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Freshwater Ecosystems – Pollution and Loading from the Biological Point of View

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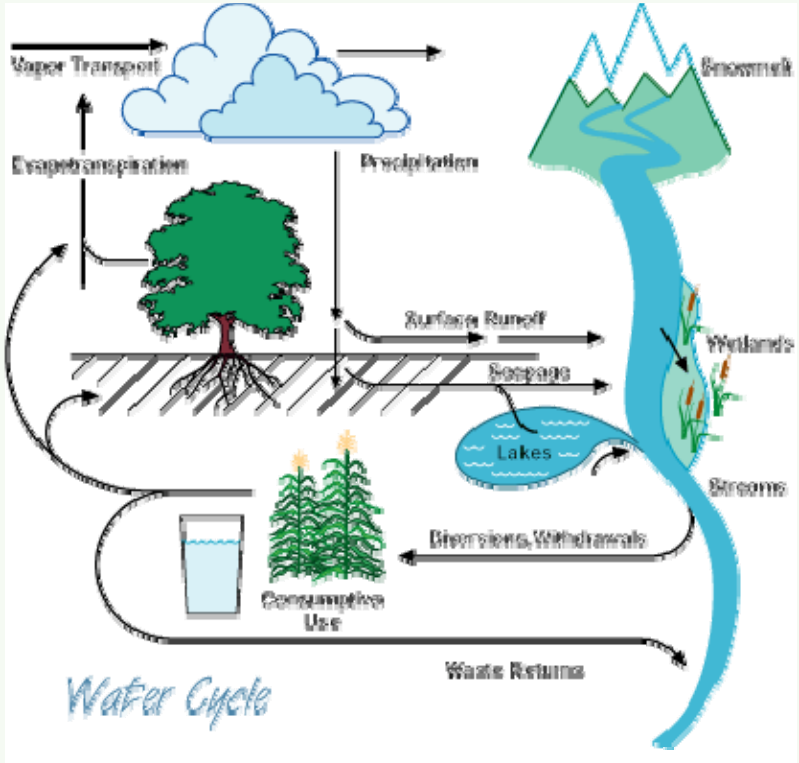
Starting-points for water ecosystem understanding

1. **Water is medium, water as substance**: physical and chemical properties defined life in water, unique thermal-density properties, salinity.
2. **Water body as ecosystem**: matter (nutrient) cycling and energy flow, termodinamic concept of ecosystem, different water bodies, running and standing ones, what is common and what different, populations and communities, metabolic activities.
3. **Water body as a recipient**: influences of terrestrial ecosystems, land and atmosphere as a food source, energy and toxicants, loading and pollution of water environment.
4. **Water as a natural good:** environment services. Do we understand and respect water (=life) as unique natural good**?**

Water Ecology

- structure and function
- multidiscipline approach, biology, chemistry, physics, hydrology (major component), geology, etc.
- Biocenosses (community organization based mainly on ecosystem size hierarchies more than on species niche)
- influences of biotic and abiotic factors



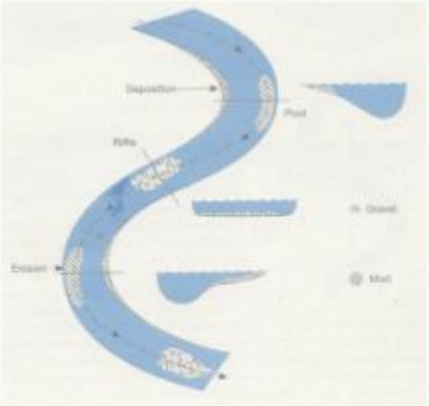
Running waters, different flow regime, different habitats and biocenosis, basis for self-purification efficiency

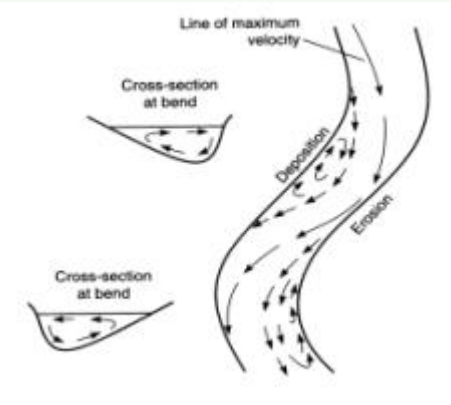
River-bed (channel) as a living space

Variability of organisms, habitats and processes is defined by **current**/flow.

Meander is an unit with erosion and deposition sites

Substrate is the main factor for running waters biota: periphyton, macrophytes, macroinvertebrates (and fish).





Periphyton and macroinvertebrates, significant biocenoses in running waters

- **periphyton**: heterogeneous assemblages of primary producers (mainly algae), sec. producers (animals) and decomposers (mostly bacteria and fungi)
- **macroinvertebrates**: different groups of animals, larger than 0.5 mm, important part insects larvae

Bottom vitality is important for water quality!

Both biocenoses important in water quality assessment!

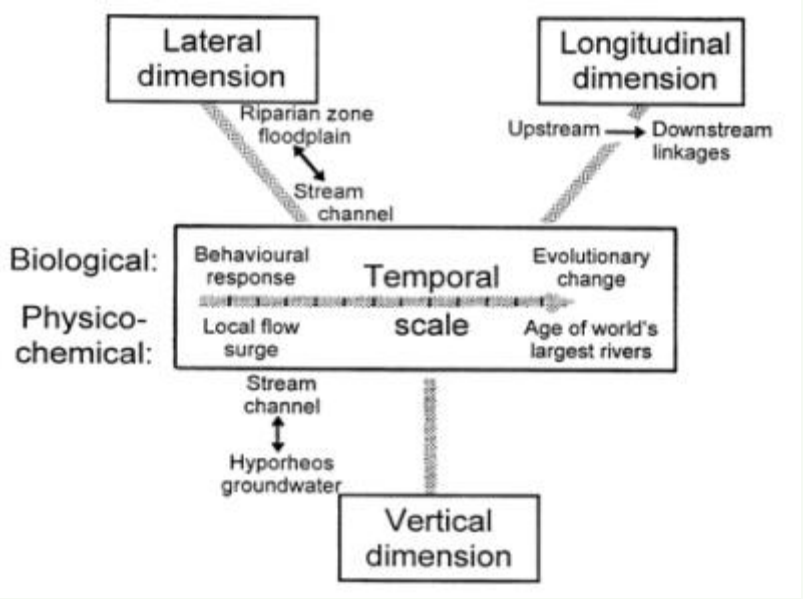
Basic data for different biotic indices and also in WFD.

Four-dimensional system of running waters

Dynamic system!
Biological, physical in chemical properties are influenced by:

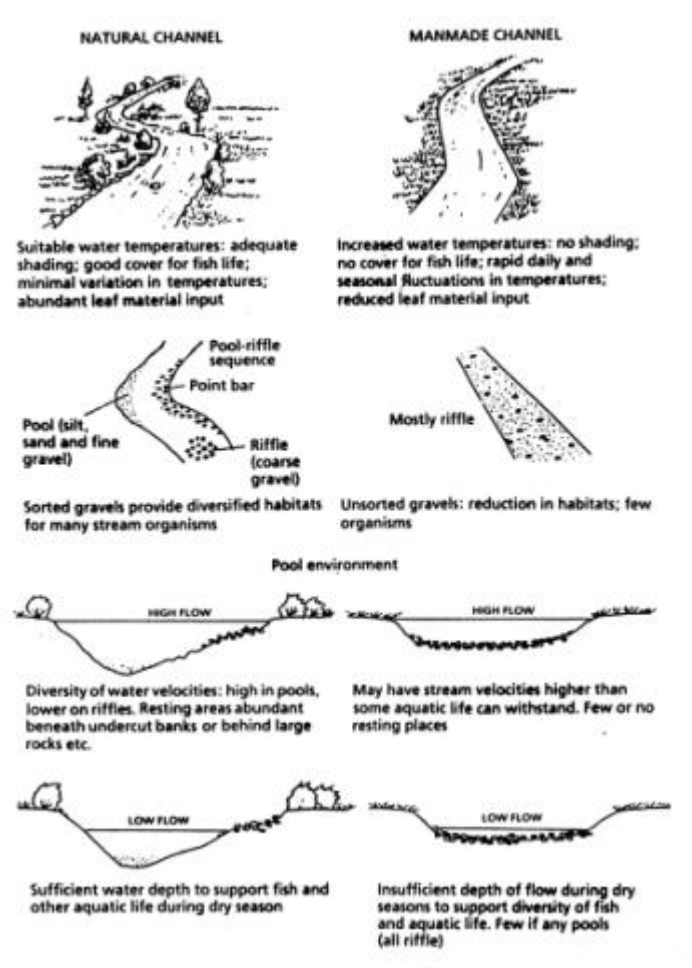
- **lateral impacts**
- **longitudinal changes**
- **vertical connections**
- **temporal scale**

River regulations drastic change such system!



The most important lateral impacts have flooding zone, vertical connections include hyporeic zone and define quality of groundwater.

Natural and regulated (manmade) channel



Morfology and hydrology are very different. Main changes include:

1. temperature regime
2. light
3. hiding-place for fish, mammals
4. organic matter input (leaves)
5. substrate heterogeneity
6. current, flow regime
7. sufficient water in dry season
8. species/community diversity

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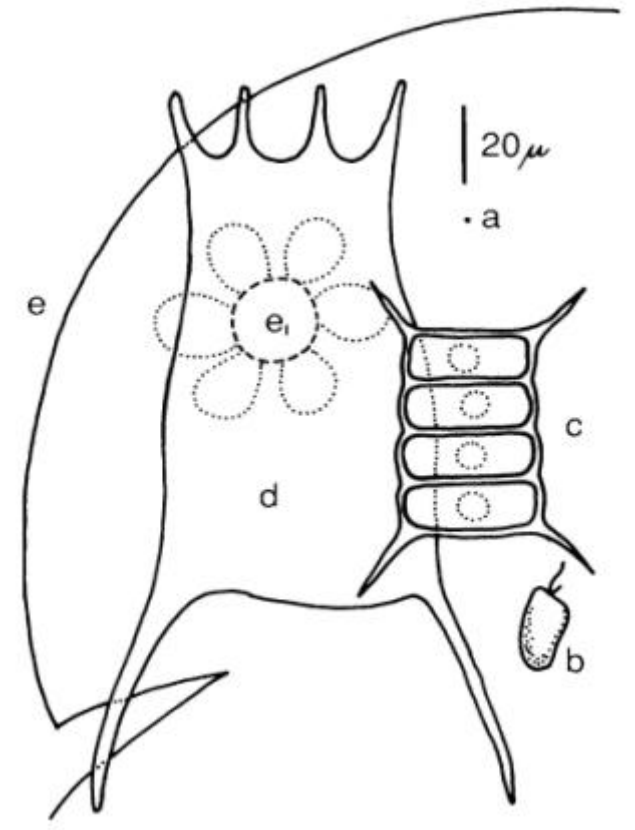
Standing water: plankton - significant biocenosis

- **bacterioplankton**
- **phytoplankton**
  - algae
  - cyanobacteria
- **zooplankton**
  - Protozoa
  - Metazoa

Bioindication, basis for food web understanding

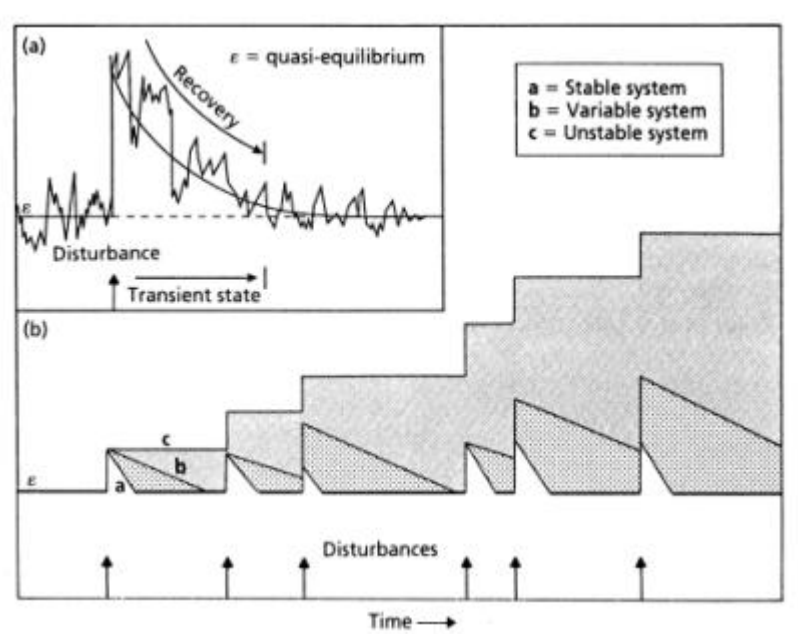
T and light gradient the most important abiotic factors in SW



Polution and loading

- Changes in natural cycling of matter and in energy flow
- **Pollutant**: organic and inorganic matters (nutrients, heavy metals etc.)
- **Loading** include different physical changes in water courses, regulations, canalization, water dams, river reservoirs etc.
- Direct and indirect influences, synergistic and antagonistic effects

Disturbances



Relation between disturbances (pollution) and recovery processes in streams.

- **a)** changing, dynamic ecosystem
- **b)** disturbances with different results: a-high efficiency recovery processes; b- medium efficiency; c- very unstable system, no recovery, "new" ecosystem with "new" biota

Waste waters

- degradable and undegradable (mainly point source)
- wide range of chemical and biotic characteristics
- urban and industrial
- agriculture waste (diffuse source)
- pathogen μorganisms
- toxic substances (direct and/or indirect effects)

Biomonitoring

SYSTEMATIC USE OF BIOLOGICAL RESPONSES TO EVALUATE CHANGES IN THE ENVIRONMENT WITH THE INTENT TO USE THIS INFORMATION IN A QUALITY CONTROL PROGRAM. THESE CHANGES OFTEN ARE DUE TO ANTHROPOGENIC SOURCES (Mathews, 1982).

Biological evaluation of water ecosystem quality

Environment characteristics	Periphyton	Zoobenthos
Sampling site description: •water flow regime •chanel morphology •habitate structure •physical properties •chemical properties •biotic properties	bacteria and funghi (sewage fungus)	saprobic index
	algae (mainly diatoms)	Biocenotic analyse (longitudinal zonation)
	saprobic index (without diatoms)	macroinvertebrate feeding groups
	Trophyc state	diversity

Saprobic system

- water organisms (microorganisms, algae, animals) presence and activity indicate different level of water quality)

- Kolkwitz&Marson 1909
- Liebmann 1951, 1962
- Pantle & Buck 1955
- Sladeček 1965

SI	saprobic level	sabrobic status
1.0 – 1.5	oligo-saprobic	not polluted
1.5 – 2.5	β mezo-saprobic	mild polluted
2.5 – 3.5	α mezo-saprobic	heavy polluted
3.5 – 4.0	poly-saprobic	pollutes

Biotic indeces

1. loss of information
2. more objectivity
3. mathematical “pseudo accuracy”

Two main mistakes:

1. index does not indicate the effects which happened
2. index indicate the effects which not happened

Biotic indices and macroinvertebrates

Why macroinvertebrates (MI)

- MI express quality of water environment due to different tolerance to pollutant
- MI are visible, abundant and relatively fixed on substrate
- easy for sampling and sorting (family level!)
- MI have relatively long life cycle in aquatic environment (weeks – years)

Assessment of ecological status of rivers (Water Framework Directive 2000/60/ES)

1. **Biological elements for assessment**

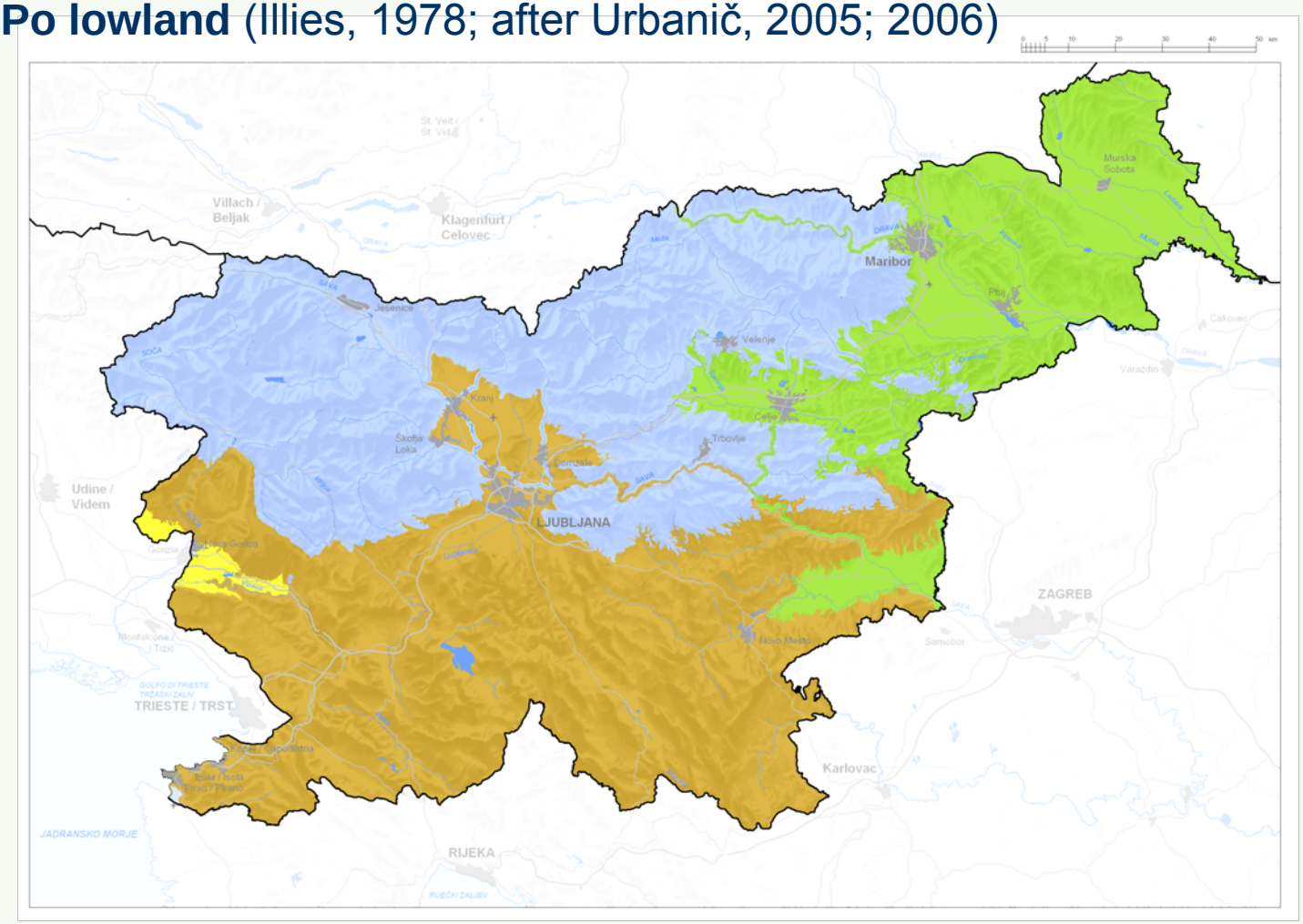
- Aquatic vegetation (species composition and No of individuals)
- benthic invertebrates (species composition and No of individuals)
- Fish (species composition, No of individuals, age structure)

2. **Assistant elements**

- hydro morphological (hydrology, flow regime, morphological conditions: depth and width, substrate and river banks structure
- chemical and physical and chemical elements: general (T, O_2, salinity, acidity, nutrients) and specific pollutants (synthetic, non-synthetic)

Each member State develop its own system of assessment of ecological status

For the purpose of WFD application Slovenia was divided into four hydroecoregions namely Alps, Dinarids, Pannonian lowland and Po lowland (Illies, 1978; after Urbanič, 2005; 2006)



Pressures on rivers in Slovenia

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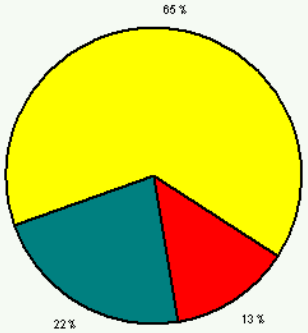
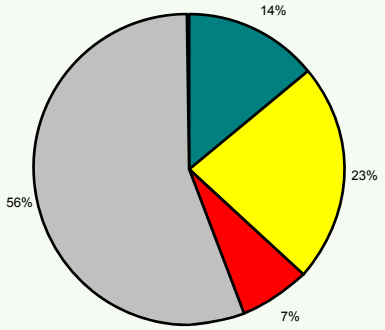
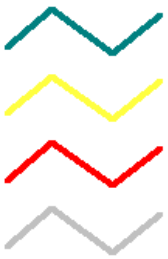
Hydromorphological alteration

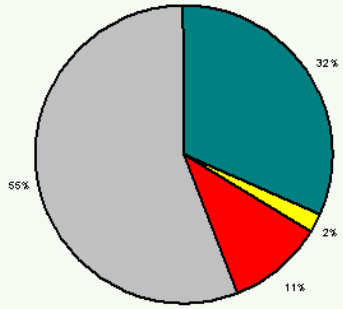


Organic pollution

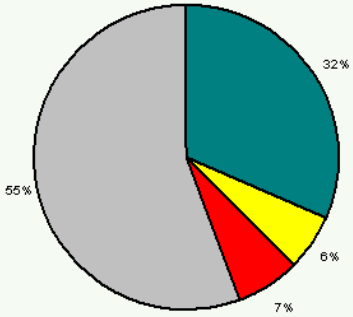




Eutrophication



Toxic substances



Pressures and bioindicators

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Pressure

Pragmatic approach

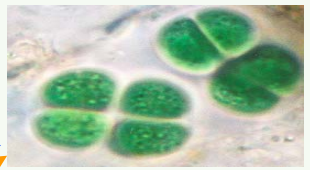
Biological element

Eutrophication

Organic pollution

Hydromorphological alterations

Toxic substances



Pressure specific approach!

No data

Pressures and bioindicators

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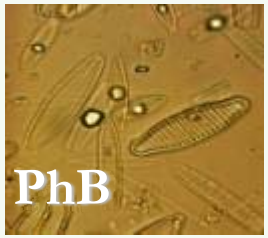
Pressure	Pragmatic approach	Biological element
Eutrophication		Trophic Index, River Macrophytes Index
Organic pollution		Saprobic Index
Hydromorphological alterations		MMI_HM
Toxic substances		



Tradition

Pressure specific approach!

Programme of measures!

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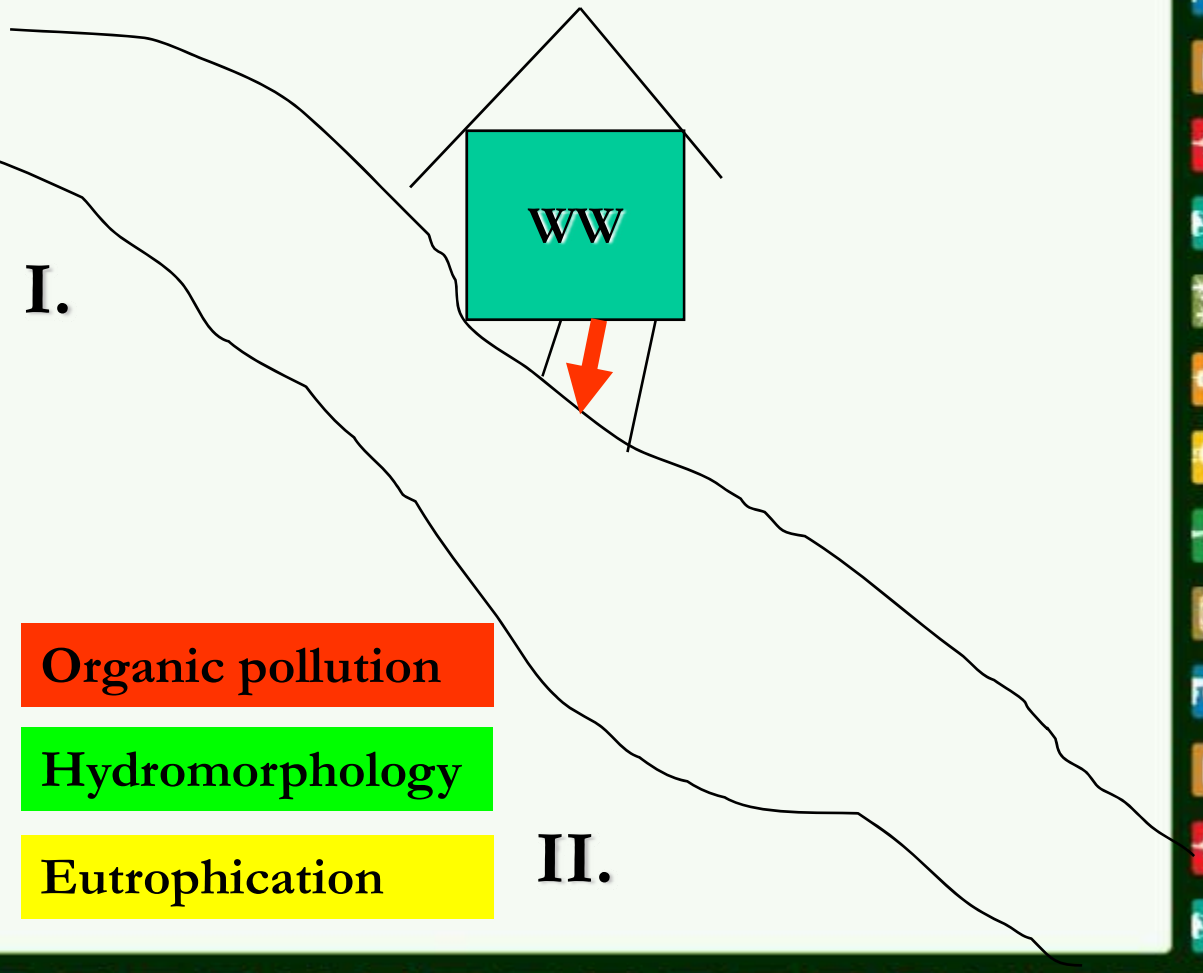
Case study 1 - single pressure; organic pollution

Organic pollution

Hydromorphology

Eutrophication

I.



Organic pollution

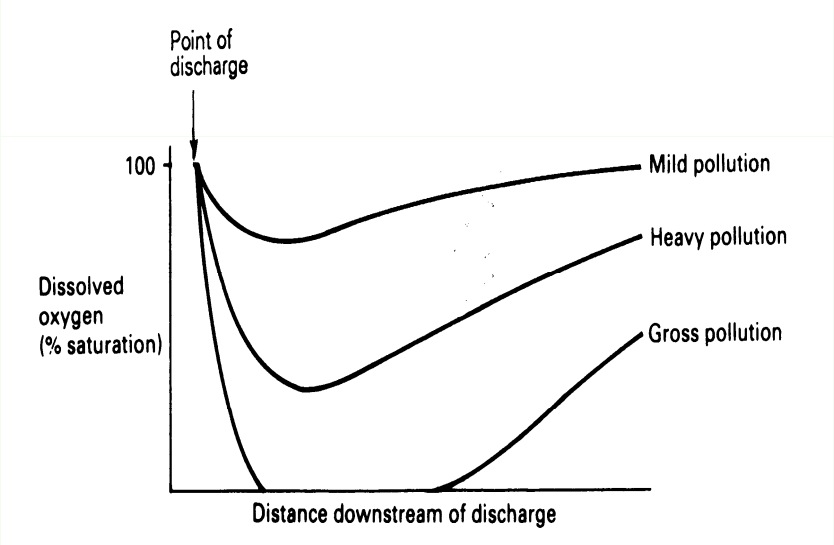
Hydromorphology

Eutrophication

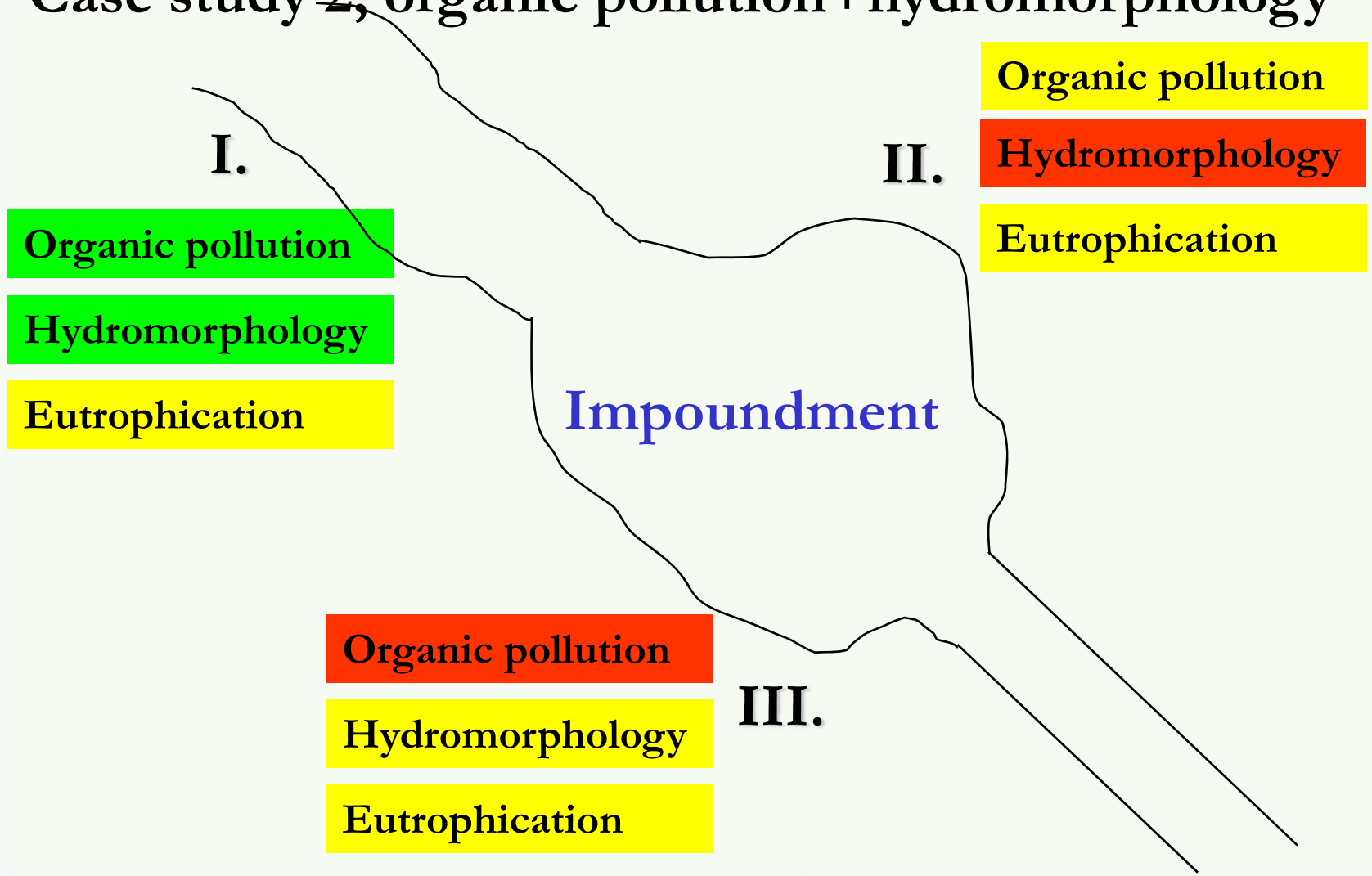
II.

Deoxygenation

- result of respiration activity of μ-organisms
- deoxygenation rate depends on:
  - ➢ BOD values of the waste
  - ➢ type and quantity of wastes
  - ➢ reaeration and D.O. from photosynthetic activity
  - ➢ type of organisms and the adaptation



Case study 2; organic pollution+hydromorphology



Watercourses influenced by agriculture

1. Slovenian watercourses support rich and diverse macrophyte communities.
2. Heterogeneous environment results in non-uniform distribution of macrophyte species.
3. The most diverse community developed in moderately influenced lowland streams, flowing through agricultural landscape and in some karstic streams.
4. The worst environment condition and lower macrophyte diversity was detected in heavily modified streams influenced by intense anthropogenic activity.
5. The influence of the single environment parameter depends on characteristics of certain region.
6. The presence of natural disturbance (intermittance, drought) could influence macrophyte community.

⇒ **Environment assessment:**

Modified Riparian, Channel and Environmental (RCE) Inventory (Petersen, 1992)

11 parameters (4-levels describing the quality gradient)

1. **Properties of the land beyond the riparian zone.**
2. **Structure of riparian zone.**
3. **Channel properties which are a consequence of a catchment and longitudinal character of the river.**

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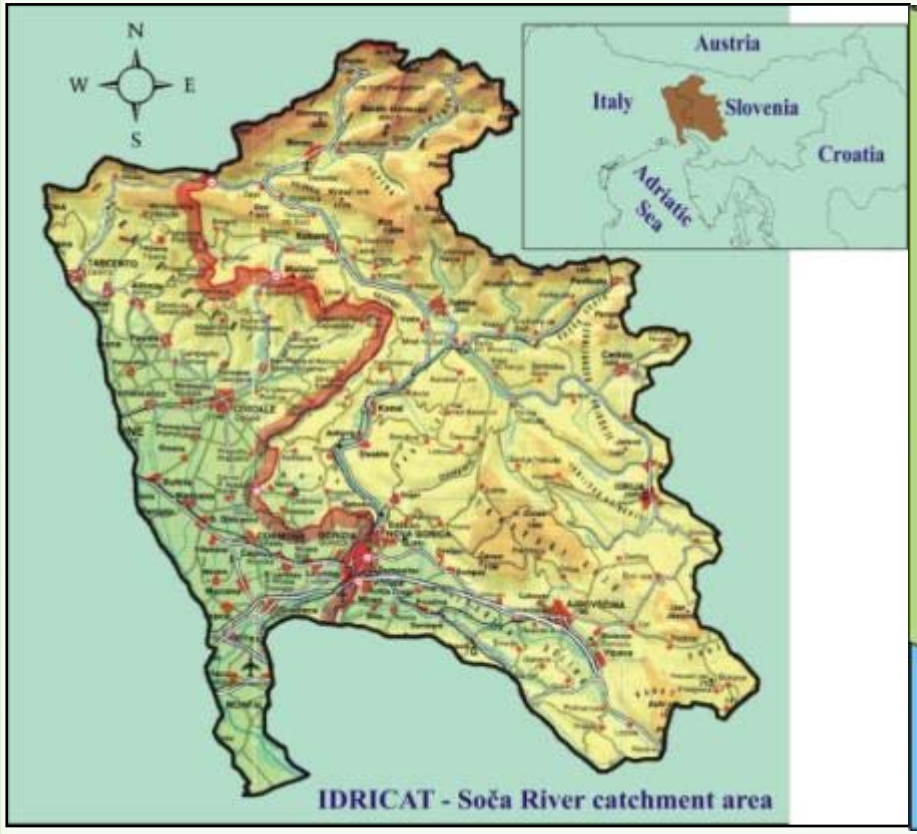
IdriCat - Study area

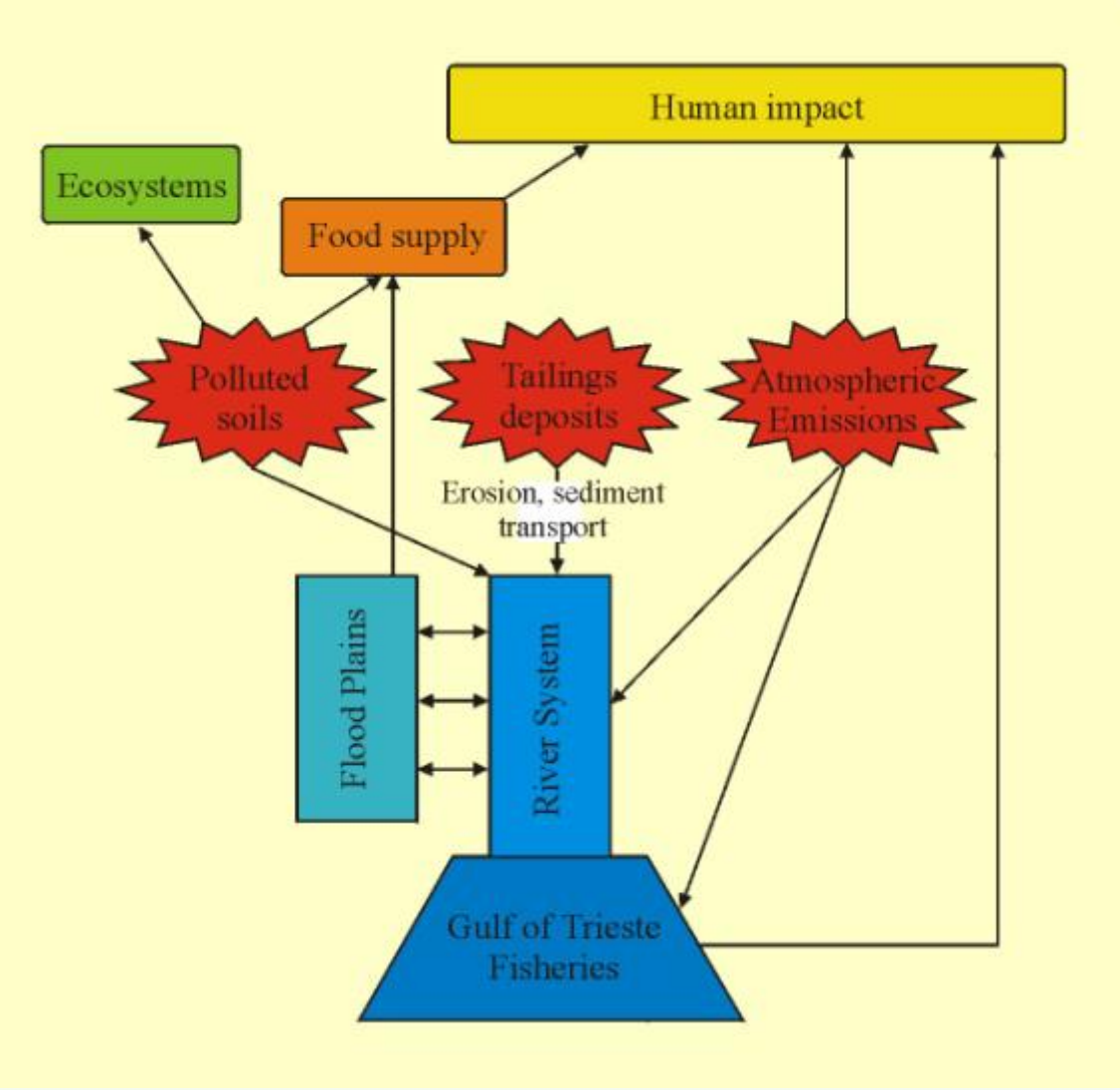
- Catchment area: 3300 km^2
- Soča at the mouth: 170 m^3/s (extreme 3000– 4000 m^3/s)
- Precipitation: 1500 mm/y
- 0.3 Mio inhabitants



Mercury Mine, Idrija, Slovenia

- 500 years of mining (1490-1990)
- 107.000 tons of Hg extracted
- 37.000 tons lost into the environment

Impact of mercury mining in the area



Why is Hg-pollution relevant at all?

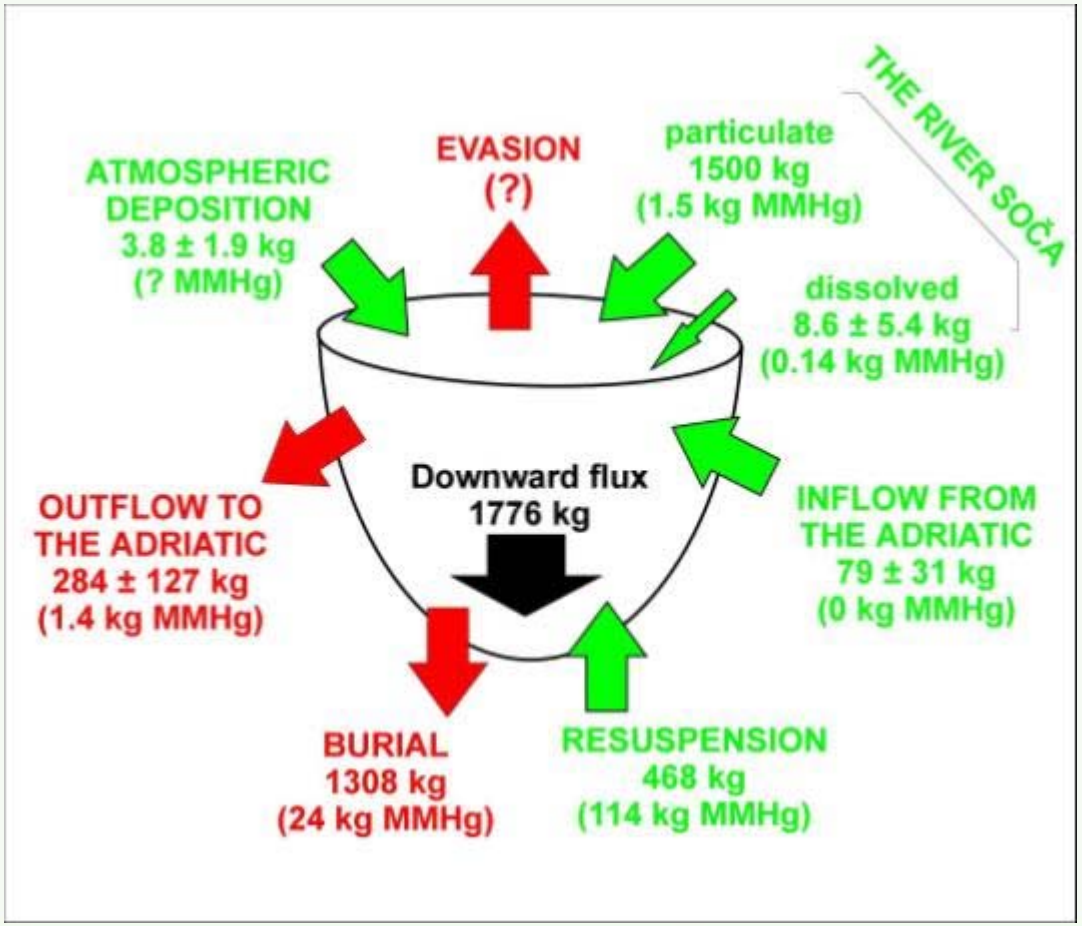
Estimated daily intakes of Hg in humans expresses in µgHg/day/kg$_{bw}$

	Idrija		Coastal area	
	T-Hg	MeHg	T-Hg	MeHg
Air	**0.05 - 0.10**	**-**	**0.001 - 0.005**	**-**
Fish (100g/day)	**0.20 - 3.33**	**0.18 - 3.20**	**0.18 - 1.35**	**0.17 - 1.33**
Other food	**0.66**	**0.132**	**0.05**	**0.01**

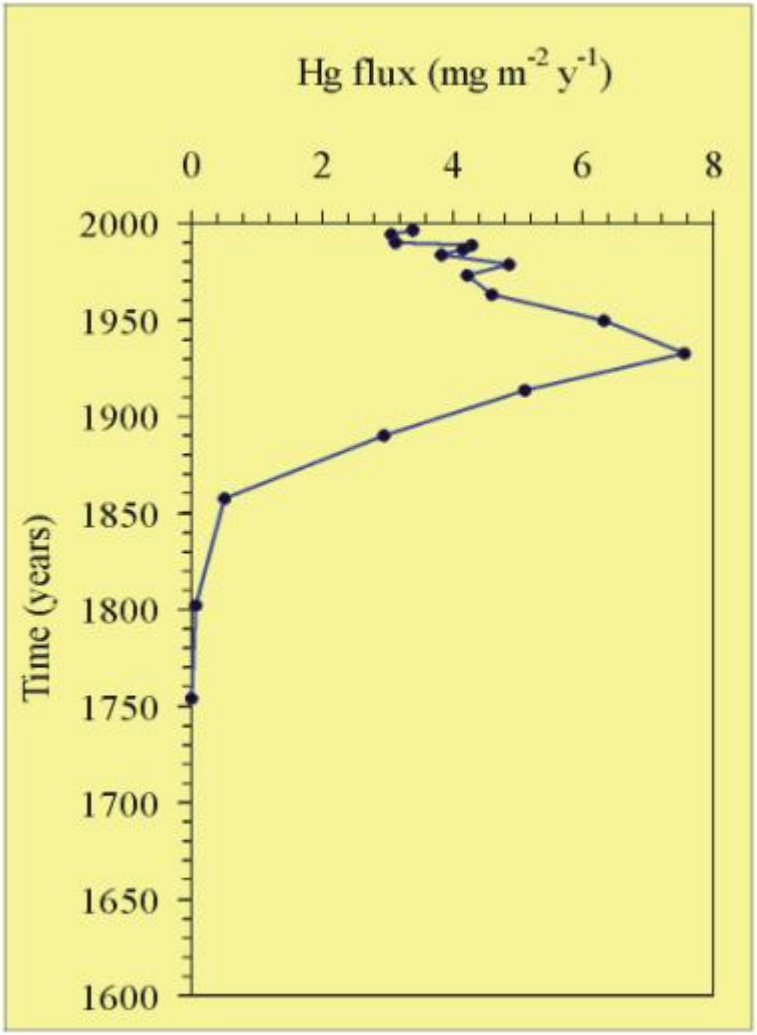
US EPA recommended RfD is 0.1 µgHg/day/kg$_{bw}$ (note: 60 kg body weight)

Some existing data:

Preliminary mass balance of Hg in the Gulf of Trieste



Hg flux into the Gulf of Trieste



Covelli et al. 1999

- **the formation and bioaccumulation of MeHg is the most critical point of environmental quality in mercury contaminated sites**

- **the reduction of MeHg in food (e.g. fish!) can therefore be defined as the priority objective**

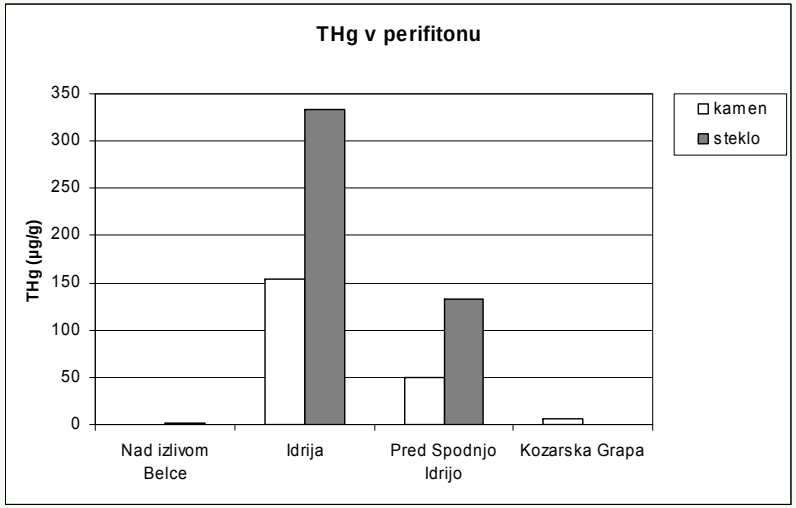
To reach this objective two principal strategies are considered:

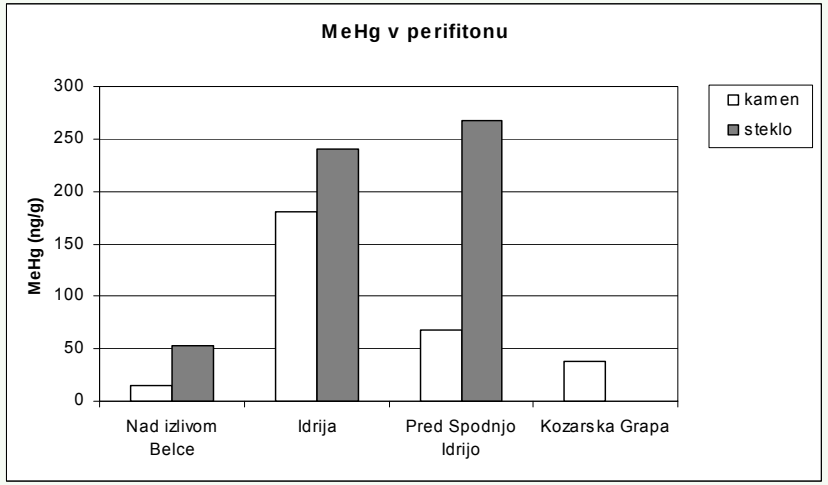
- reducing the input of mercury to the system
- changing the conditions to reduce the formation

of methylmercury

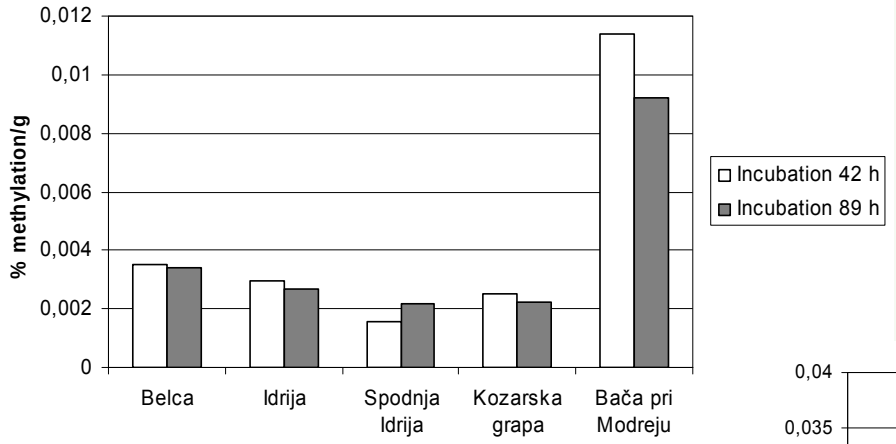
Results – Hg in periphyton
(sampling date 18.10.2006)

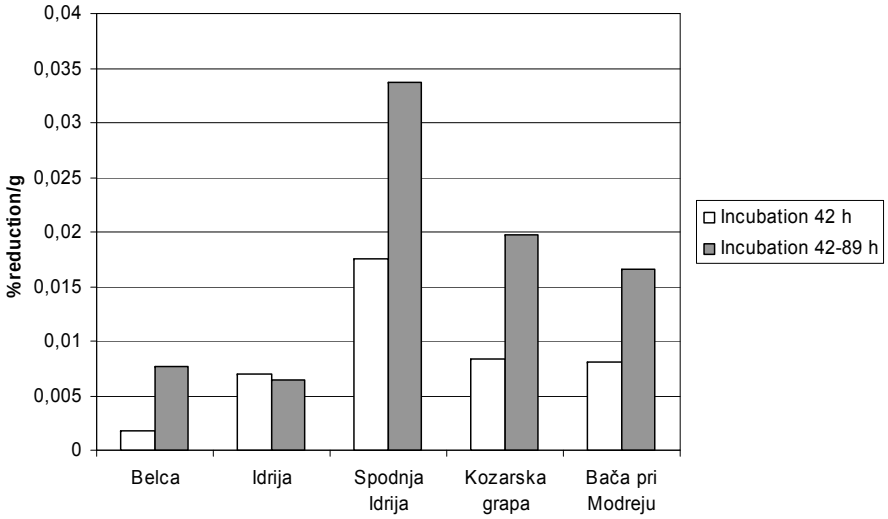
	THg (µg/g)		MeHg (ng/g)		% Hg as MeHg	
	stone	glass	stone	glass	stone	glass
Nad izlivom Belce	0,066	1,25	15,4	53,2	23,3	4,26
Idrija	154	334	180	240	0,12	0,07
Pred Spodnjo Idrijo	49,9	133	67,7	268	0,14	0,20
Kozarska Grapa	6,01		37,8		0,63	





Results – methilation and reduction in sediments (sampling date 18.10.2006)





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Wetlands – Unexploited Natural Potetial or the Burden of the Future

WETLANDS

Lands transitional between terrestrial and aquatic systems where the water table is at or near the surface or the land is covered by shallow water.

hydrologicaly complex and dynamic ecosystems, high species diversity, the kidneys of the landscape, ecological, supermarkets, diversity of food webs

GREEN COME ACROSS BLUE

Wetland – bufer zone

- "hotel" = micro-habitat
- "restaurant" = food-webs
- reducing impacts from terrestrial system and from the atmosphere
- sink of nutrients
- decomposition of organic matters
- improving water quality
- potential of drinking water
- reducing flood risk

Wetland – accumulation zone

- natural treatment plant **with limited capacity**
- accumulation of nutrients and organic substances
- accumulation of toxic substances and therefore secondary source of pollution
- decomposition of organic matter slower than production , high sedimentation
- source of biogenic gases (e.g. methane, H_2S, CO_2)

Conclusions

It is only ONE Biosphere, it is only ONE Hydrosphere.
All ecosystems are adaptable.
Water ecosystems are not separate from terrestrial ecosystems and from atmosphere – mutual impacts! Landscape ecology is fundamental to avoid conflicts between stakeholders!

For OUR (not nature!) protection and surviving we invented **Ecosystem management:** the bureaucratic activity to do nothing!? Anthropocentric activities!
We need large scale conservation programmes.

Keystone for future activities

What we need in ecosystems is **dynamic balance, not steady state system.**

Humans are **part of nature, not a supervisor.**

CHANGES? Yes in our mind. Let's do it together (with Nature)!

The Earth survived earthquakes, volcanic activities, meteorites, fire and floods. It will survive also the human being. Should we?

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THANK YOU

for your attention