

Macrophytes: vascular plants

- relatively low coverage
- majority in slow waters
- few species in fast flowing parts
- emergent, floating-leaved, free-floating plants



Myriophyllum alterniflorum



Potamogeton alpinus



Batrachium fluitans



Woody debris

- slow breakdown - half-life
- diameter <1 cm – ca 5 to 10 years
 - 5-10 cm – ca 50 years
 - large trunks – 100-250 years



Sources of FPOM

- Breakdown of CPOM
- Feces of small consumers
- From DOM by microbial uptake
- From DOM by physical-chemical processes

- Sloughing of algae*
- Sloughing of organic layers
- Forest floor litter and soil

- Stream bank and channel

Major input where leaf fall or macrophytes provide CPOM

Important transformation of CPOM

Organic microlayers on stones and other surfaces

Flocculation and adsorption, probably less important than microbial uptake route

Of local importance, may show temporal pulses

Little information available

Influenced by storms causing increased channel width and inundation of floodplain, affected by overland versus subsurface flow

Little known, likely related to storms

FPOM

microbes

- estimates of biomass – cell counts, ATP concentration
- estimates of metabolic activity - respiration rate, uptake of labeled substrate

fecal pelets – 100 – 1000 μm in length

- amphipods, isopods – peritrophic membrane
- size, form, texture, colour, cohesion and composition of the faeces of 41 species of invertebrates found in chalk streams (Ladle & Griffiths 1980)

mean **transport distance** – hundreds of meters

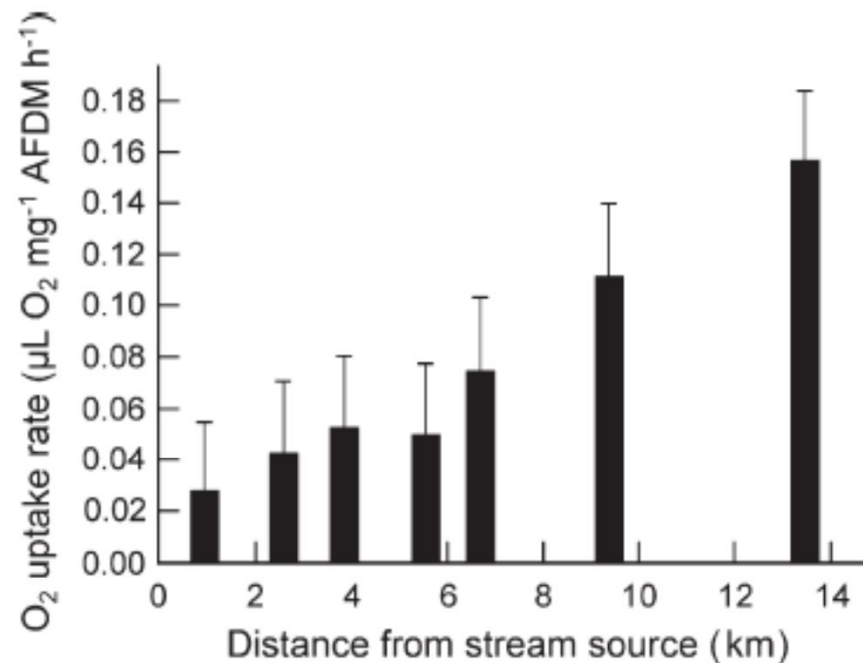


FIGURE 7.12 Downstream variation in benthic FPOM respiration in Ball Creek-Coweeta Creek at the Coweeta Hydrologic Laboratory. Values shown are means and standard errors for all sampling dates for each site. (Reproduced from Webster et al. 1999.)

ash free dry weight (AFDW)

DOM

- $<0.45 \mu\text{m}$
- largest pool of organic C in running waters
- measurements of chemical oxidation – DOM, carbon analysis – DOC
- DOM \sim 45-50% of org. C mass
- carbohydrates; fatty, amino and hydroxy acids; humic and fulvic acids (50-75%, up to 90%)



Sources of DOM

● Groundwater	1-2 mg/l	Major input, relatively constant over time, often highly refractory
● Subsurface or interflow	2-30 mg/l	More important during storms
● Surface flow		Possibly important during storms causing overland flow
● Leachate from detritus of terrestrial origin		Major input, pulsed depending upon leaf fall
● Throughfall		Smaller input, dependent on contact of precipitation and clouds with canopy
● Extracellular release and leachate from algae*		Of local importance, may show seasonal and diel pulses
● Extracellular release and leachate from macrophytes*		Of local importance, may show seasonal and diel pulses

Much OM originates outside the stream reach where it is measured. Some (sources marked with an asterisk) is produced by photosynthesis within the stream and subsequently enters the pools of dissolved or particulate OM.

Transformation of DOC

- fast uptake of DOC
- **abiotic**
 - adsorption
 - chemical complexing
 - flocculation (Lush & Hynes 1973)
- **biotic** - uptake by microorganisms, assimilation, consumption, re-mineralization
 - in sediments
 - tight internal nutrient cycling between heterotrophs and autotrophs, accumulation of exoenzymes

Biofilm

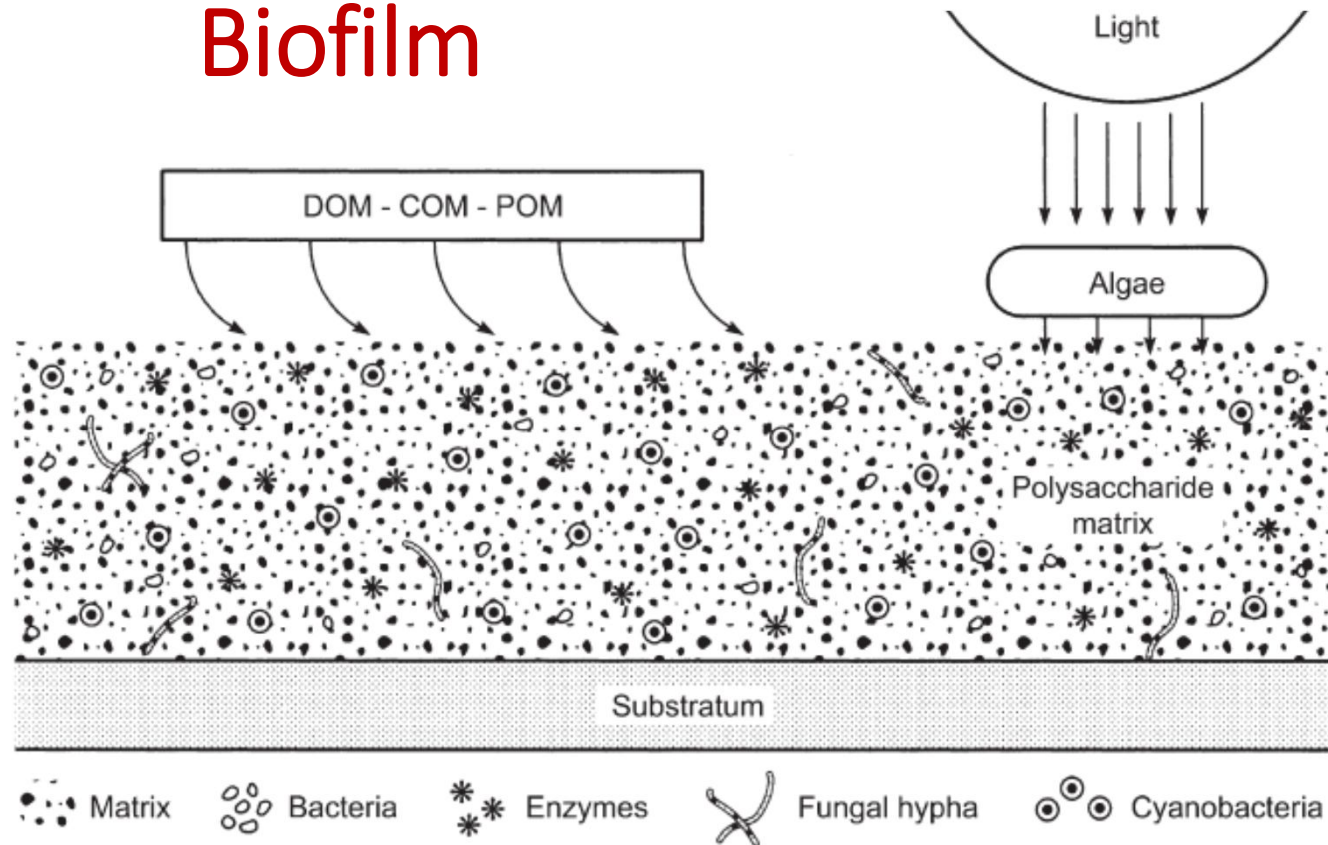
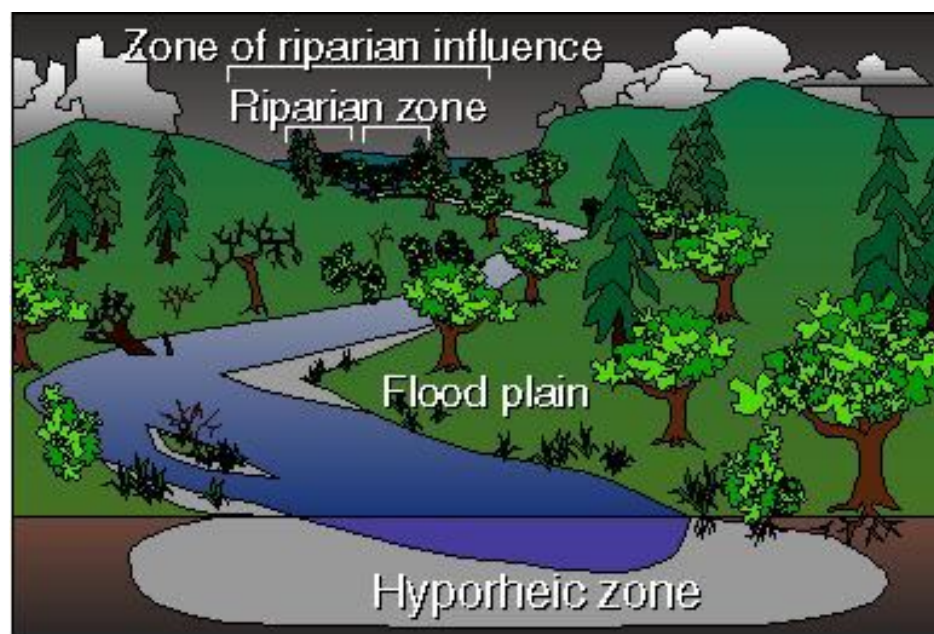


FIGURE 7.13 A structural and functional model of the organic microlayer-microbial community found as a surface biofilm on stones and other submerged objects in streams. The matrix of polysaccharide fibrils produced by the microbial community binds together bacteria, algae, and fungi, and is inhabited by protozoans and micrometazoans that graze on this material. Detrital inputs include dissolved, colloidal, and fine particulate organic matter, while light energy is trapped by algal photosynthesis. Within the matrix, extracellular release and cell death result in enzymes and other molecular products that are retained due to low diffusion rates and thus available for utilization by other microorganisms. (Modified from Lock 1981.)

Hyporheic zone

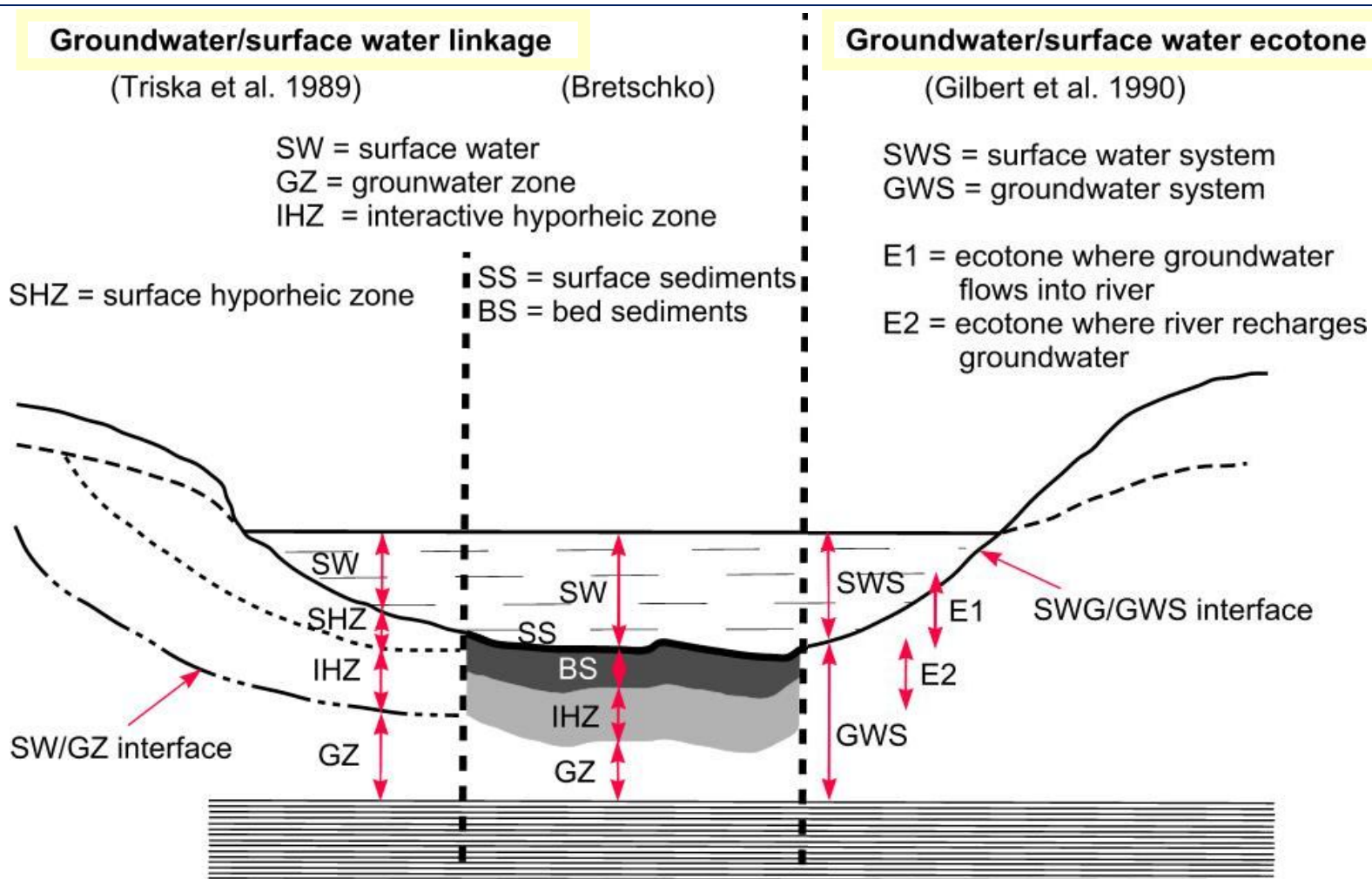


Tok:
povrchová voda
+
zvodnělé sedimenty
(akvifer)

hyporeická zóna:
pod vlastním tokem
+
freatická zóna

History

- předpoklad, že část říční fauny obývá sedimenty pod říčním dnem a vykazuje vertikální distribuci - Kühtreiber (1934)
- kopání jam ve freatické zóně (Chappuis 1942)
- termín „hyporheic“ použil poprvé Orghidan (1959)
- hyporeál (intersticiál) jako součást podzemních vod, rozvinut ve štěrkovitých sedimentech, pro říční faunu plní funkci refugia a líhně (Schwoerbel 1961)
- u nás se výzkumu ve freatické zóně věnoval O. Štěrbá (60.-70. léta) - „poříční podzemní voda“
- „ekotonální“ přístup: hyporeál jako ekoton mezi systémem povrchových a podzemních vod; diverzita zde ale dosahuje jen středních hodnot! (Gibert et al. 1990)
- různé přístupy ovlivněny použitou vzorkovací metodou: freatobiologové vs. limnologové



Ecotonal and hyporheic concepts are used to describe linkages between groundwater and surface water systems (from Vervier et al. 1990).

Hyporeos

- epigeická vs. hypogeická fauna

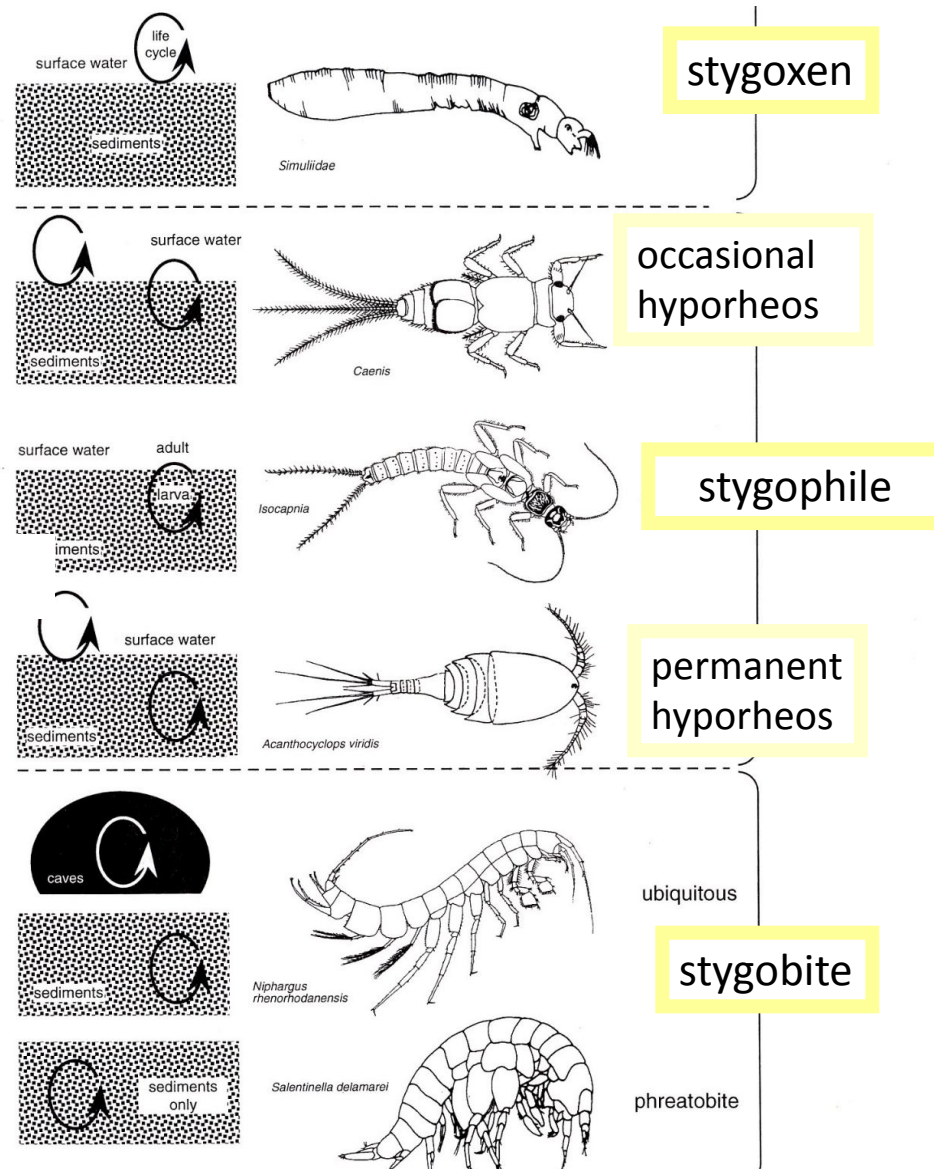
morfologické adaptace

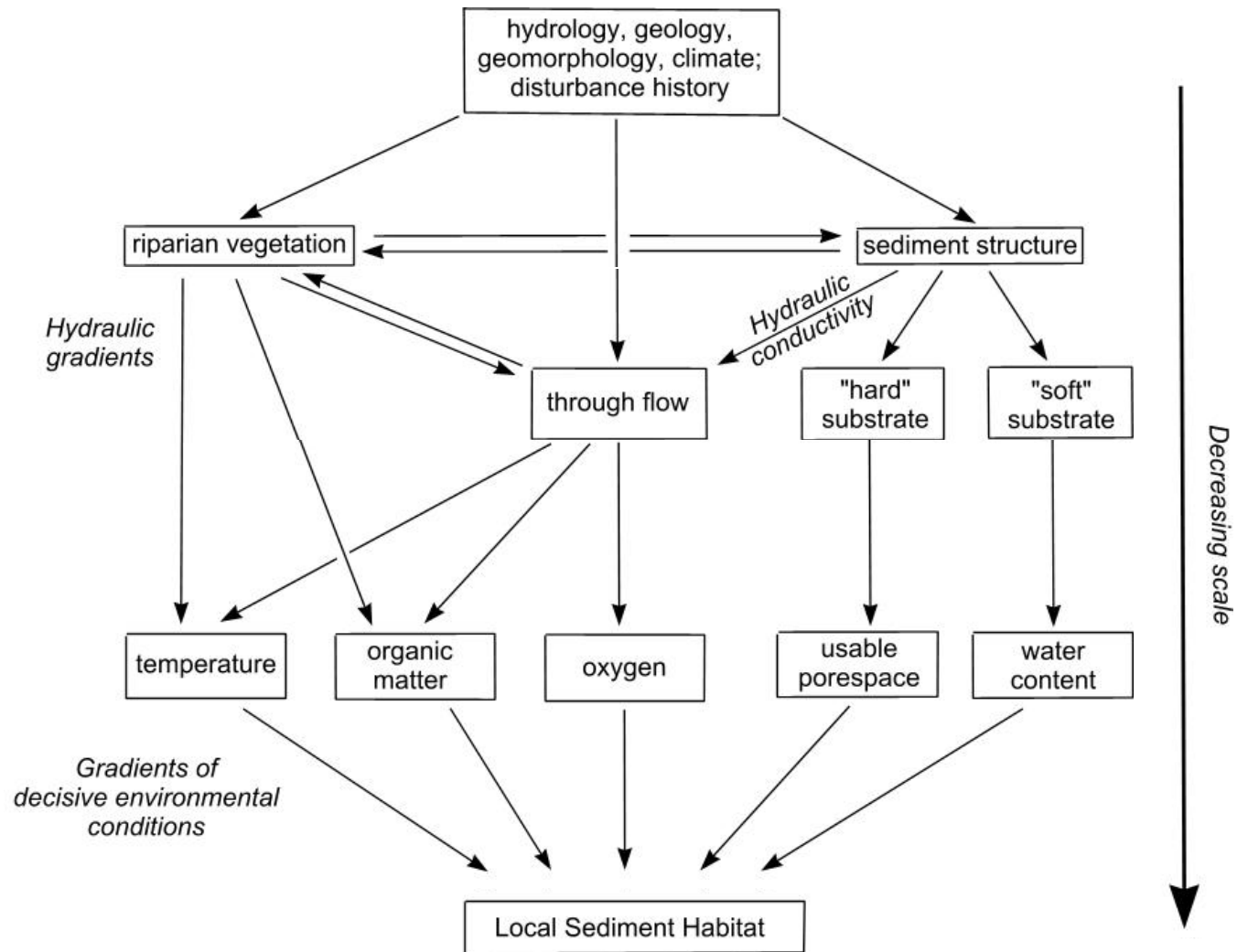
- větš. micro- a meiofauna
- tvar těla
- způsob pohybu

biologické adaptace

- pomalý metabolismus, dlouhý generační cyklus, tolerance k hypoxii

adaptace vs. preadaptace

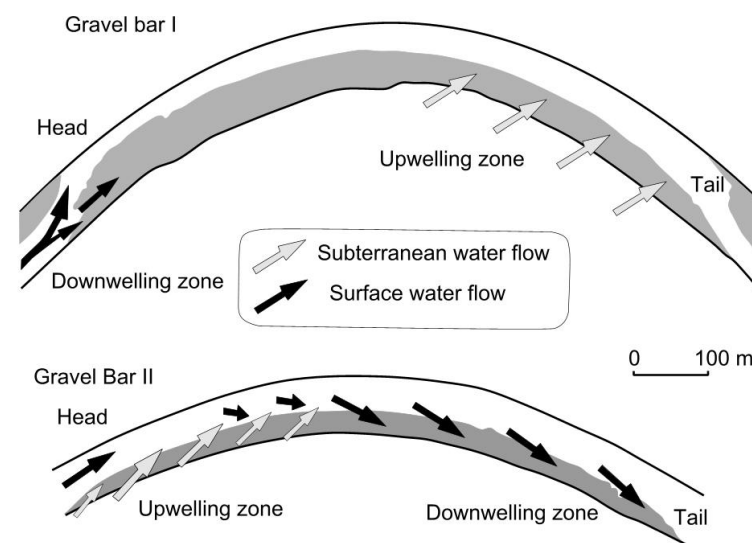
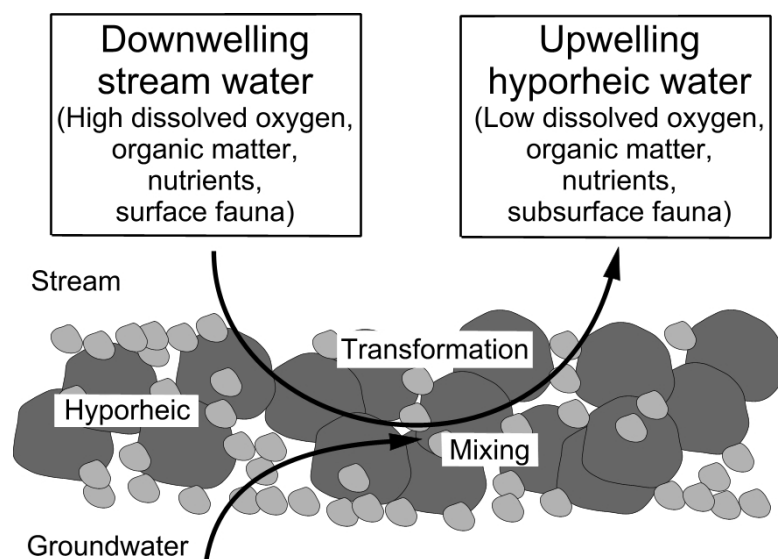




Hierarchical conceptualisation of factors controlling local sediment habitat conditions of major importance to interstitial metazoans (from Ward et al. 1998).

Komunikace mezi povrchovou a podzemní vodou

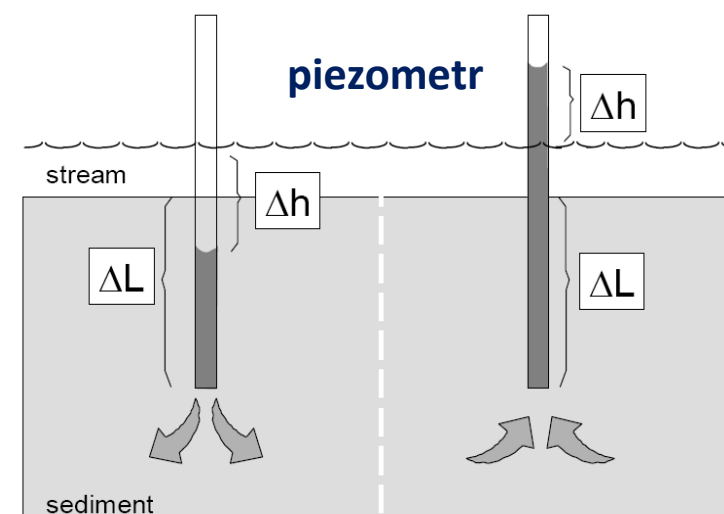
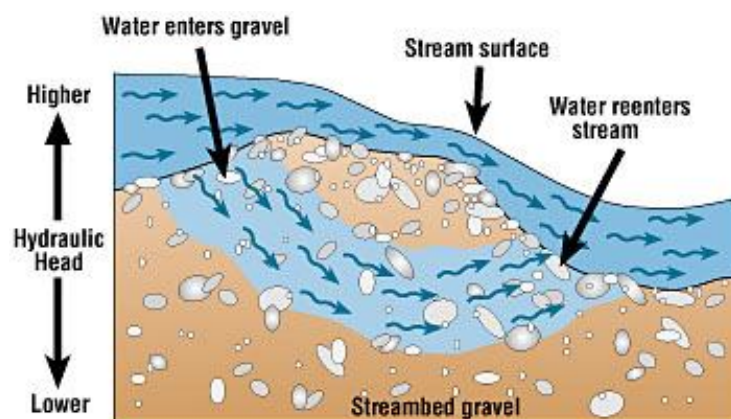
- horizontální proudění, infiltrace, exfiltrace, kapilární síly
- průtok hyporeálem závisí na propustnosti dna a povrchovém průtoku
- variabilita v podélném a příčném profilu i v čase
- kolmatační vrstva



Miribel Canal (France), from Dole-Olivier et Marmonier (1992)

Tok vody substrátem: pojmy

- **Hydraulická výška („hydraulic head“), hydraulický potenciál** = míra energie, kterou má hmota vody vzhledem ke své poloze v prostoru, tlaku a rychlosti proudění
- **Hydraulický gradient (spád)**
- **Hydraulická vodivost („hydraulic conductivity“)** = množství vody, které proteče plochou 1 m² za sekundu, závisí na propustnosti a nasycení kapalinou
- **Propustnost („permeability“)** - funkce pórovitého prostředí



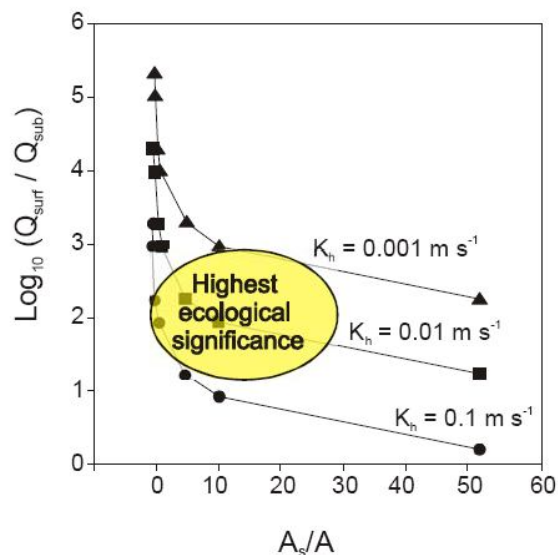
$$\frac{\Delta h}{\Delta L} = -'$$

Downwelling

$$\frac{\Delta h}{\Delta L} = '+'$$

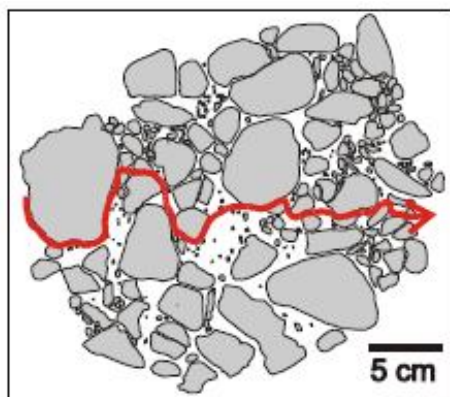
Upwelling

Rychlost toku vody v substrátu



Findlayho model (Boulton 1998)

- velké měřítko (povodí)
- K_h = hydraulic conductivity, $Q_{\text{surf}}/Q_{\text{sub}}$ = poměr povrchového a podzemního průtoku, A_s/A = poměr ploch zóny ukládání a celého toku v příčném profilu
- predikuje optimální podmínky pro hyporeos



- v malém měřítku průtok intersticiálem velmi heterogenní, nepredikovatelný
- skutečná rychlost vody je vyšší, protože je delší dráha
- vyžaduje přesné měření (Wagner et Bretschko 2002)

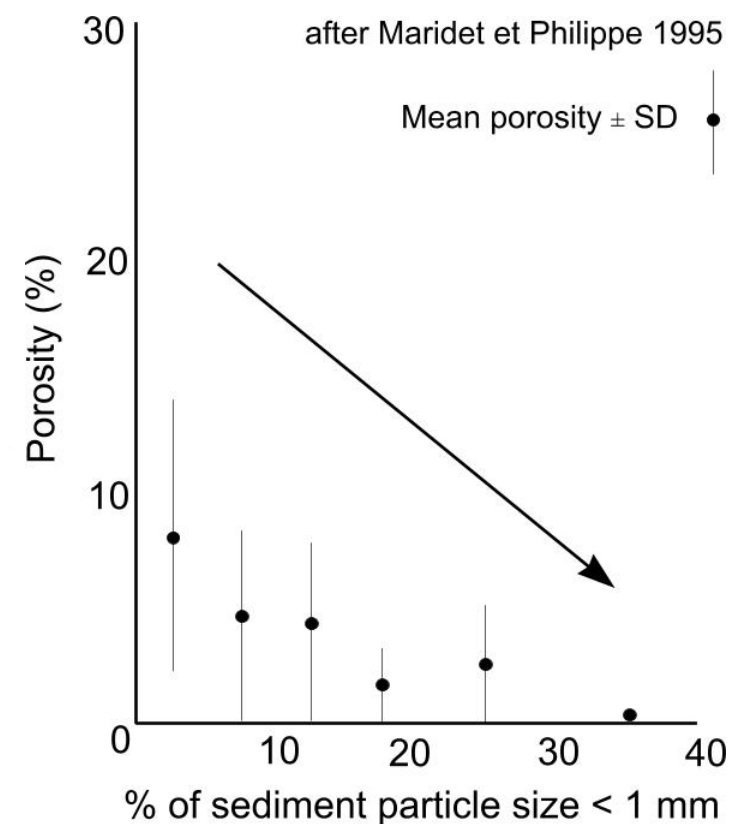
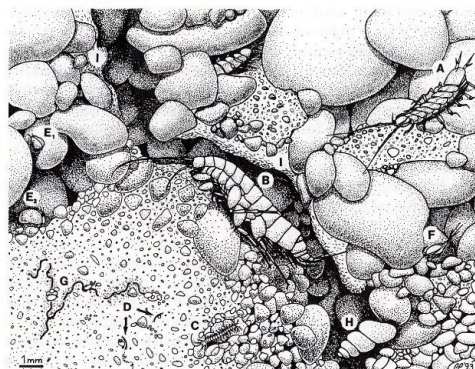
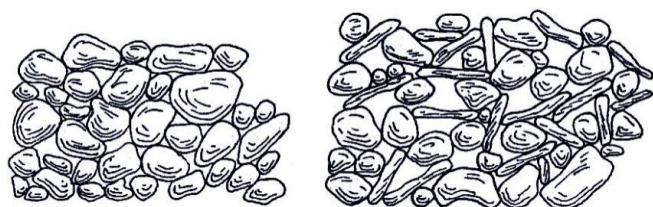
Vliv struktury sedimentu

- přímo ovlivňuje denzitu, diverzitu a velikostní složení společenstva
- důležitý je dostupný intersticiální prostor
- obsah jemných částic jako limitující faktor
- porozita (%)

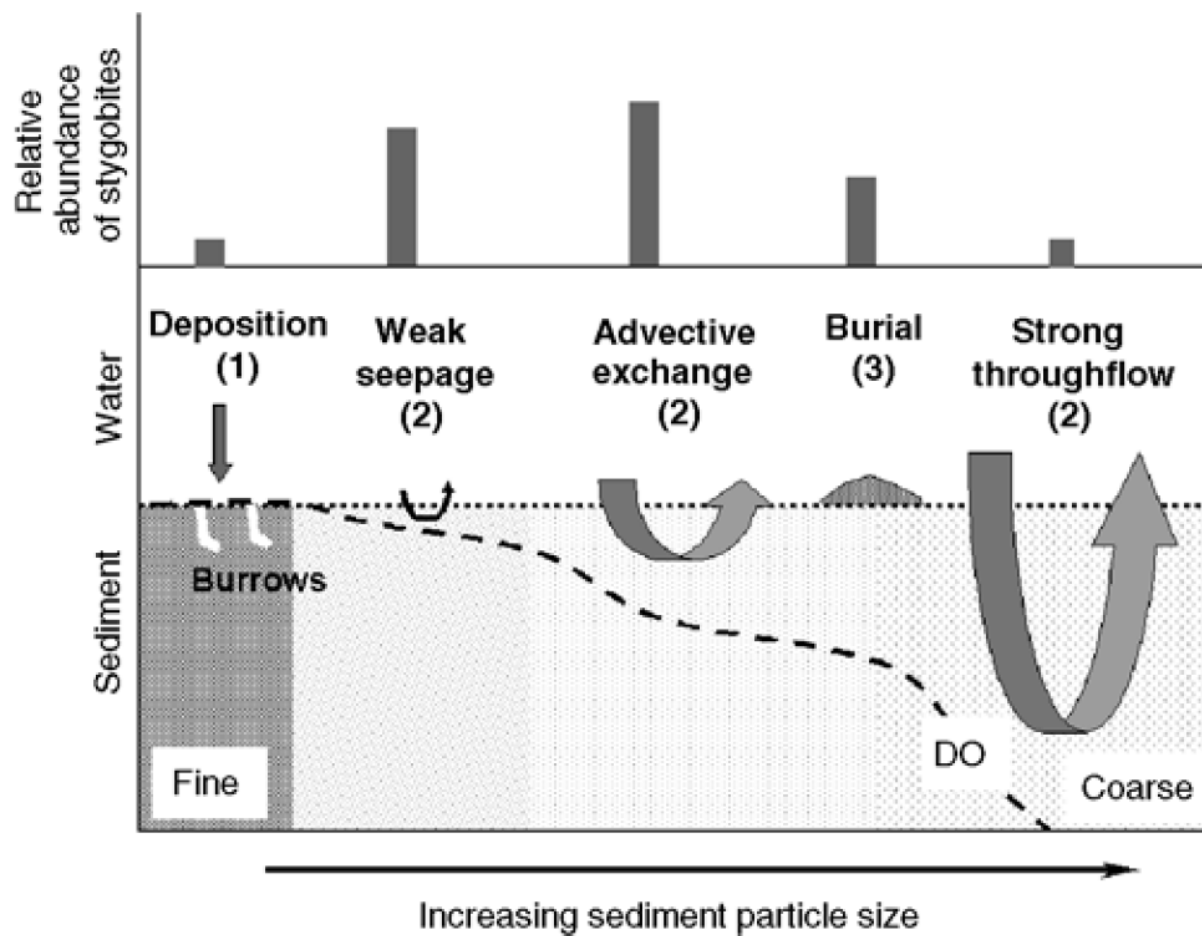
$$P = \frac{V_w}{V_s} \times 100$$

V_w = objem vody
 V_s = objem sedimentu

- velikost pórů závisí i na tvaru zrn



Vliv struktury sedimentu na typ proudění



Biological station Lunz



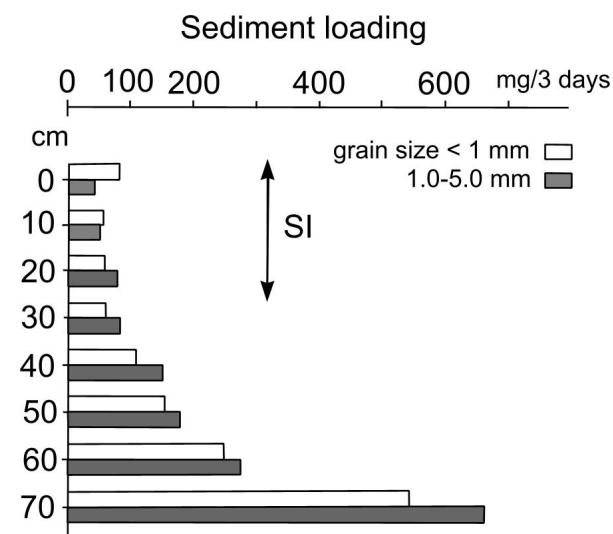
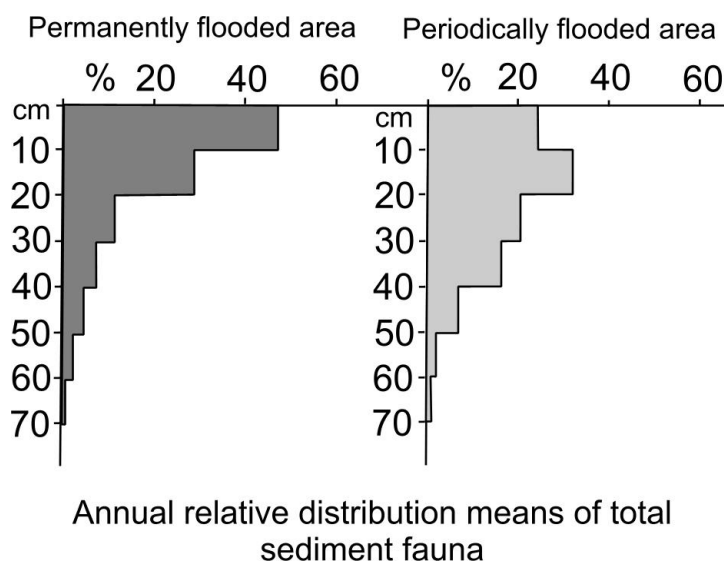
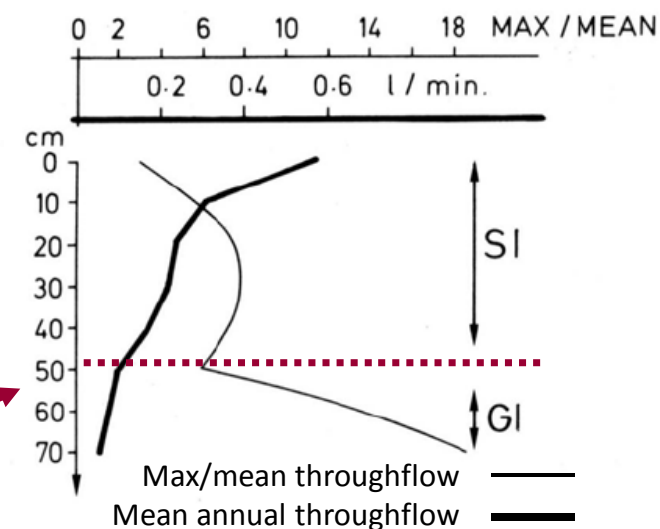
In memoriam GERNOT BRETSCHKO (1938–2002)



Vertikální změny průtoku v sedimentu

Bretschko (1992): Seebach, Austria

- část vertikálního profilu ovlivněná povrchového průtokem (SI), část podzemní vodou (GI)
- dolní hranice (99%) výskytu hyporeosu relativně stabilní



Hyporheic refuge hypothesis

- mechanism of surviving disturbances and recover
- Palmer et al. 1992: field sampling during and after flood (Goose Creek, USA), experiments in flume
 - significant loss (50-90%) of meiofauna from a streambed during moderate and severe floods, hyporheic zone disturbed only in surface layers
 - copepods and chironomids: small-scale downward migration only in the experimental flume (at $U=5-23$ cm/s) but not in the field
 - re-colonization from hyporheic zone important only in rotifers and copepods but similar magnitude that from water + streambed surface

Active migration into hyporheic zone

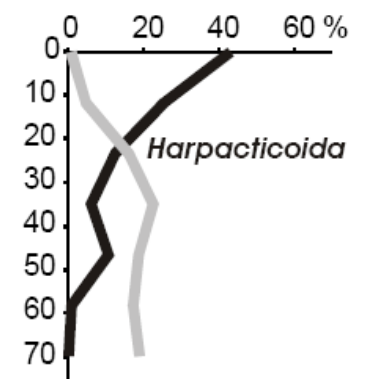
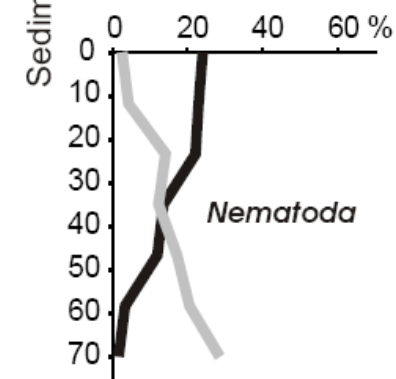
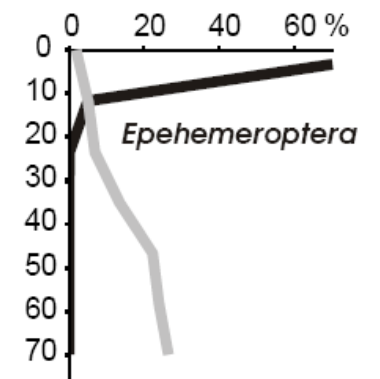
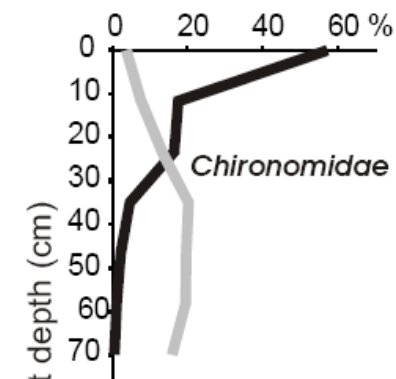
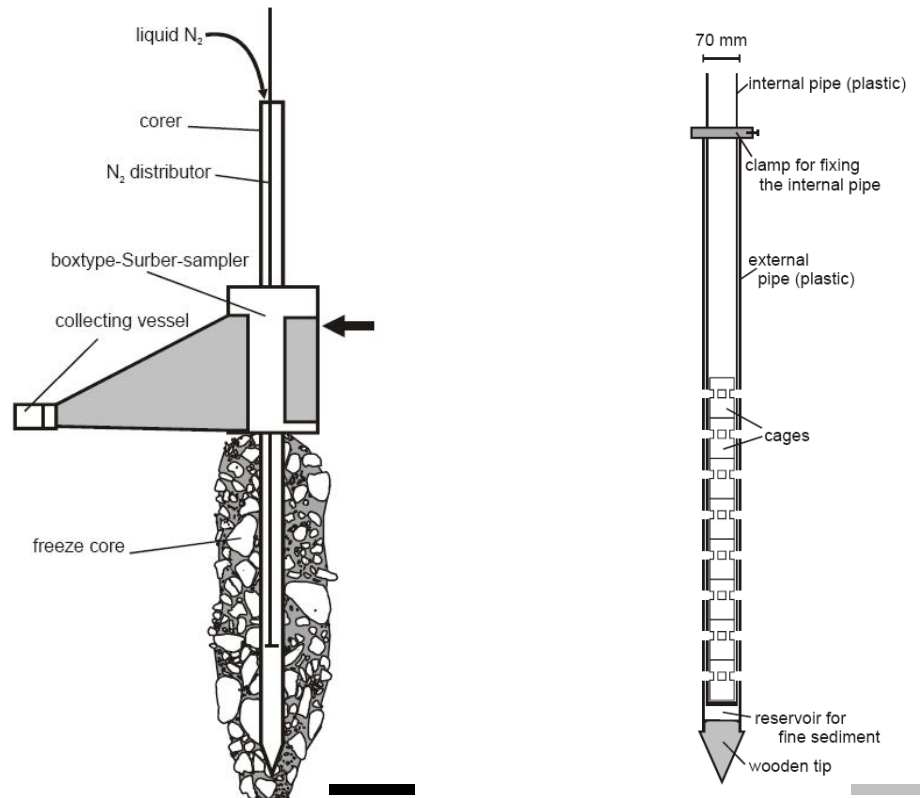
Stubbington 2010

Table 4. Taxon-specific evidence of active migrations by benthic macroinvertebrates into the hyporheic zone
Studies noting active migrations identified using Tables 1–3; only taxa recorded as actively migrating by some studies are noted

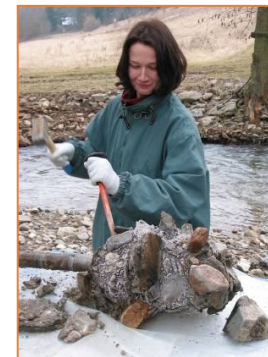
Class	Taxon	Active migrator?	References
Tricladida	Planariidae	Yes	Marmonier and Creuzé des Châtelliers (1991)
Gastropoda	<i>Potamopyrgus</i>	Yes	Holomuzki and Biggs (2000)
Amphipoda	<i>Gammarus</i>	Yes	Dole-Olivier and Marmonier (1992a); Dole-Olivier <i>et al.</i> (1997); Wood <i>et al.</i> (2010); Stubbington <i>et al.</i> (2011b)
Ephemeroptera	Not specified	No	Dole-Olivier <i>et al.</i> (1997); Gayraud <i>et al.</i> (2000)
		Yes	Marmonier and Creuzé des Châtelliers (1991)
		No	Marchant (1995); Gayraud <i>et al.</i> (2000) (Heptageniidae)
Plecoptera	Leptophlebiidae	Yes	Delucchi (1989); Holomuzki and Biggs (2000)
	Not specified	Yes	Marmonier and Creuzé des Châtelliers (1991)
Trichoptera	Not specified	No	Marchant (1995)
		Yes	Delucchi (1989); Dole-Olivier and Marmonier (1992a)
		Yes	Dole-Olivier and Marmonier (1992a)
		Yes	Marmonier and Creuzé des Châtelliers (1991)
Coleoptera	Not specified	No	Marchant (1995)
		Yes	Dole-Olivier and Marmonier (1992a)
		Yes	Holomuzki and Biggs (2000)
		Yes	Dole-Olivier and Marmonier (1992a)
		Yes	Holomuzki and Biggs (2000)
Diptera	Chironomidae	Yes	Marchant (1988); Dole-Olivier and Marmonier (1992a); Marchant (1995)
		No	Gayraud <i>et al.</i> (2000)

Sampling methods

- freeze-core vs. cage pipes (Wagner 2002)
- abundance vs. activity of hyporheos

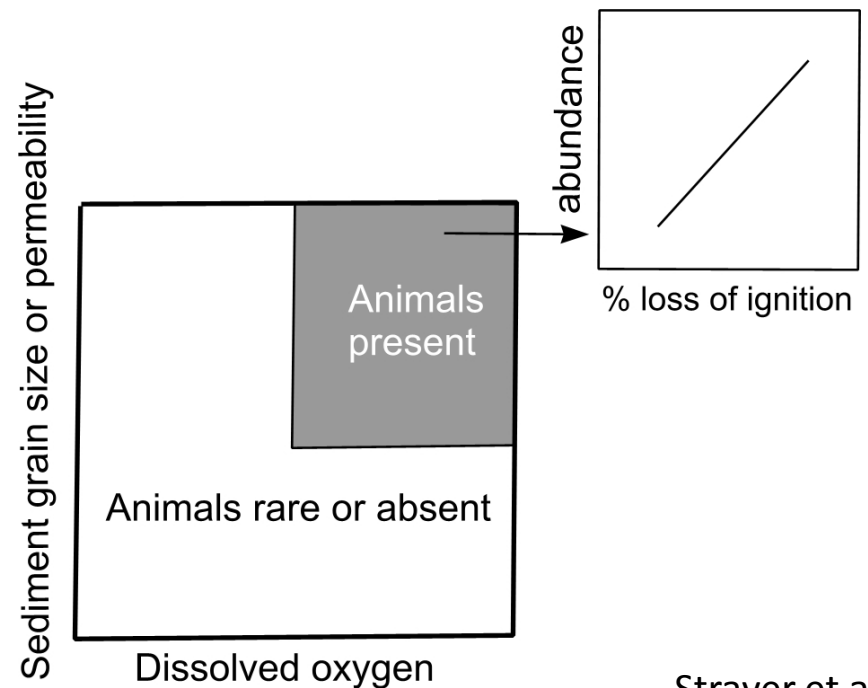


„Freeze coring“



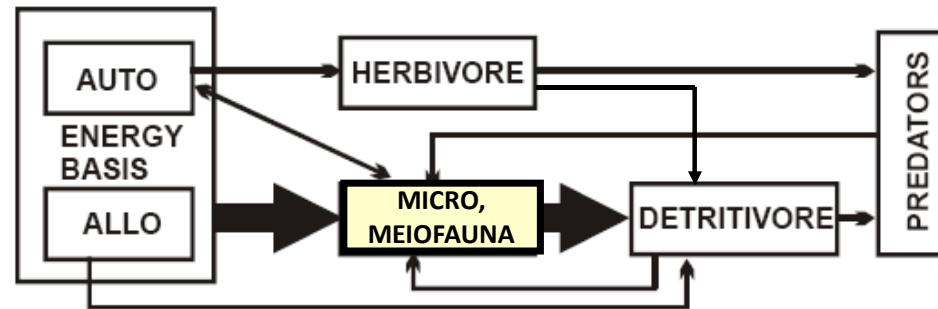
Key factors

- vliv DO, OM a struktury sedimentu na faunu v různých studiích různý, kterýkoli z nich může být limitující faktor
- hypotéza: pozitivní korelace mezi abundancemi a koncentrací POM nastává při dostatečně vysoké koncentraci DO a permeabilitě
- potvrzeno, ale korelace slabé
- vlivy teploty, hydrologie, disturbační historie a biologických interakcí



Strayer et al. 1997

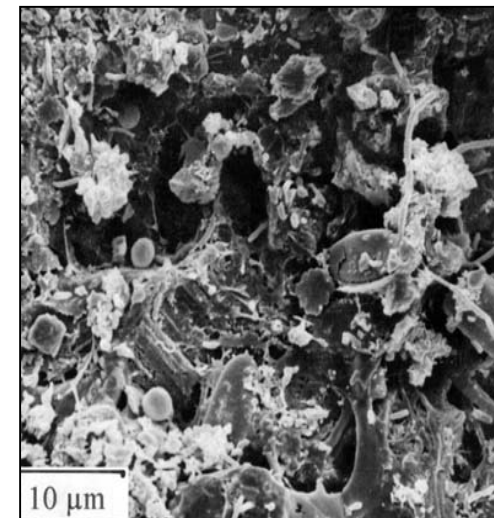
Food chain and energy flow



Autochtonní org. materiál – fotická vrstva, zelené řasy, rozsivky, sinice

Allochtonní org. materiál (POM, CPOM, FPOM, DOM)

- listový opad - sezónní závislost
- eroze břehových partií
- pohřbívání a rozklad
- retenční kapacita sedimentu
- biofilm



Functional significance (Boulton 1998)

- hrabání – bioturbance, rozrušování sedimentu, změna velikosti pórů a rychlosti vody v nich, oxygenace a transport org. látek, disperze bakterií a spór
- vyměšování – tvorba „bobků“ („pellets“), zdroj DOC a NH_4^+
- spásání biofilmů - zvyšování mikrobiální aktivity
- rozmělnění potravy – rozklad a mineralizace „pohřbené“ POM, zpřístupnění OM dalším detritovorům a bakteriím
- biologické interakce – predace a kompetice, „top down“ kontrola meiofauny většími bezobratlými
- účast na výměně energie mezi HZ a povrchovým tokem – migrace temporární i permanentní fauny, vyplavení během povodní poskytuje potravu povrchovým predátorům
- emergence hmyzu – přenos energie do terestrického systému

Stream order

- **Horton** (1945), **Strahler** (1952, 1964)
- hierarchically nested system of streams and drainage basins (watershed, catchment)

TABLE 1.1 Number and lengths of river channels of various sizes in the United States (excluding tributaries of smaller order). (From Leopold et al. 1964.)

Order	Number	Average length (km)	Total length (km)	Mean drainage area (km ²)
1	1,570,000	1.6	2,510,000	2.6
2	350,000	3.7	1,300,000	12.2
3	80,000	8.8	670,000	67
4	18,000	19	350,000	282
5	4,200	45	190,000	1,340
6	950	102	98,000	6,370
7	200	235	48,000	30,300
8	41	540	22,999	144,000
9	8	1,240	9,900	684,000
10	1	2,880	2,880	3,240,000

approximately 5,200,000 total river kilometers

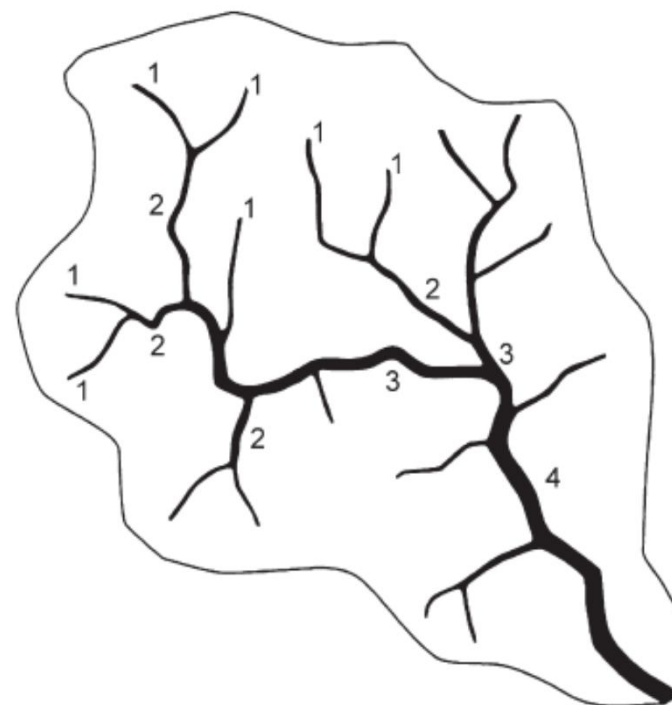
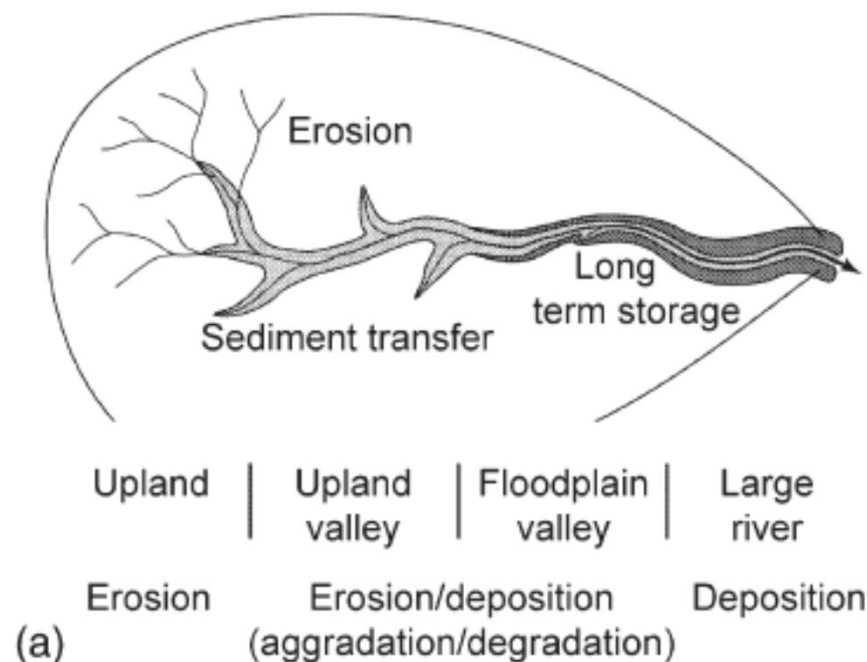


FIGURE 1.2 A drainage network illustrating stream channel order within a fourth-order catchment. The terminus may be a lake or the junction with a larger river. Intermittent streams occur upstream of the first-order tributaries, and often extend nearly to the catchment divide.

Longitudinal patterns

- **headwaters** – steep gradient, deep V-shaped valleys, rapids, waterfalls, zone of erosion
- **mid-elevation streams** – broader valleys, gentler slopes, tributaries, meandering, sediment transfer
- **lower elevation streams** – broad, flat valleys, meandering, multiple channels, sediment deposition

FIGURE 3.13 A drainage basin, illustrating some of the principal longitudinal trends in stream channels. (a) Three principal longitudinal zones: an upland zone where the drainage forms and from which sediments are exported; a middle, transitional zone where erosion and deposition of sediments may be approximately in balance; and a lower floodplain where sediments may accumulate.



Spatial scale

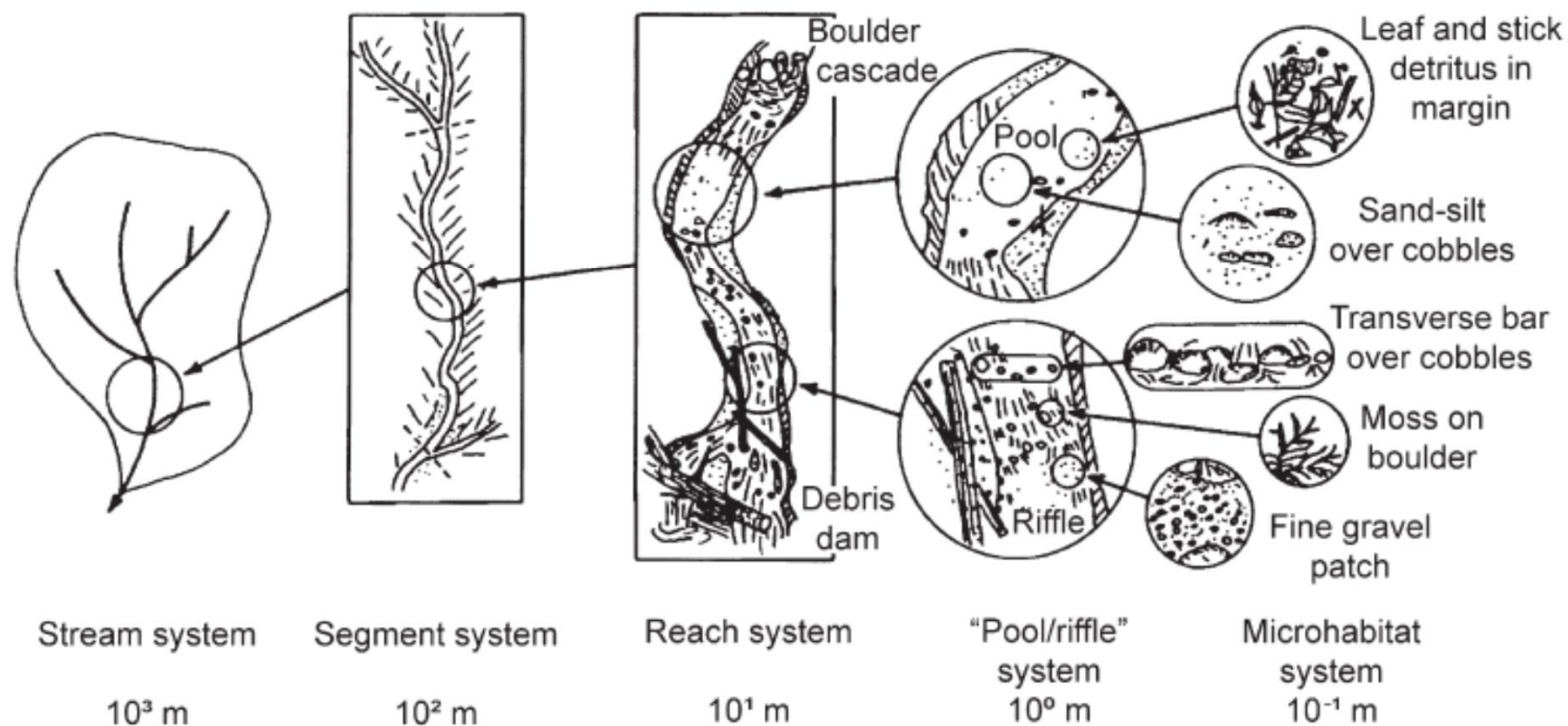


FIGURE 1.3 The hierarchical organization of a stream system illustrating how smaller units are repeating elements nested within larger units. Upper hierarchical units exert considerable influence over lower hierarchical units, but not vice versa. (Reproduced from Frissell et al. 1986.)