity Zone (MTZ). This occurrence affects the structure and functioning of the microbial community, may be limiting to photosynthesis (suspended particulate matter $> 50 \text{ mg L}^{-1}$), contributes to the increase of heterotrophic processes and results in the degradation of organic material, what may lead to depletion of oxygen concentrations. In this zone the transition between freshwater and marine environments occurs. Phytoplankton and bacterioplankton transported down a river will experience salt stress. The freshwater microbial population will lyse and die in this zone.

The composition and spatial distribution of groups of organisms like phytoplankton, zooplankton and benthic invertebrates in estuaries are primarily regulated by salinity and only secondarily by habitat factors, such as sediment structure and depth. Due to their ability to osmotically regulate, fishes are less affected by salinity changes.

Estuaries are also important nursery areas for several invertebrate and fish species. Protection against predators and loss by outwelling currents increases success of larval development and recruitment. River discharge and the consequent river plume, associated with tides, export estuarine nutrients and organisms to coastal areas, enhancing coastal food web dynamics, supporting coastal fisheries and contributing to global ocean productivity.

The structure, broad range and biodiversity of coastal habitats provides a large number of ecological tools and services, such as storage and cycling of nutrients, filtration of pollutants from inland freshwater systems, and protection from erosion and storms. Coral reefs, mangroves, tidal wetlands, seagrasses, estuaries and a variety of other habitats, each provides its own distinct goods and services and faces different pressures. Human modification on shorelines changes currents and sediment loading, affecting coastlines and habitats in some areas.

WHY ARE ESTUARIES AND COASTAL AREAS CONSIDERED SUSCEPTIBLE?

Many coastal areas are ecologically productive, biologically diverse and climatically and physically attractive and, therefore, are preferred places for the settlement of human populations. Thus, estuaries and coastal areas became the final receptacles of innumerable human and natural factors from land, riverine and oceanic origins.

In the last century, development of cities with millions of people on estuarine margins contributed to the massive destruction of vegetation cover and other habitats. Cumulatively, construction of river diversions (barrages, dams, etc) aimed to provide enough fresh water for human consumption and uses, affects water quality and quantity in estuaries and coastal areas. This human migration to the coast occurred both in developed and developing countries. The resulting stress has become apparent as populations increase, watersheds are deforested and fisheries are over exploited.

Considering the expected human population growth and the increasing need for food, water and space, pressure on estuaries and coastal areas will continue to rise. The consequences could be aggravated under predicted global changes and sea-level rise scenarios.

WHAT FACTORS INFLUENCE ESTUARIES AND COASTAL AREAS?

Estuaries and coastal areas are affected by both continental and oceanic factors, from exogenous and endogenous origins. As noted above, continental (land and river) originating factors and processes (e.g., run-off, changes in riverine discharges, changes in agricultural practices, etc.) affect estuaries and coastal areas. Moreover, oceanographic factors and processes (e.g., longshore or upwelling currents) also influence water characteristics and affect coastal biological communities and sediment composition and distribution. Endogenous fluctuations in estuarine and coastal communities are expected, for example, as a result from seasonal reproductive cycles. Exogenous impacts caused by anthropogenic activities (e.g., water canalization, pollution, destruction of riparian and salt-marsh vegetation or construc-

tion of piers) influence water quality, quantity and circulation and modifies habitats, affecting the basic structure of species organization in estuarine and coastal ecosystems (Box 3.6).

WHY DO WE NEED A STANDARDIZED MANUAL FOR ECOHYDROLOGICAL AND PHYTOLOGICAL APPLICATIONS IN ESTUARIES AND COASTAL ZONES?

Implementation and development of mitigation and restoration techniques based on ecohydrology and phytotechnologies can provide an adequate basis for the integrated and sustainable development and management of estuaries and coastal areas. These concepts use intrinsic characteristics and processes of ecosystems to solve ecological problems. This is accomplished by increasing the natural response of a system and, by doing that,

increasing the capacity to absorb impacts and their consequences.

However, application of these management techniques needs an in-depth knowledge of a system's functioning and the technical skills to make interventions as precisely as possible. In estuaries and coastal areas the complexity of processes and factors involved adds an extra difficulty to the application of these techniques. Basic to the general application of ecohydrological and phytotechnological solutions to estuaries and coastal areas is the need for harmonization of sampling methods, sample processing and analysis of information, as proposed in this manual. This will allow comparisons and exchange of ecohydrological and phytotechnological successful solutions between different estuaries and coastal areas.

