DIKTAS II

The importance of biodiversity in the DIKTAS 2 project

2nd STEERING COMMITTEE MEETING

and

1st in-person EXPERT MEETING

8-10 JULY 2025

Trebinje, Bosnia and Herzegovina

Challenges in Karst:

The classic division between surface and groundwater in karst is highly dynamic and interconnected because surface waters quickly transition into groundwater, and groundwater often emerges on the surface through karst springs.

Groundwater in karst is dominant and moves through a complex system of fractures, channels, and cavities in soluble carbonate rocks. Karst groundwater is divided into the unsaturated zone (epikarst and vadose zone) and the saturated zone (phreatic zone) with a network of karst channels that have high hydraulic conductivity. The movement of groundwater in karst is very heterogeneous and complex due to fracture porosity and rock karstification - this is important for biodiversity in the underground environment

Challenges in the DIKTAS project:

- In the project DIKTAS 1 biologists were not included, biodiversity was analyzed at a general level.

- It is necessary to find and agree on appropriate bioindicators for groundwater **in Dinaric karst area for the first time**, which so far have not been prescribed nor **in the Water Framework Directive nor in the Groundwater Directive.**

- Need to be defined and agreed physical-chemical indicators important for the preservation of groundwater biodiversity.

Challenges in the DIKTAS project:

- **Protection of the unique underground water ecosystems characteristic of the Dinaric Karst area.**
- **Promotion of fair and sustainable use of transboundary water resources.**
- **Introduction of integrated management principles of large cross-border karst aquifers on a global scale**

WHAT ARE THE ENVIRONMENTAL OBJECTIVES OF THE WFD?

ENVIRONMENTAL OBJECTIVES OF THE WFD

SURFACE WATERS

For natural water bodies, maintain high water status where such status exists, prevent deterioration of the existing status and achieve at least "good status"

Good status = good ecological and chemical status

Heavily modified and artificial water bodies → ……prevent the deterioration of the existing situation and achieve at least “good potential”

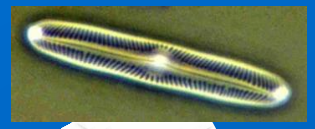
GROUNDWATER

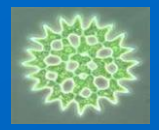
Good chemical and quantitative state of groundwate

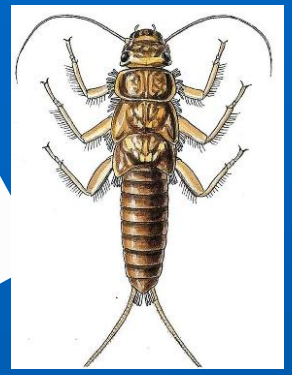
Elements of the assessment of the ecological status of surface waters

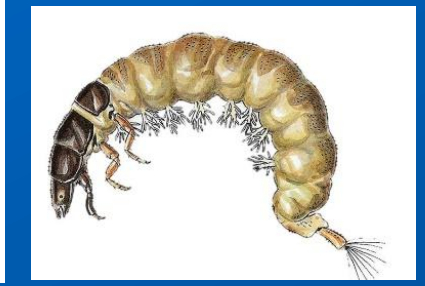
Biological quality elements

- ✓ Phytoplankton/periphyton
- ✓ Macrophytes
- ✓ Benthic Macroinvertebrates
- ✓ Fish







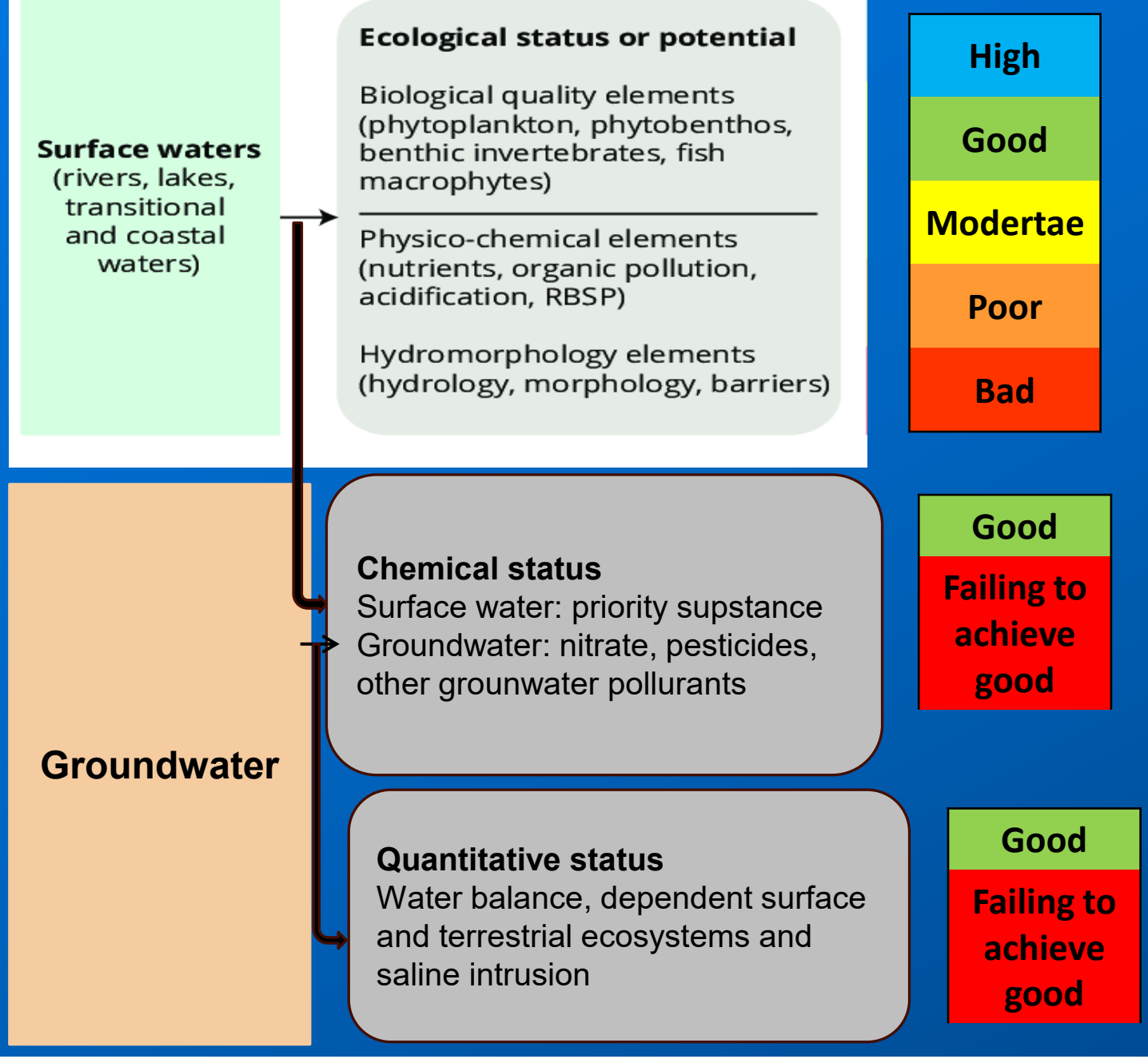


Basic physico-chemical and chemical elements

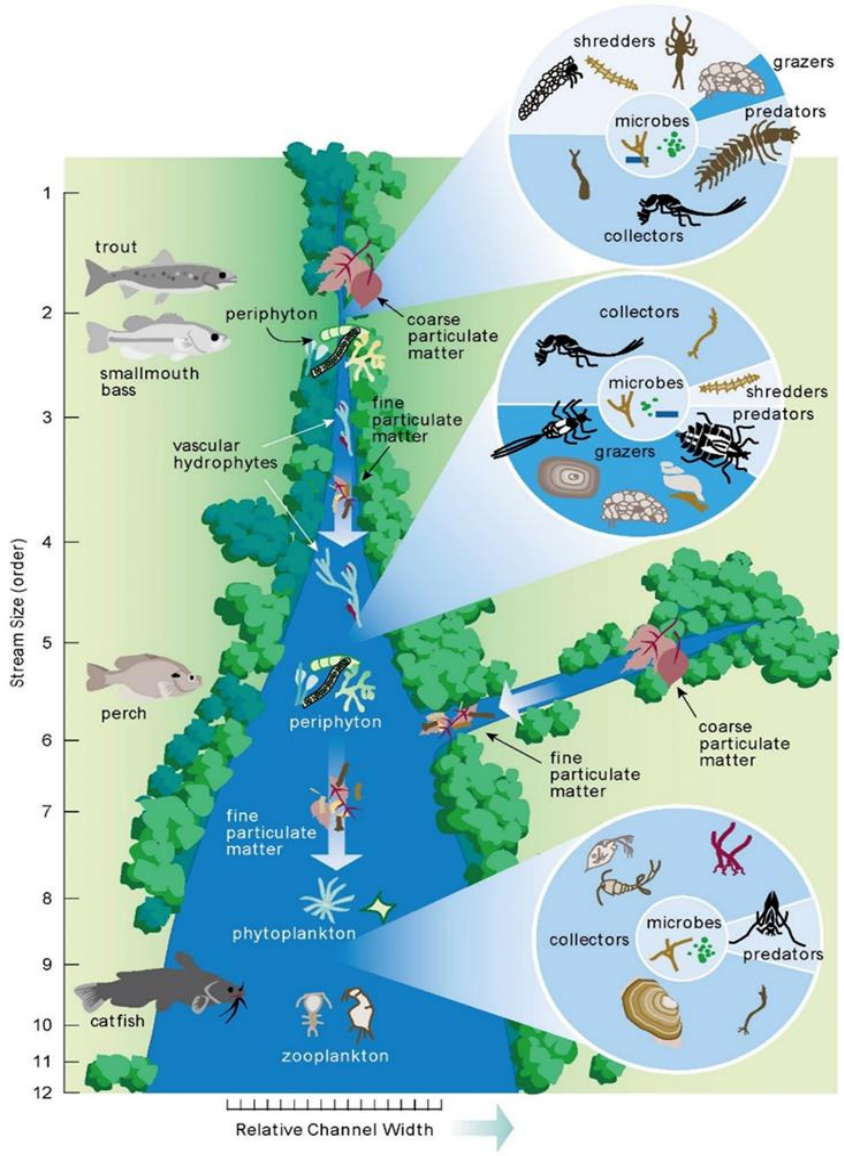
- ✓ Temperature
- ✓ Oxygen regime
- ✓ Ion content
- ✓ Nutrients……

Hydromorphological elements accompanying biological elements

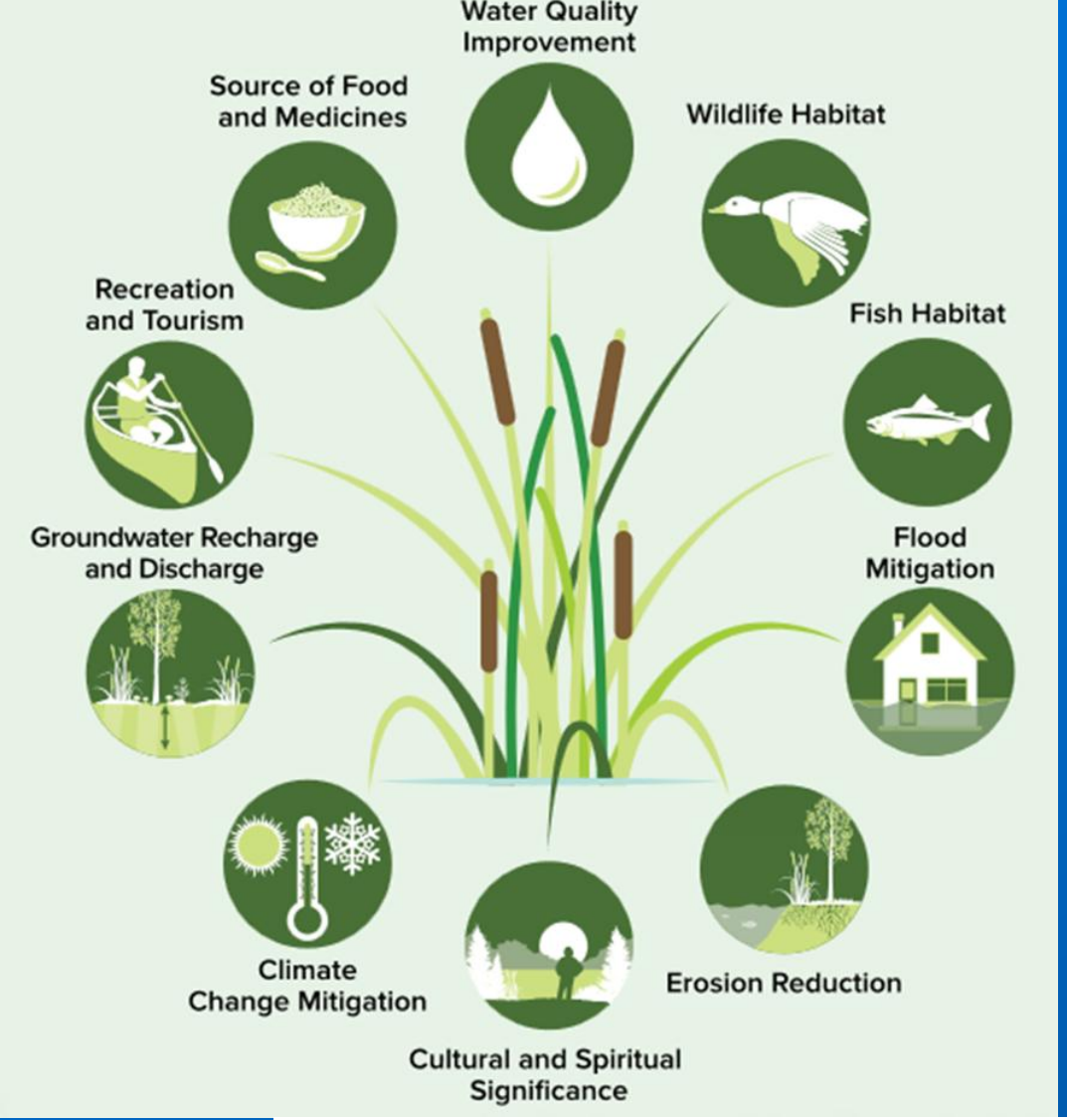
- Longituninal continuity
- Hydrology
- Morphology


Surface waters
(rivers, lakes, transitional and coastal waters)
Ecological status or potential
Biological quality elements (phytoplankton, phytobenthos, benthic invertebrates, fish macrophytes)
Physico-chemical elements (nutrients, organic pollution, acidification, RBSP)
Hydromorphology elements (hydrology, morphology, barriers)
High
Good
Modertae
Poor
Bad
Groundwater
Chemical status
Surface water: priority supstance
Groundwater: nitrate, pesticides, other grounwater pollurants
Good
Failing to achieve good
Quantitative status
Water balance, dependent surface and terrestrial ecosystems and saline intrusion
Good
Failing to achieve good

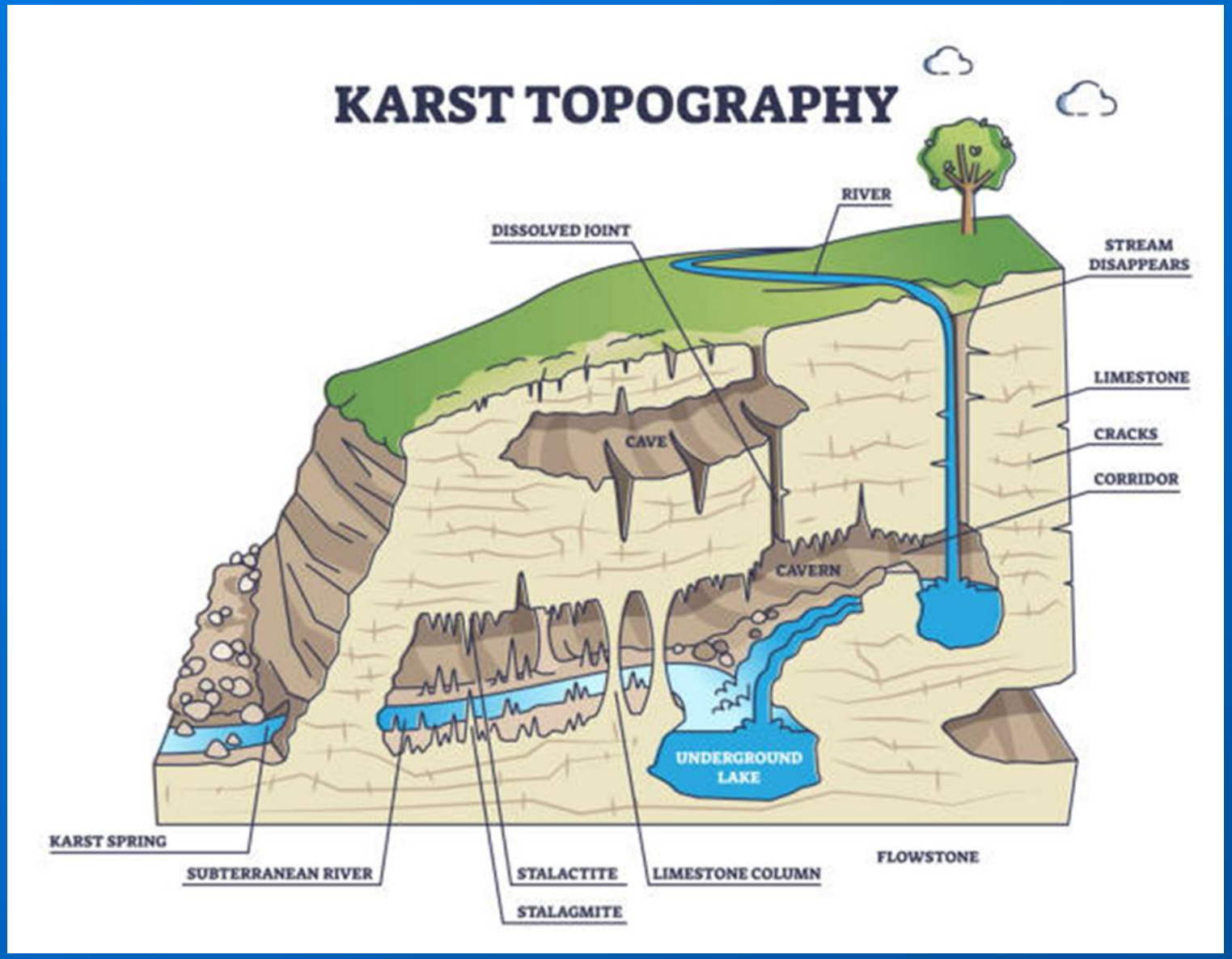
The River Continum Concept, (Vannote at al.1980)

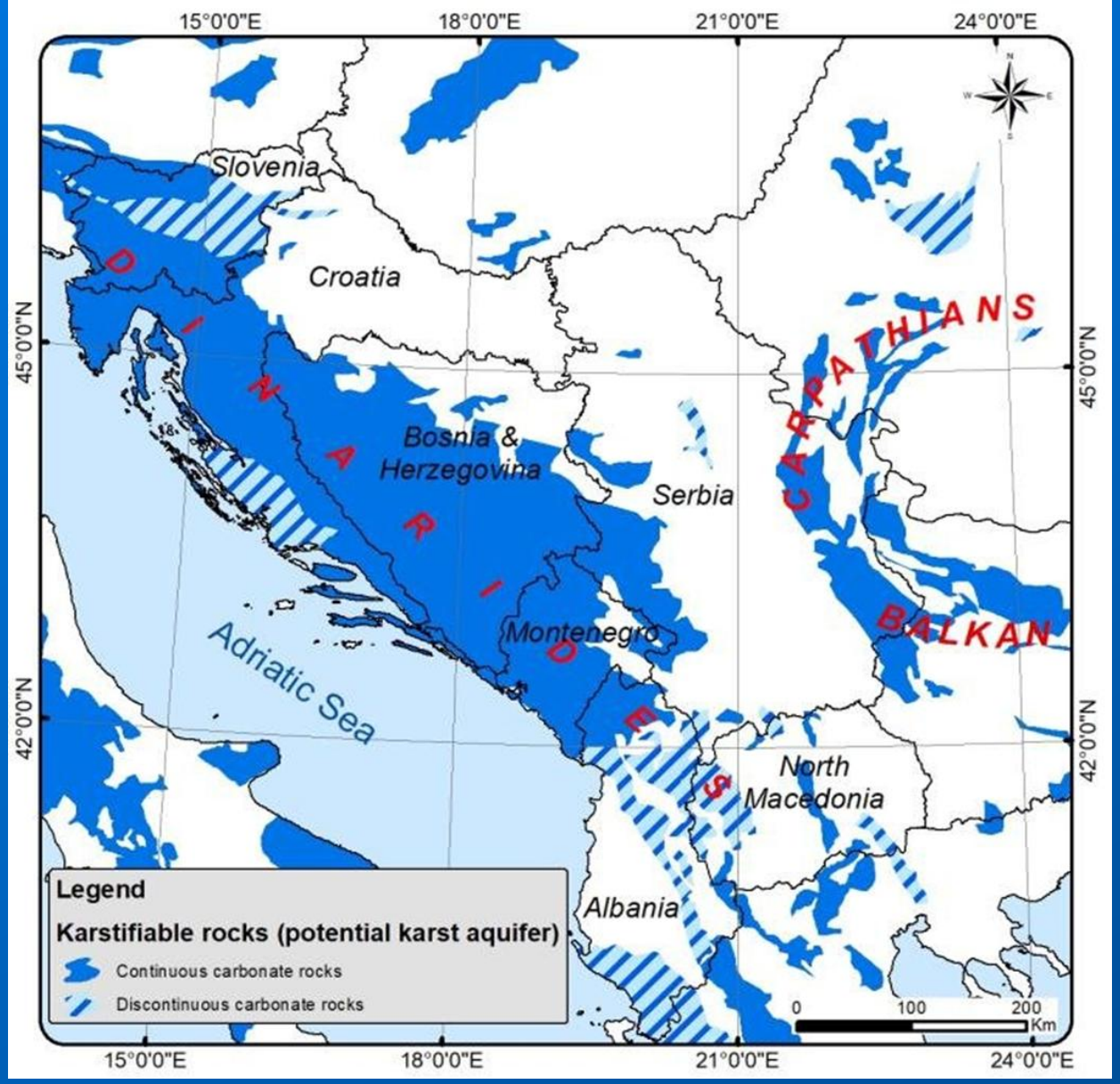


Presentation of the concept of the river continuum (The River Continuum Concept, Vannote et al. 1980). This is a concept that proposes the relationship between stream size and the definition of the composition and structure of plant and animal communities, depending on the abiotic functional characteristics of individual sections of the studied watercourse.



Freshwater Ecosystem services


KARST TOPOGRAPHY
RIVER
DISSOLVED JOINT
STREAM DISAPPEARS
LIMESTONE
CRACKS
CORRIDOR
CAVE
CAVERN
UNDERGROUND LAKE
KARST SPRING
SUBTERRANEAN RIVER
STALACTITE
STALAGMITE
LIMESTONE COLUMN
FLOWSTONE



WOKAM project - World Karst Aquifer Map (established by IAH and UNESCO, 2012)

WHY BIODIVERSITY IS IMPORTANT IN SURFACE WATER AND GROUNDWATER?

1. Understanding ecosystems dependent on groundwater

Biological research is crucial **for the identification and protection of specific ecosystems that depend on groundwater**, such as karst lakes (e.g. Plitvička jezera) and high-quality water sources. **These ecosystems often contain endemic species that are adapted to the specific conditions of karst habitats.**

2. Biodiversity monitoring

Includes a biodiversity assessment to identify endangered species and habitats. Biological data help to develop strategies to conserve natural resources and prevent ecosystem degradation caused by human activity or natural hazards.

3. Protection against pollution

Biological aspects help to assess the impact of pollution on aquatic organisms and ecosystems. **This is crucial for the implementation of measures that will reduce negative impacts on water quality and preserve its long-term sustainability.**

4. Support for sustainable development

Biological research provides the basis for the sustainable use of natural resources, including the development of policies that balance the needs of local communities with nature conservation.

Ecological characteristics of underground habitats in Croatia

- Subterranean habitats are one of the most significant natural features of Croatia.

- The characteristics of subterranean habitats, compared to surface habitats, include the absence of light, a relatively small amount of food which comes entirely from surface habitats, very high and stable relative air humidity, relatively stable air temperature, and relatively low and stable water temperature.

- From the aspect of biological diversity in Croatia's underground, it is important to emphasize that Croatia extends through several biogeographical regions, encompassing various types of relief as well as diverse geological, hydrological, pedological, and climatological areas. **This is why different subterranean ecosystems occur in Croatia's underground.**

- More than 500 subterranean taxa are known in Dinaric karst area of Croatia, almost 7% of the world's species. More than 50% of them are endemics.

- The largest number of terrestrial cave species are beetles (Coleoptera), with more than 100 species, followed by pseudoscorpions (Pseudoscorpiones), spiders (Araneae), snails (Gastropoda), and millipedes (Diplopoda). Among aquatic cave species, crustaceans (Crustacea) dominate, especially amphipods (Amphipoda).

- The only known freshwater subterranean bivalves are the Dinaric cave clams *Congeria* spp.
- The only European freshwater subterranean vertebrate is the olm, *Proteus anguinus.*
- The only subterranean freshwater cnidarian is *Velkovrhia aenigmatica*, and the only subterranean freshwater polychaete is *Marifugia cavatica*.

- There are no plants in the underground; the ecosystem is fundamentally different from the surface one, and the only primary producers are bacteria.

- **Organic matter enters the underground exclusively from surface ecosystems, via water and air.**

- At the bottom of the cave food chain are various types of decomposers or detritivores, i.e., animals that feed on dead organic matter, playing the role that plants have in the outside world.

Ecological characteristics of underground habitats in Albania

- The characteristics of subterranean habitats, compared to surface habitats, include the absence of light, a relatively small amount of food which comes entirely from surface habitats, very high and stable relative air humidity, relatively stable air temperature, and relatively low and stable water temperature.

- Subterranean habitats in Albanian Karst/dinaric karst are almost not studied and limited to subterrenian gastropods (Grego J. et al, 2017).

- There are monitorings of the growndwater chemistry in some limited areas (e.g. Bushati N., Neziri A., (2020); The Microbiological and Physico Chemical Quality of Surface and Groundwaters of Buna River-Protected Landscape and Velipoja (Albania); *J. Int. Environmental Application & Science*, Vol. 15(4): 224-232.).

- Subterrenian biology is limided only to gastropods in the northern karst area of Albania.

Karst Subterranean gastropods in Albania

- Discovery of the first subterranean freshwater gastropod population has occurred only in **2006** in Albania.
- This was first reported as *Paladilhiopsis cf. serbica* (Pavlović, 1913) by Fehér and Erőss (2009), but considered later as a presumably distinct species (Reischütz et al. 2013).
- Since then, the number of **subterranean freshwater species described from Albania has increased to 11** (Reischütz and Reischütz 2008; Reischütz et al. 2014, 2016, Glöer et al. 2015), and the total known Albanian fauna is **comprised of 16 species in 2016** including the two new records and 3 known undescribed species.
- During the field trip in **2016 are sampled 16 springs and cave outflows altogether**, and, in fact, are discovered new species, while underground species were detected in almost half of the investigated localities.
- This suggests that these known species represent just a small fraction of the actual species richness, and most of the Albanian subterranean gastropod diversity is still waiting to be discovered.

Source: Grego J, Glöer P, Erőss ZP, Fehér Z (2017); Six new subterranean freshwater gastropod species from northern Albania and some new records from Albania and Kosovo (*Mollusca, Gastropoda, Moitessieriidae* and *Hydrobiidae*). Subterranean Biology 23: 85–107. https://doi.org/10.3897/subtbiol.23.14930

Karst Subterranean biodiversity in Montenegro

- This fauna is considered rich and endemic, but it is estimated that data are lacking - there are no precise, systematized and comprehensive data;

- The Dinaric karst area was sporadically researched with focus on target groups as gastropods (snails, less common shells), leeches, crustacea and coleoptera (cave species);

- E.g. Coleoptera: the specialization of troglobiont beetles in filtering underground water in the deep caves of Montenegro indicates a high level of adaptation and biological diversity, making these habitats an important source for the discovery of new, still unknown species to science. Described species from the larger genus *Hadesia* and the very small species of the genus *Nauticiella* live together in underground waterfalls of the very deep caves and pits of Orjen, Krivošije, Grahovsko Polje, and Lovćen (Polak, 2025);

- E.g. Coleoptera: In the underground lakes of Montenegro lives cave shrimp from the genera *Troglocaris* and *Speleocaris*. Among aquatic isopod crustaceans, species from the genus *Monolistra* inhabit the subterranean environment, while the large subterranean predatory crustacean *Sphaeromides* is found in the Obod Cave. In underground waters, including karst springs, amphipod crustaceans such as representatives of the genus *Niphargus* are commonly seen. Numerous endemic species have been described from Montenegro, inhabiting various subterranean aquatic habitats. Endemic to this part of the Balkans are also species from the genera *Metohia* and *Typhlogammarus*, which are capable of crawling on wet stalactites and moving outside of water (Polak, 2025).

Ecological characteristics of underground habitats in Montenegro

- The most data on the karst subterranean fauna belongs to gastropods;

- Hydrobiids have been studied by several authors (e.g., Schütt 1959, 1960, Bole 1961, Radoman 1973, 1983, Reischütz and Reischütz 2008, Glöer and Pešić 2010, Pešić and Glöer 2012, 2013,...) who described some new subterranean freshwater gastropods from Montenegro, e.g.:

  - 2014: *Plagigeyeria lukai* and *Zeteana ljiljanae*, village Pričelje near Pogorica (Glöer & Pešić, 2014).

  - 2019: *Paladilhiopsis cattaroensis, Paladilhiopsis matejkoi, Bosnidilhia vitojaensis, Plagigeyeria feheri* and *Stygobium hercegnoviensis*, Herceg Novi and Kotor (Grego et al., 2019).
  - 2021: *Travunijana djokovici*, Danilovgrad (Grego & Pešić, 2021).

- Also, there are significant data on crayfish from the group Amphipoda, such as representatives of the genus *Niphargus* (Karaman, many papers).

Source: Polak, S. (2025): Život u tami pećina i jama Crne Gore. Katalog izložbe, Prirodnjački muzej Crne Gore, Podgorica.

The chemical indicators important for species living underground (basis for harmonization and further development in the DIKTAS project:

- pH value
- Water temperature
- Amount of dissolved oxygen
- Nutrient salts
- Turbidity
- Major cations (e.g., calcium, magnesium, sodium, potassium)
- Anions (e.g., bicarbonates, sulfates, nitrates, chlorides)
- Concentrations of metals (e.g., iron, manganese, and other metals)
- Other hydrogeochemical indicators that reflect the geological and hydrogeological structure of the aquifer and its interaction with surface waters

The biological characteritics in karst

- For monitoring the state of groundwater-dependent ecosystems, interesting representatives of subterranean aquatic invertebrates **include: protozoa (Protozoa) and micrometazoa (Gastrotricha, Nematoda, Nemertina, Rotifera, Tardigrada, etc.), sponges (Porifera), flatworms (Turbellaria), snails (Gastropoda), oligochaetes (Oligochaeta), polychaetes (Polychaeta), leeches (Hirudinea), aquatic insects (Insecta), water mites (Hydrachnellae), and among vertebrates, amphibians (Amphibia) and fish** (Gottstein 2010, Gottstein et al. 2001).

- Many of the above species are endemic species with restricted ranges, **which poses numerous difficulties in selecting appropriate fauna representatives that would be unique bioindicator**

- However, findings of many subterranean fauna representatives in neighboring groundwater-dependent ecosystems can **be a good indicator of the dependency of those systems on groundwater.**

Bioindicators of springs

Include crenobiontic invertebrate species, which are species that inhabit exclusively springs and are extremely sensitive to any changes in their habitat, including changes in the physical-chemical conditions of groundwater (especially temperature changes).

Among the crenobiontic species in Croatia, aquatic insects should be mentioned, such as certain species of water beetles (Coleoptera) from the genus **Agabus** and caddisflies (Trichoptera) from the genera *Drusus* and *Micropterna*; some species of flatworms (Turbellaria), such as *Crenobia alpina*; a large number of snail species (Gastropoda), such as those from the genus *Belgrandiella*; amphipods (Amphipoda) from the genus *Fontogammarus* and some species from the genus *Niphargus*; decapod crustaceans (Decapoda) from the genus *Austropotamobius* (*A. pallipes and A. torrentium*); and numerous other taxa of aquatic invertebrates,

Drusus sp.

Niphargus sp.

Crenobia aplina

Cetina Spring – Vukovića vrelo