

Změny sladkovodních ekosystémů v prostoru a čase

Z8025 (učebna Z2)

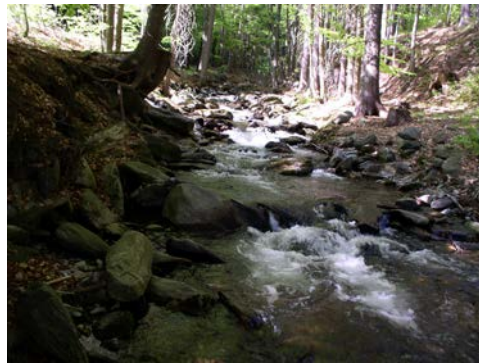
4. Laterální a vertikální interakce vodních toků s okolním prostředím



GEOGRAFICKÝ ÚSTAV
PŘÍRODOVĚDECKÁ FAKULTA MU

Mgr. Karel Brabec, Ph.D.

brabec@sci.muni.cz



SYLABUS

1. Úvod – teoretické koncepty
2. Prostorové škály říční krajiny
3. Změny vodních toků v podélném profilu
- 4. Laterální a vertikální interakce vodních toků s okolním prostředím**
5. Stojaté vody – vztahy k povodí, procesy ve vazbě na prostorové členění
6. Dlouhodobé trendy ve vývoji vodních ekosystémů
7. Sezonní dynamika faktorů prostředí a biologických společenstev
8. Teplotní režim povrchových vod
9. Ekologické aspekty průtokového režimu a hydraulických podmínek
10. Antropogenní modifikace vodních ekosystémů (se zřetelem na časoprostorové aspekty)
11. Potenciální dopady změn klimatu ve sladkovodních ekosystémech
12. Časo-prostorové aspekty adaptačních opatření a revitalizací degradovaných ekosystémů
13. Případové studie

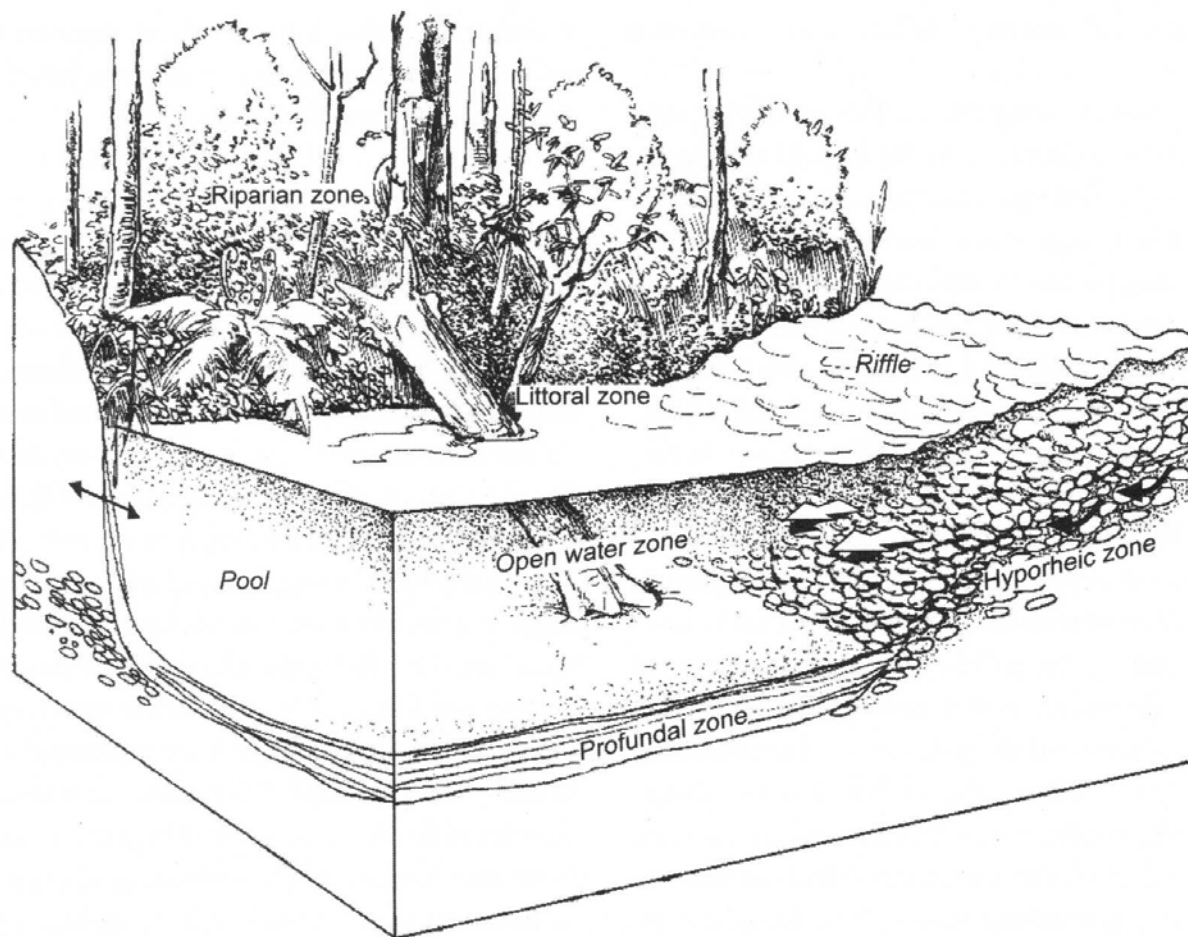


FIGURE 6.1. Rivers are often subdivided into pools (slow to zero flow) and riffles (faster flow, turbulent), and within these are habitats such as open water and profundal and littoral zones. Below, where water exchanges, is the hyporheic zone and laterally, the river interacts with bankside vegetation in the riparian zone.

- Thorp et al. (2006)
- hydromorfologicky definované plošky utvářené geomorfologickými charakteristikami povodí a průtokovým režimem
- propojení geomorfologie, hydrologie a ekologie/biologie
- umožňuje hodnotit vztahy struktur a funkcí ekosystému na různých prostorových a časových škálách

KONEKTIVITA ŘÍČNÍCH SYSTÉMŮ

- dynamika metapopulací a kontinuita krajinných struktur
- hydrologická konektivita
- pohyb látek a organismů, přenos energie

Stream-Floodplain-Riparian System

Riparian buffer function:

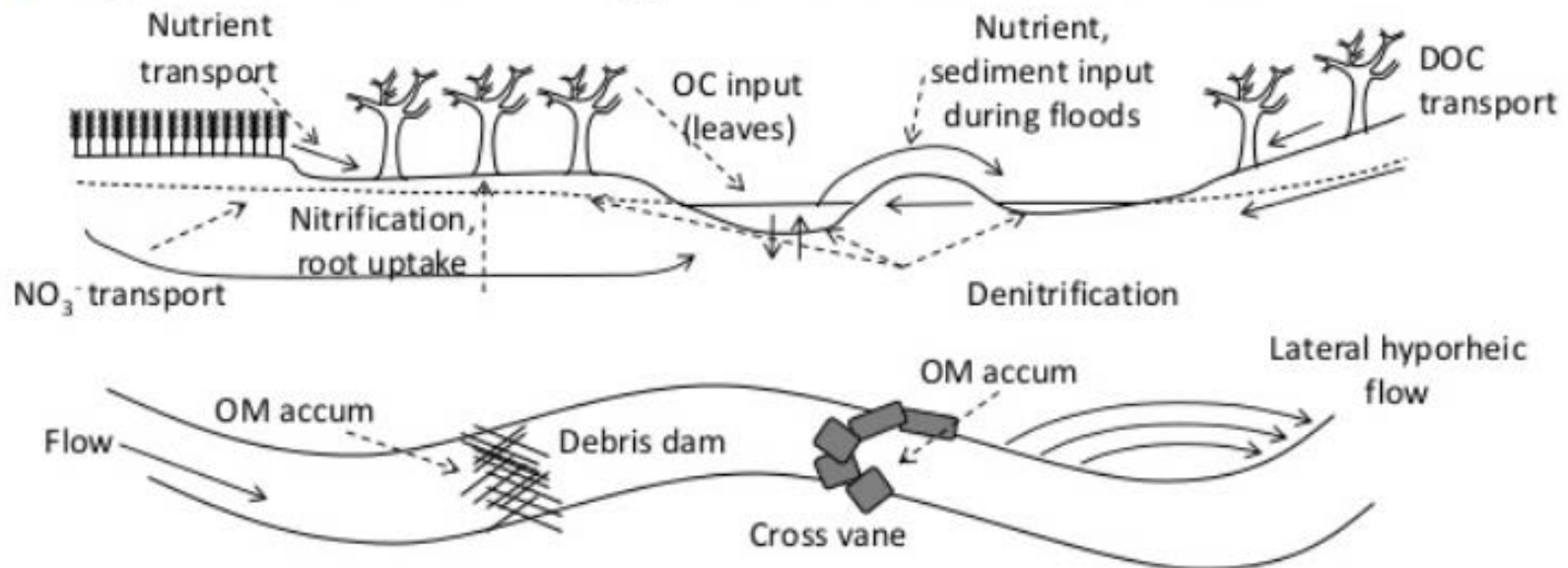
- Transform and remove nutrients from adjacent uplands

Floodplain function:

- Overbank flow + enhanced hyporheic exchange attenuates peak flow and retains/transforms nutrients & sediment

Stream function:

- Hyporheic flow & retention in deep pools retains and transforms nutrients



- flood pulse concept
- telescoping concept

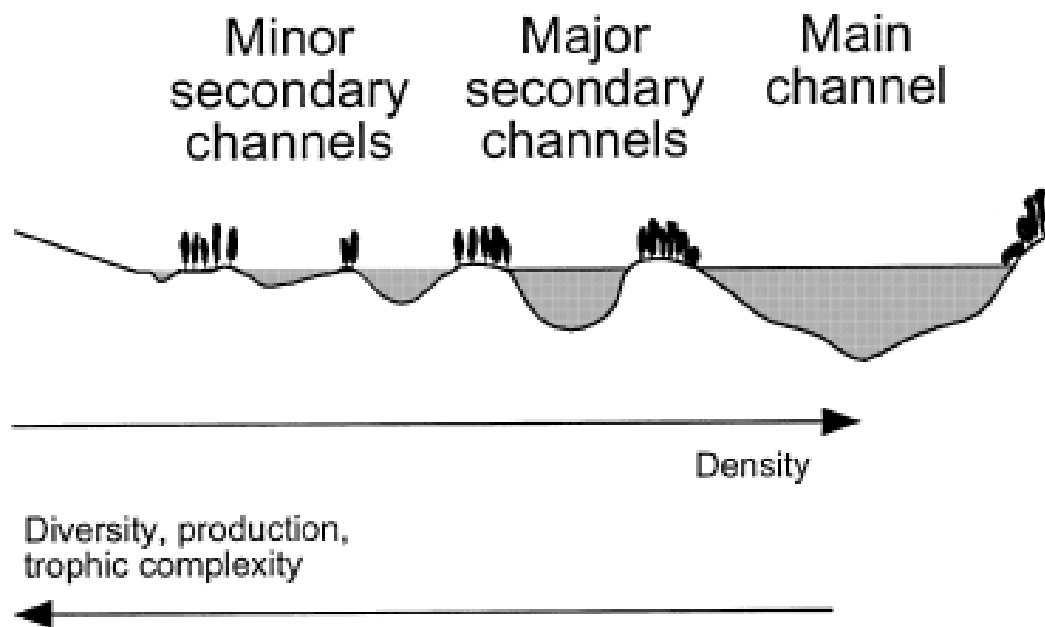


Fig. 1 Lateral gradients in community parameters and production of benthic invertebrates in a large flood plain river: the Middle Paraná. Modified from Marchese & Ezeurra de Drago (1992).

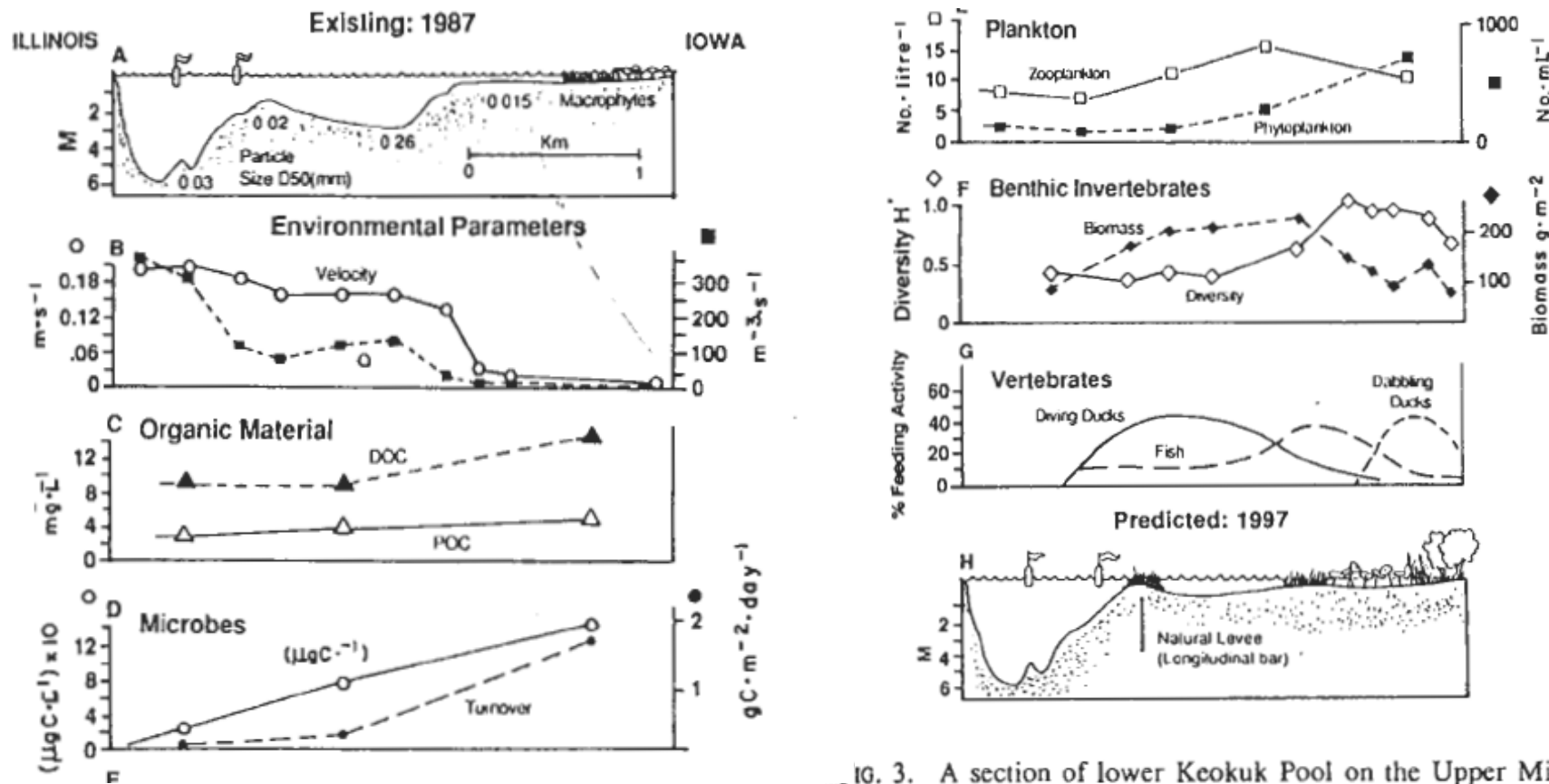


FIG. 3. A section of lower Keokuk Pool on the Upper Mississippi (A-G) with a projection of the stabilized system by the end of the century (H) (unpublished data from R. V. Anderson, R. E. Sparks, J. W. Grubaugh, K. S. Lubinski, and R. W. Gorden).

FLOOD PULSE CONCEPT (TEORIE PERIODICKÝCH ZÁPLAV)

- říční niva (floodplain) – je periodicky ovlivňována transportem vody a rozpuštěného/partikulovaného materiálu
- aquatic – terrestrial transitional zone (ATTZ)
- velké toky (poměrně dlouhé zaplavení ATTZ, rozsáhlé a časově omezené stojaté vody v říční nivě)
- malé toky (krátké záplavové pulsy v ATTZ, ve kterých se vyskytuje tekoucí voda pouze po krátká období)

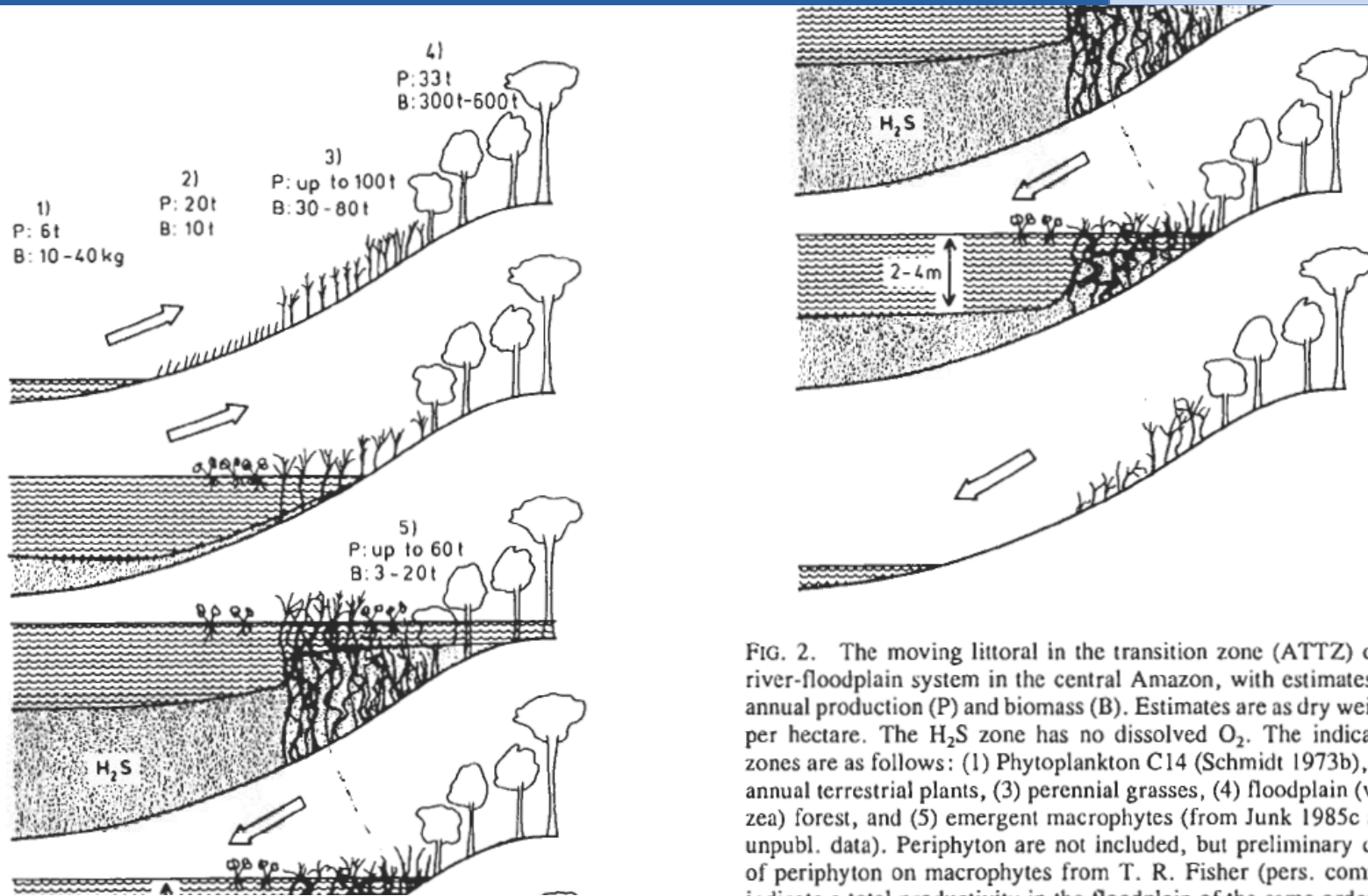


FIG. 2. The moving littoral in the transition zone (ATTZ) of a river-floodplain system in the central Amazon, with estimates of annual production (P) and biomass (B). Estimates are as dry weight per hectare. The H₂S zone has no dissolved O₂. The indicated zones are as follows: (1) Phytoplankton C14 (Schmidt 1973b), (2) annual terrestrial plants, (3) perennial grasses, (4) floodplain (várzea) forest, and (5) emergent macrophytes (from Junk 1985c and unpubl. data). Periphyton are not included, but preliminary data of periphyton on macrophytes from T. R. Fisher (pers. comm.) indicate a total productivity in the floodplain of the same order as phytoplankton (Bayley 1989).

Modely laterální dimenze a její dynamiky

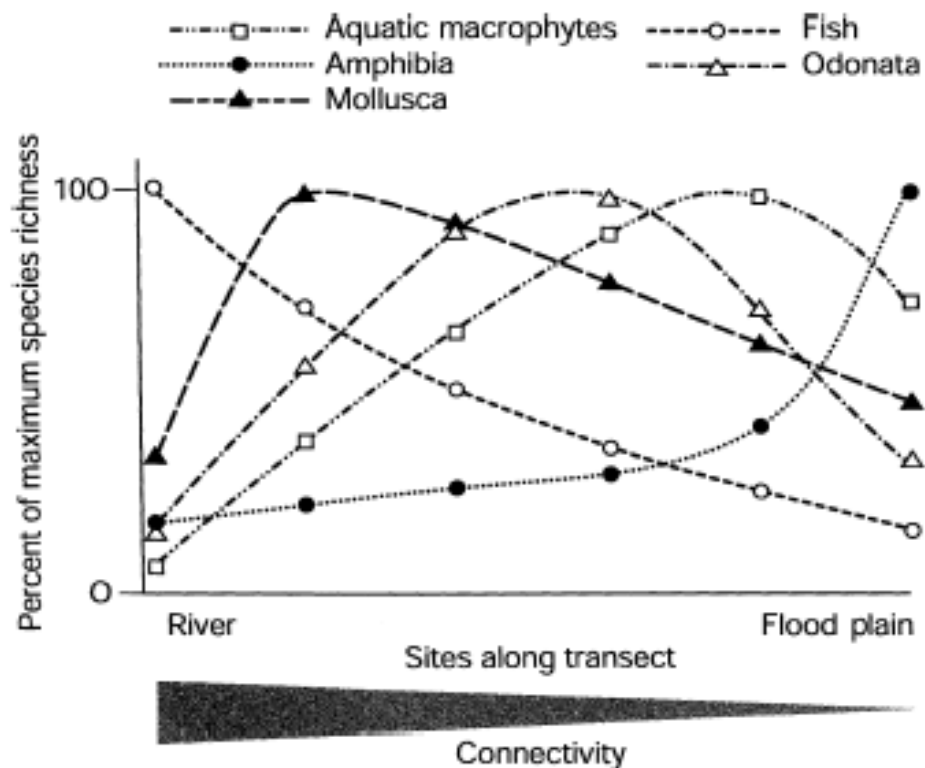


Fig. 10 Species richness peaks for different faunal and floral components (including native and non-native species) along a Danube-floodplain transect (idealized curves, modified from Tockner, Schiemer & Ward, 1998). The connectivity gradient extends from the main channel to the edge of the flood plain, a distance of about 1 km.

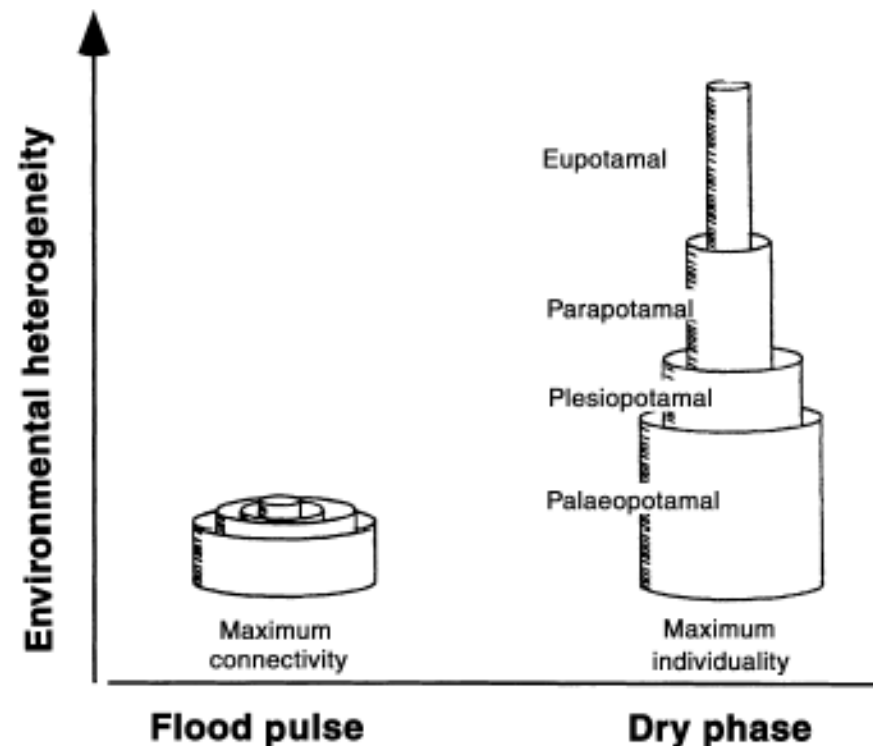
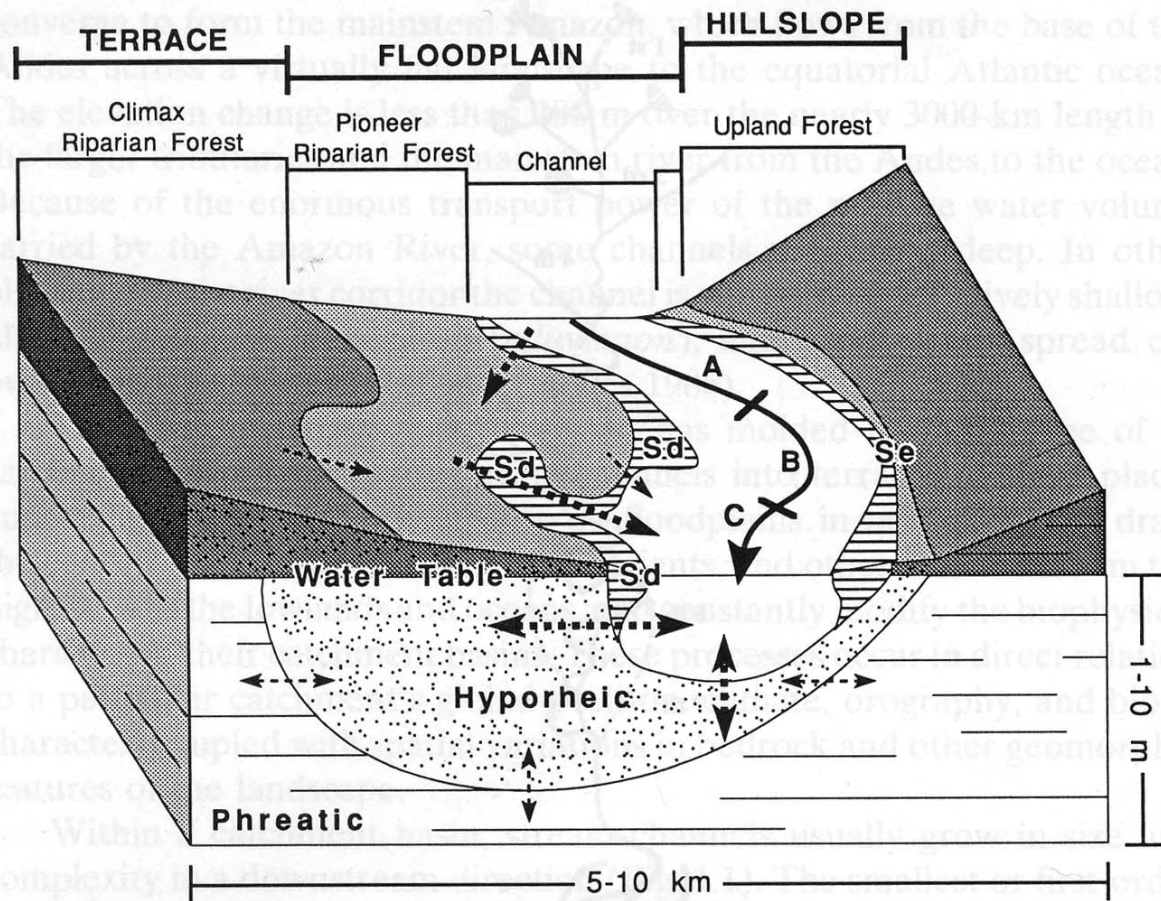


Fig. 3 A conceptual model depicting how floodplain water bodies, that exhibit essentially uniform conditions during the period of inundation, re-establish their individuality during the dry phase (based on a modification of the telescoping ecosystem model of Fisher *et al.*, 1998). Eupotamal refers to the main channel or side channels with both upstream and downstream connections to the main channel; parapotamal refers to side channels with only downstream connections to the main channel; plesiopotamal refers to a former braided channel that is connected only during high flow; and palaeopotamal refers to



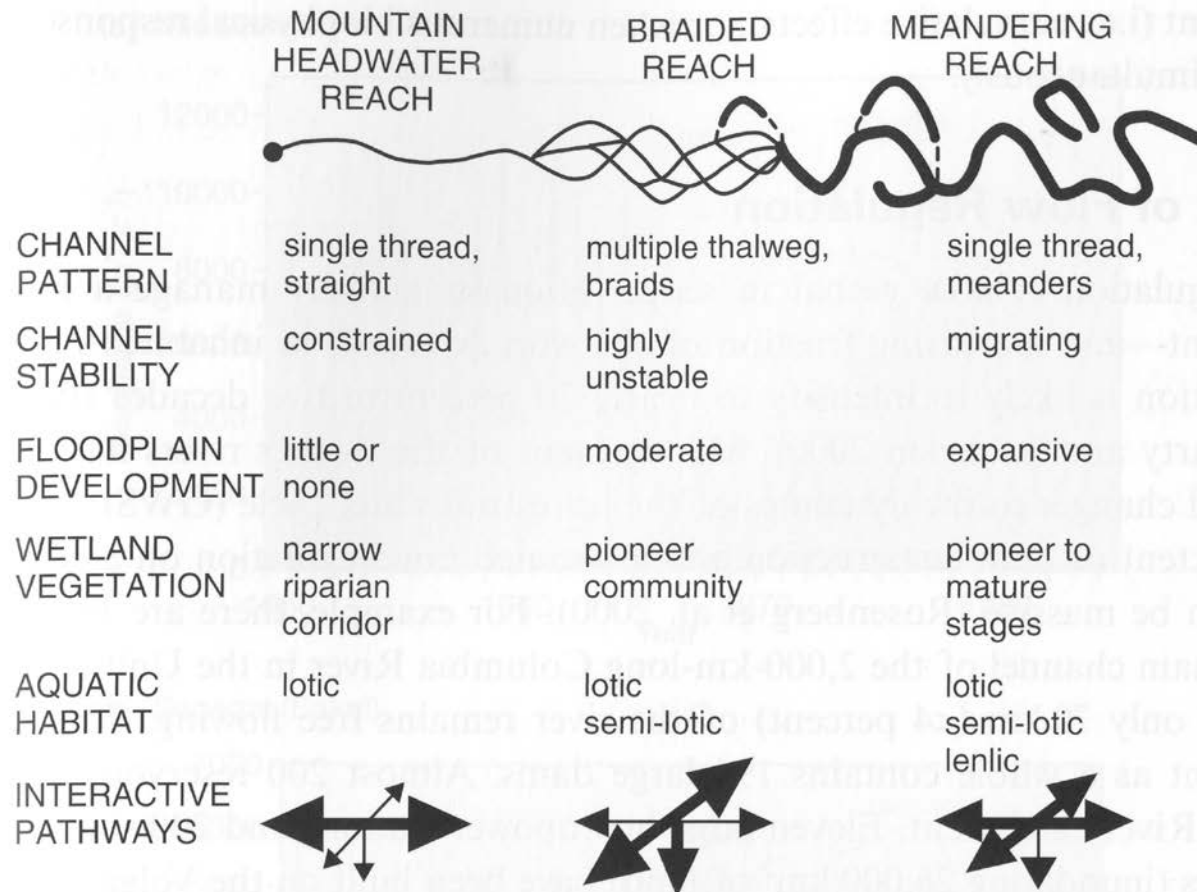
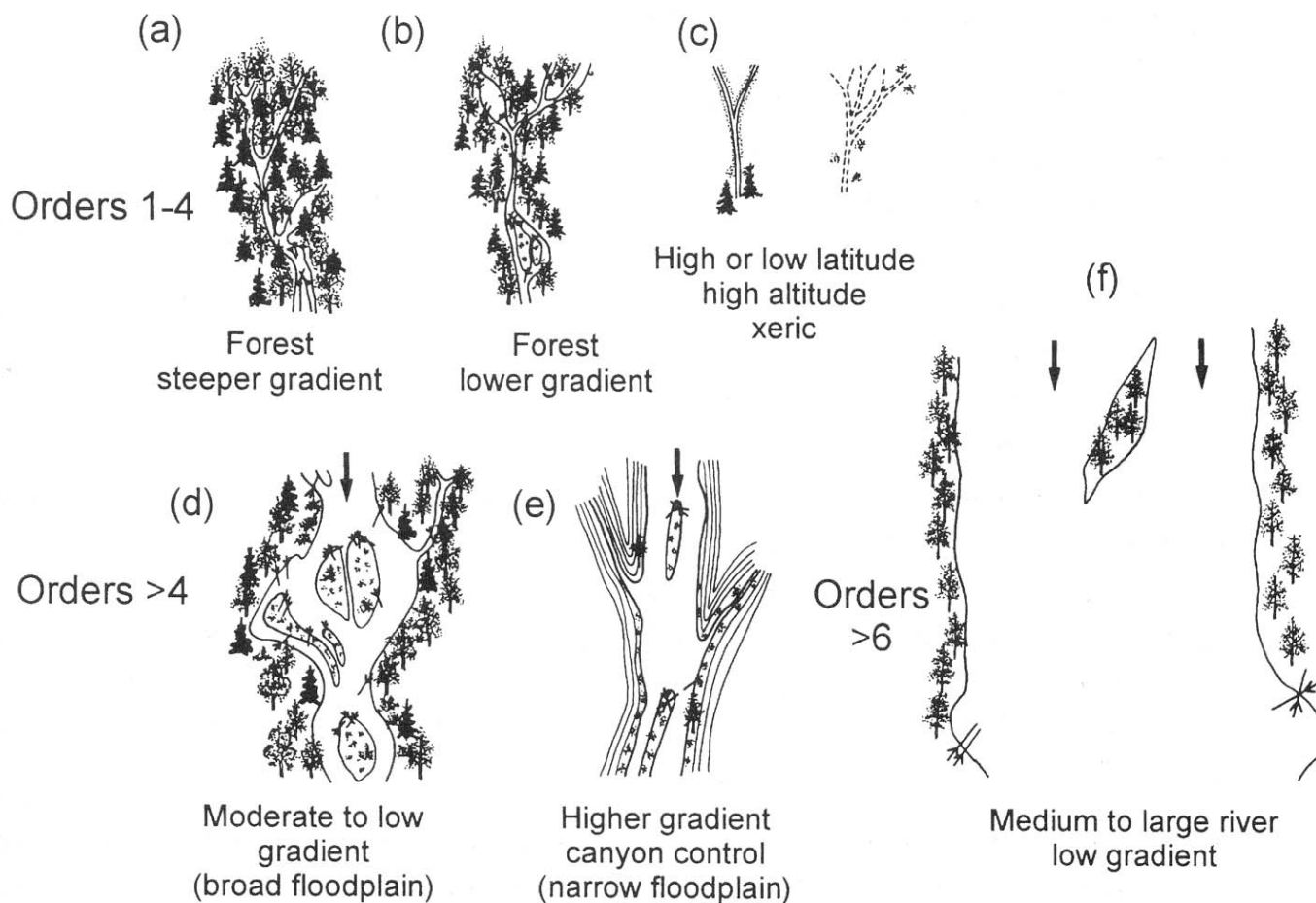


Figure 7.7 Three-reach model river-riparian system and some general features that distinguish reaches. Arrows indicate the relatively strengths of interactions along longitudinal (horizontal arrows), vertical (vertical arrows), and lateral (oblique arrows). From Ward and Stanford 1995.

Fig. 3.4 Comparison of riparian relationships of pristine streams and rivers of various order. Systems depicted in (a) and (b) show a high influence of riparian vegetation, in (d) intermediate influence, and in (c), (e) and (f) low influence. (Adapted from Cummins *et al.*, 1984.)



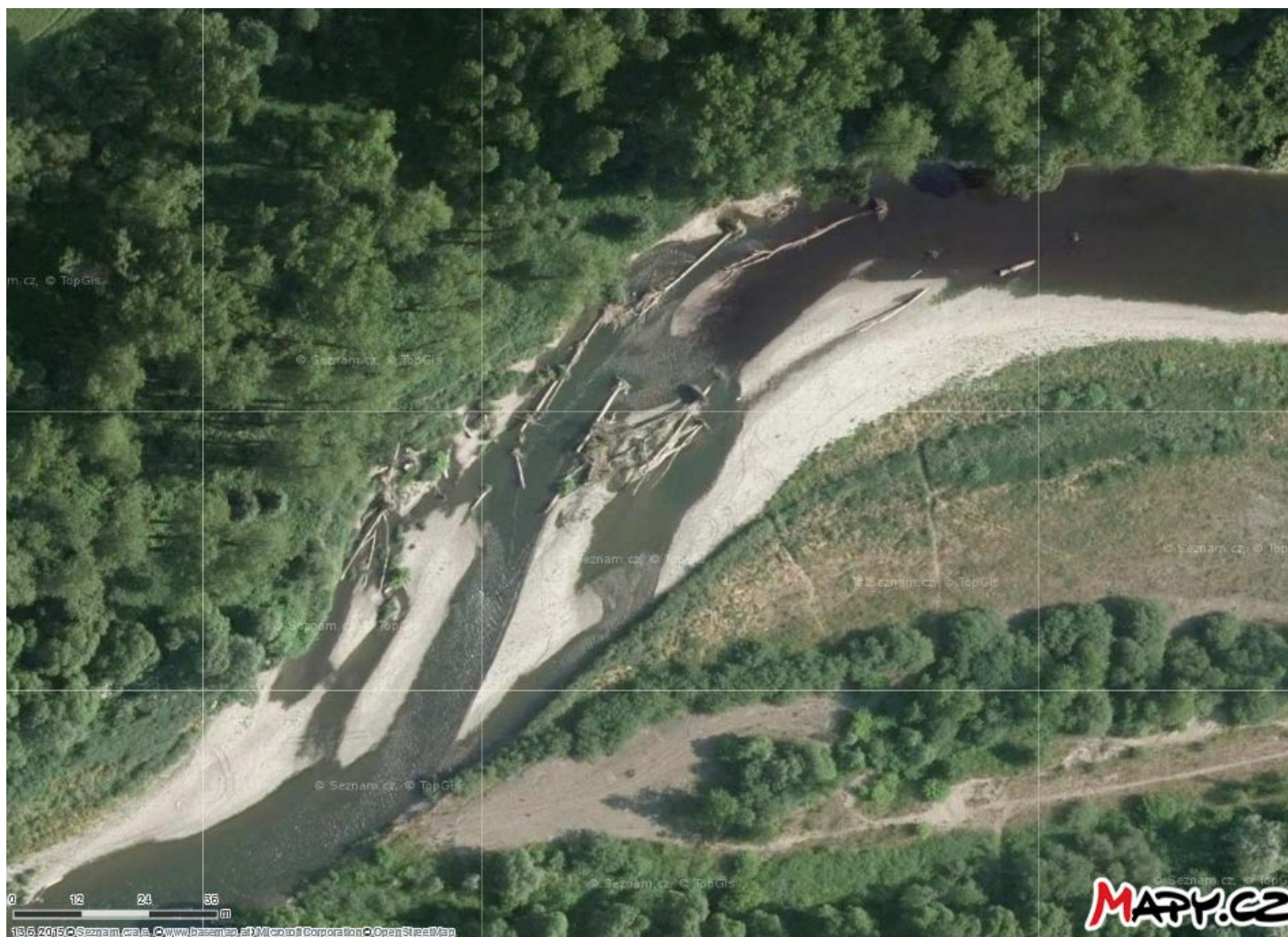
Biologické funkce pobřežní zóny

- *transport vody*
 - *toky živin*
 - *produkce organické hmoty*
 - *dynamika dekompozice*
 - *informační toky*
 - *mikro-klimatické podmínky*
- *plošky se liší vlastnostmi*
 - *hranice mezi ploškami ovlivňují toky*
 - *konektivita je zásadní charakteristika*
 - *organismy hrají důležitou roli*
 - *důležitost škály*

- *dřevní hmota v korytech toků ovlivňuje lokální korytotvorné procesy po milióny let*
- *odumřelé dřevo je důležitým prvkem přirozených toků v mírném klimatickém pásu*
- *běžně aplikovanou praxí správců toků je odstraňování dřeva z koryta, zatímco někteří vědci podporují navrácení dřevní hmoty do toků v rámci revitalizačních opatření*
- *souhrnný vliv na tvar koryta a jeho dynamiku je pozorovatelný v rámci různých prostorových a časových měřítek*
- *hydraulika, transport sedimentů, eroze břehů, vznik tůní, iniciování sedimentace a vzniku štěrkových lavic*
- *velké klády mohou spustit procesy na úrovni morfologie úseku toku i interakce řeky a jejího záplavového území*

- *v dlouhodobé perspektivě mohou toky bohaté na dřevní hmotu zadržet více sedimentů, mít nižší míru jejich transportu a větší spád než toky chudé na dřevní hmotu*
- *největší geomorfologický význam mají velké stabilní klády, které katalyzují směřování a ukládání drobnější dřevní hmoty a sedimentů. Relativní velikost klády vůči rozměru koryta je poměrně spolehlivým ukazatelem potenciální stability dřevní hmoty v korytě*
- *toky s vysokým přísunem velké a potenciálně stabilní dřevní hmoty mohou vykazovat značnou vertikální variabilitu topografie dna nezávisle na vnějších faktorech (kolísání klimatu, časové výkyvy přísunu sedimentů nebo tektonické aktivity)*
- *v některých typech toků může být vliv režimu dřevní hmoty srovnatelný s vlivem sedimentačního nebo průtokového režimu*

Bečva - Černotín



Multiple-scale effects of stream corridors on biological and chemical characteristics of small streams

Karel Brabec¹, Renata Chloupkova², Michaela Kucerova², Ondrej Hajek³

1 Research Centre for Toxic Compounds in the Environment, Faculty of Science, Masaryk University, Kamenice 753/5, 625 00 Brno, Czech Republic, brabec@sci.muni.cz

2 Institute of Biostatistics and Analyses, Faculty of Science, Masaryk University

3 Department of Zoology & Ecology, Faculty of Science, Masaryk University



REFORM



Motivations

- lack of explanatory variables at **scales** between stream stretch and catchment
- searching for method based on **remote sensing data**

Study aims

- to **classify stream corridors** on the basis of riparian vegetation types and land use adjacent to stream channel
- to **test relationships** among chemical/biological parameters and stream corridor characteristics

STREAM CORRIDORS

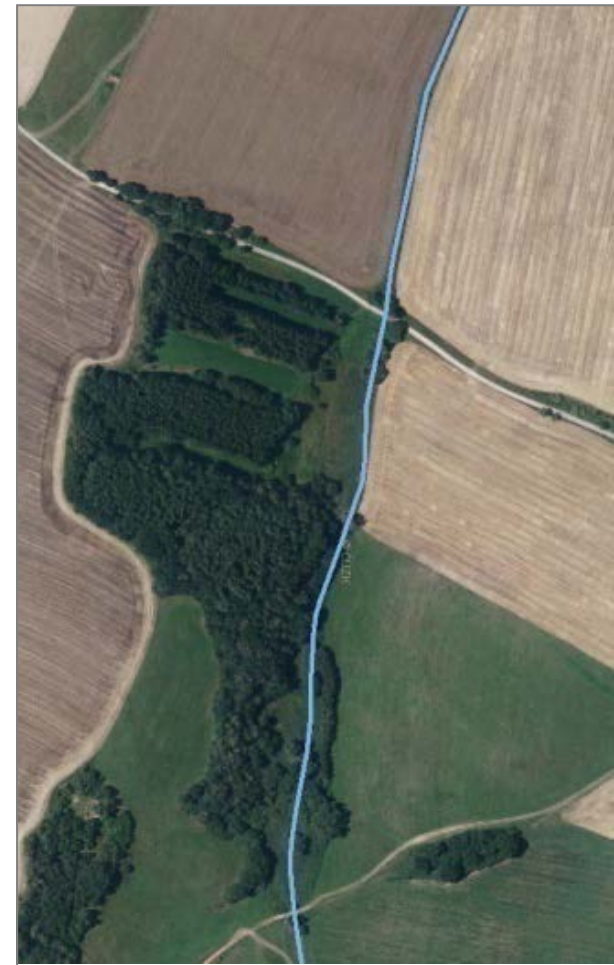


- **ecotone** – transition between land and stream
- **riparian vegetation** – shading, buffer zone, organic material
- target of stream **regulations** and **restoration** measures
- place where land-originated **pressures** interact with dynamics of fluvial ecosystems

Analyses of aerial photos (RIP method)

Development of scoring systems for riparian/bank zone and river floodplain (type of **riparian vegetation and land use in floodplain**)

- combination of floodplain LU and riparian vegetation characteristics representing potential risks and barriers
- e.g. arable land adjacent to stream may reflect in elevated fine sediment transport to fluvial systems; character of riparian vegetation may regulate resulting sediment input to streams



spatial definition of stream corridors

lateral

CORINE

- 200 m-wide buffer zone along stream network

RIP method

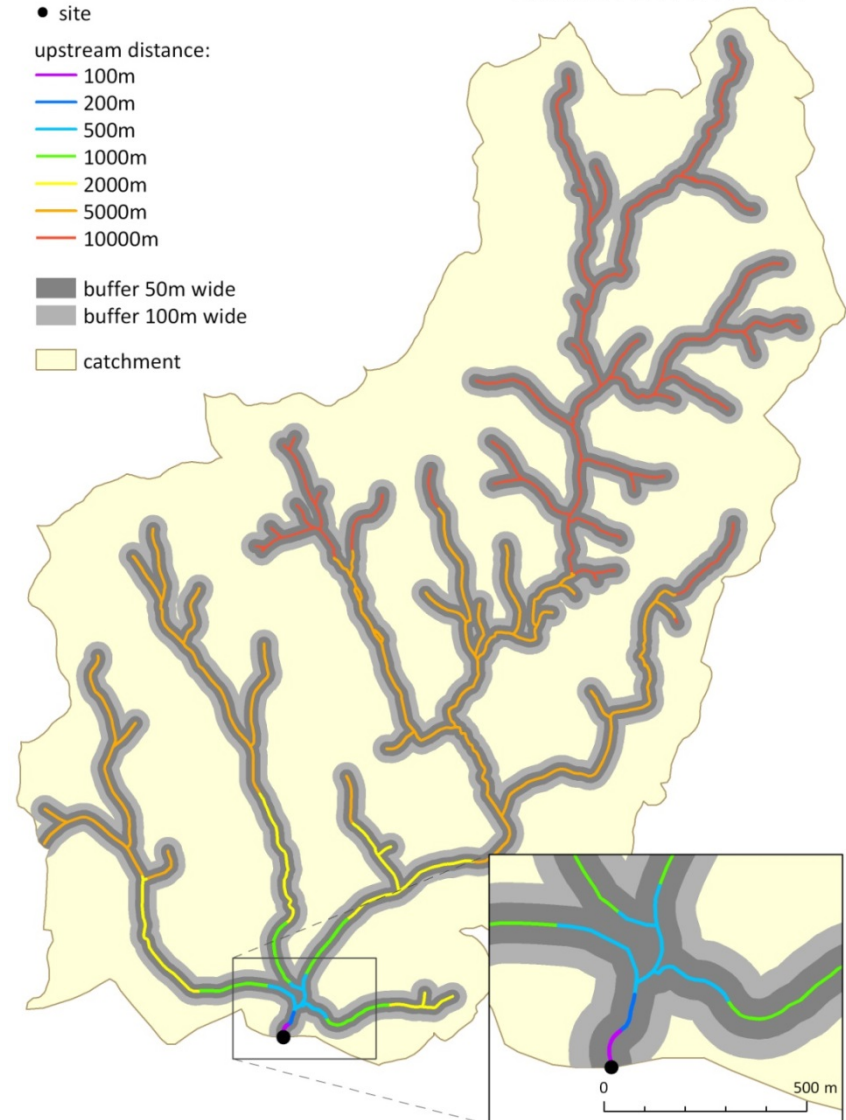
- bank zone (up to 5 m from banks)
- floodplain zone (up to 10 m from banks)
- minimum length of classified stream segment = 20 m

longitudinal

Legend

- site
- upstream distance:
 - 100m
 - 200m
 - 500m
 - 1000m
 - 2000m
 - 5000m
 - 10000m
- buffer 50m wide
- buffer 100m wide
- catchment

0 500 1000 1500 2000 m



RIP classification

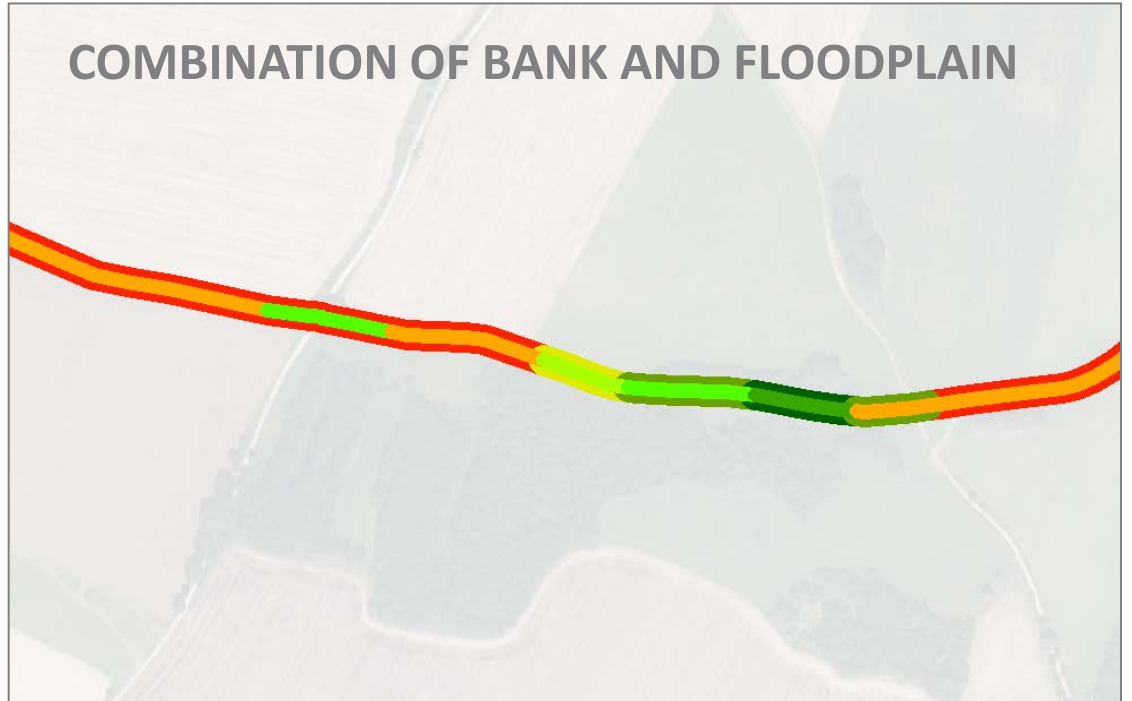
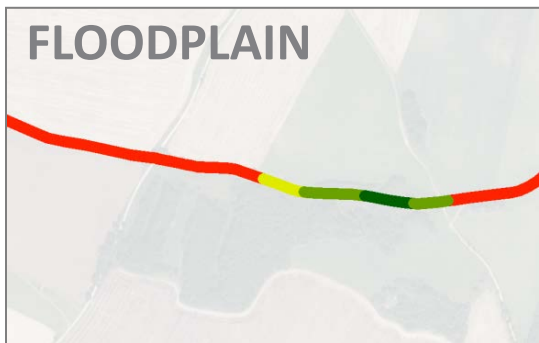
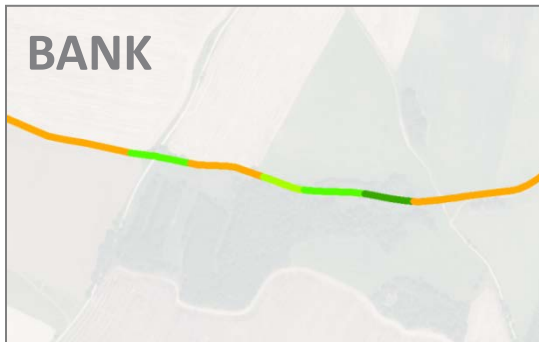
FLOODPLAIN

- cropland
- urban/unvegetated
- meadow
- forest

BANK

- bare
- grass
- woody scattered
- woody continuous





RIP scoring system

FLOODPLAIN SCORE

FLOODPLAIN	F_code	F_score
cropland both	C2	1
cropland x urban	CU	2
urban both	U2	3
cropland x meadow	CM	4
meadow x urban	MU	5
forest x cropland	FC	6
forest x urban	FU	7
meadow both	M2	8
forest x meadow	FM	9
forest both	F2	10

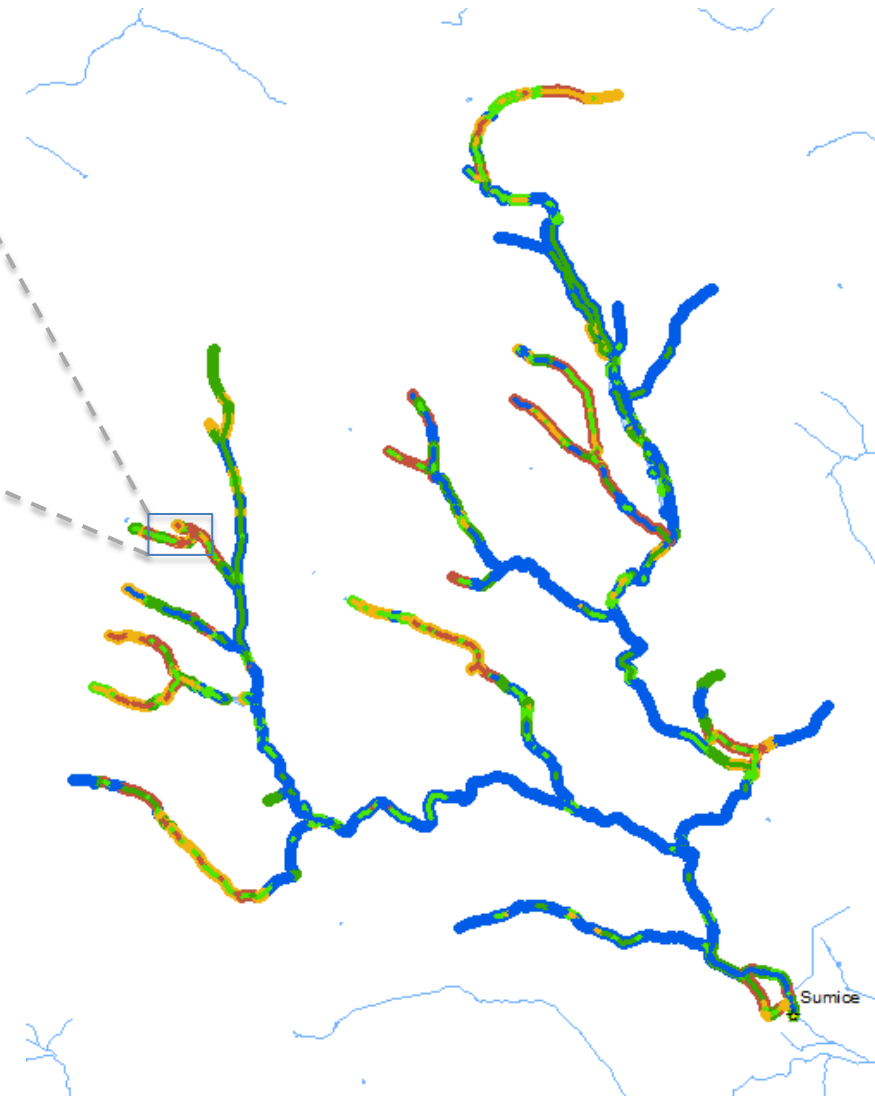
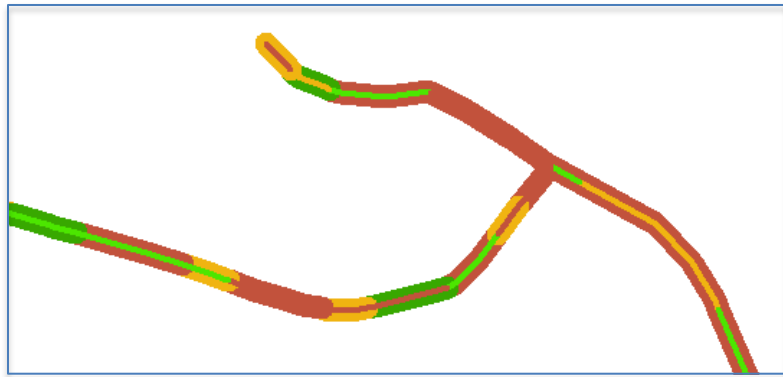
BANK SCORE

BANK	B_code	B_score
bare both	B2	1
bare x grass	BG	2
grass both	G2	3
woody continuous x bare	WCB	4
woody continuous x grass	WCG	5
woody scattered both	WS	6
woody continuous both	WC2	7

$$\text{BF SCORE} = (1/\text{Fscore})/\text{Bscore}$$

RIP scoring system

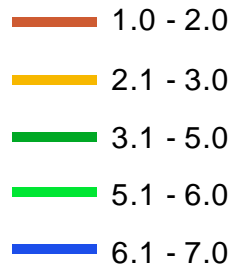
visualization and scale-dependent analyses



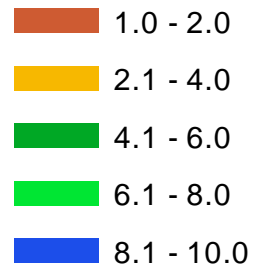
Legend

★ site

Bank score



Floodplain score

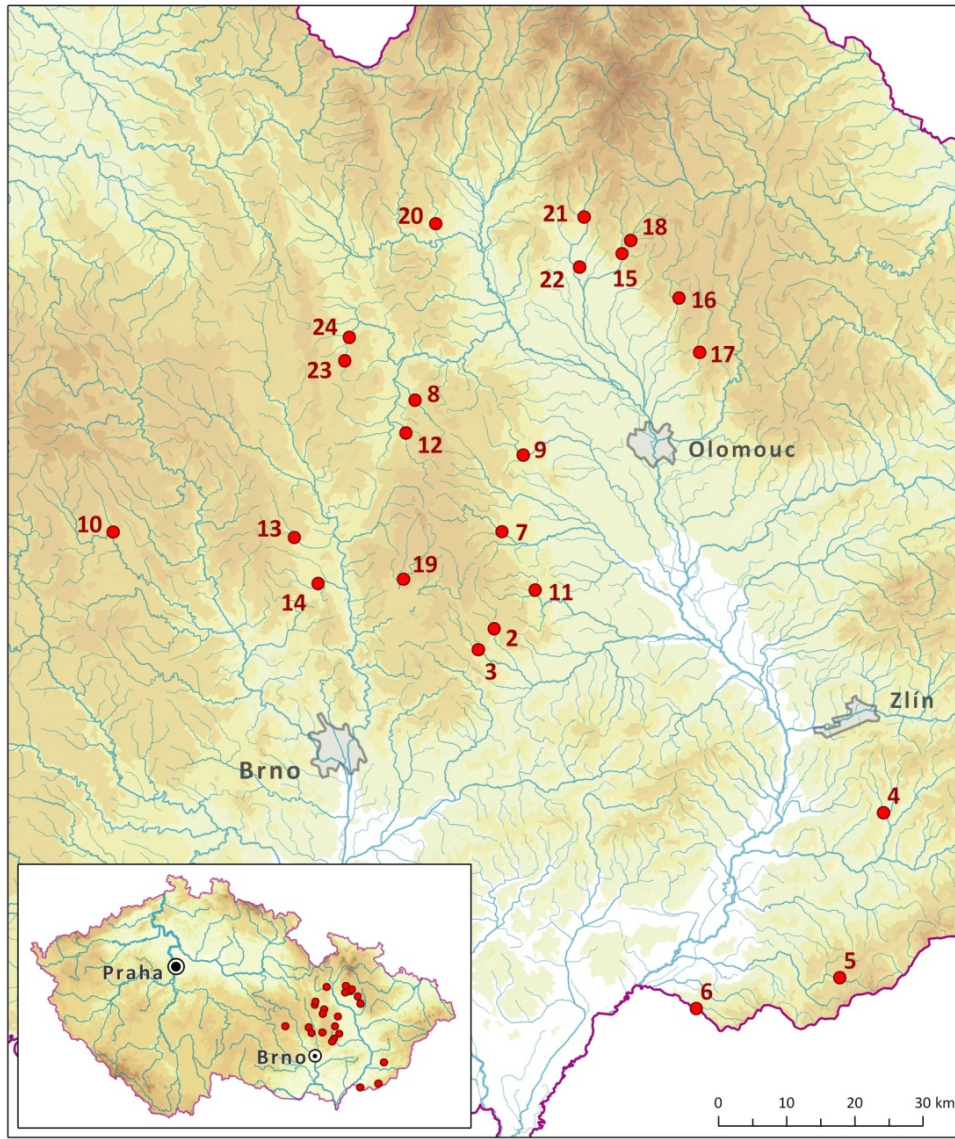


RIP scoring system

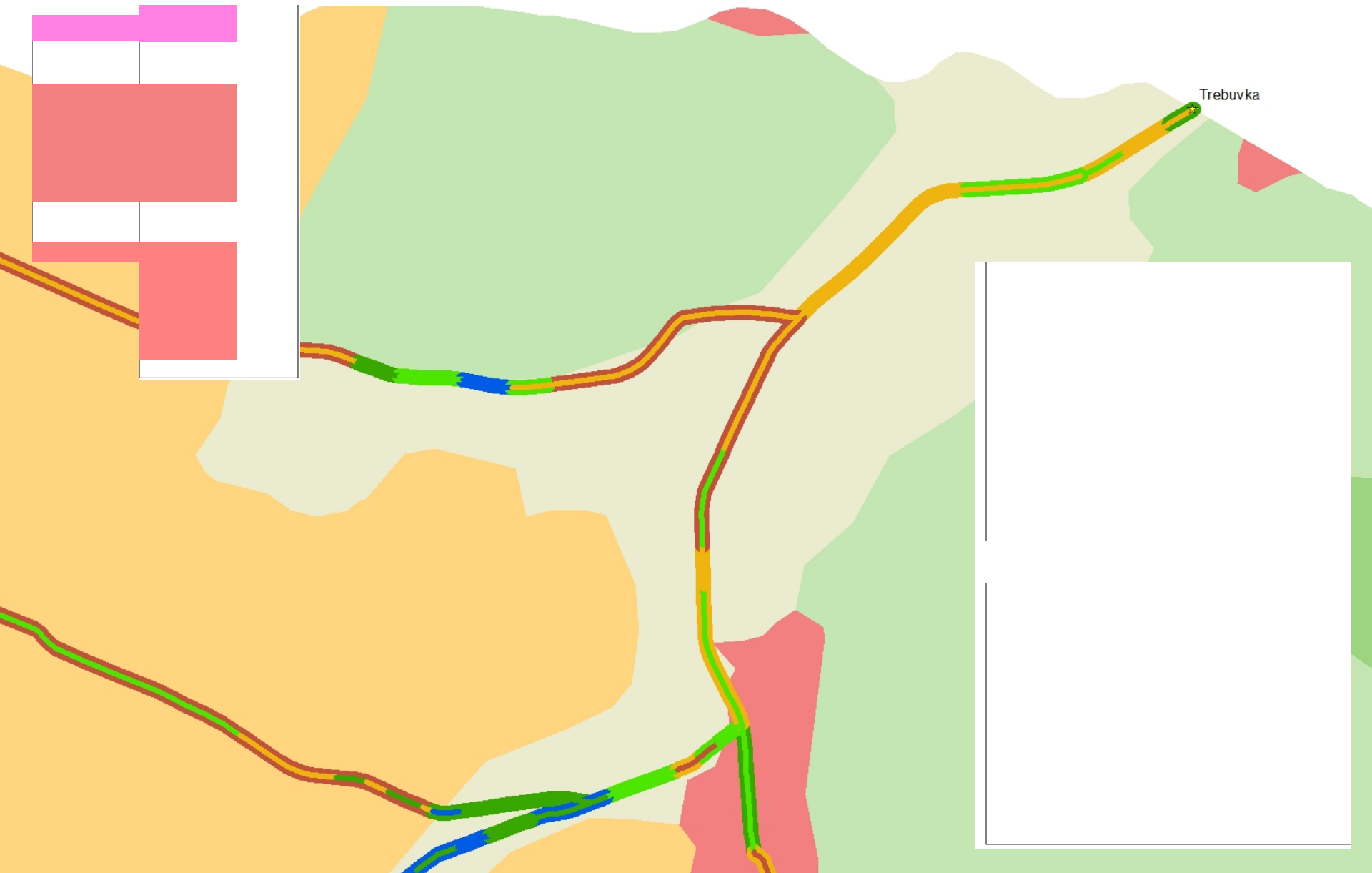


STUDY SITES

- 23 sites, catchment area 16-51 km²
- altitude 244-485 m a.s.l.

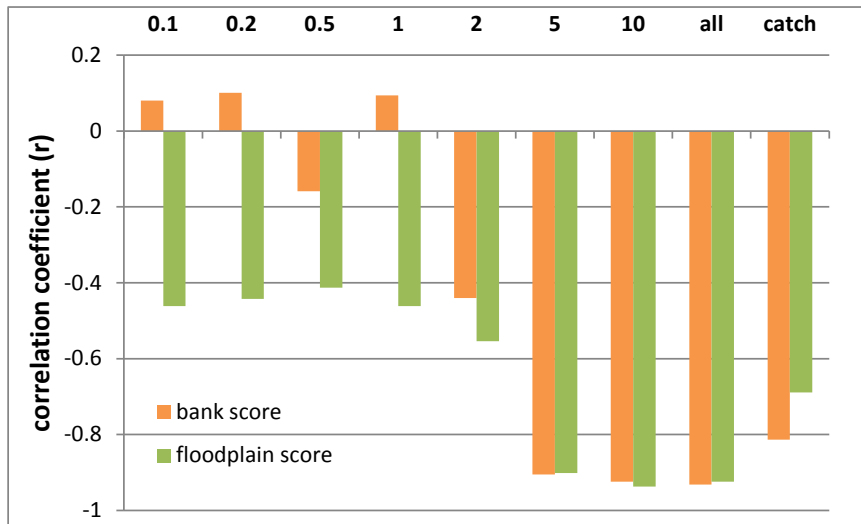


RIP scores vs. CORINE

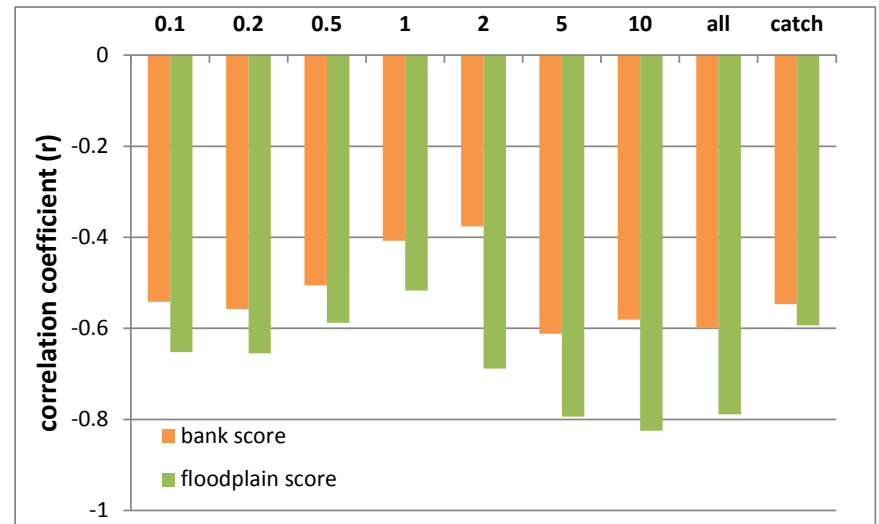


RIP scores vs. CORINE

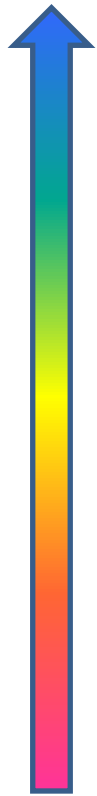
ARABLE LAND (Corine 211)



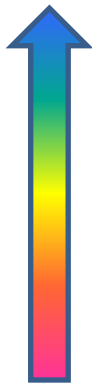
URBAN LAND (Corine 112)



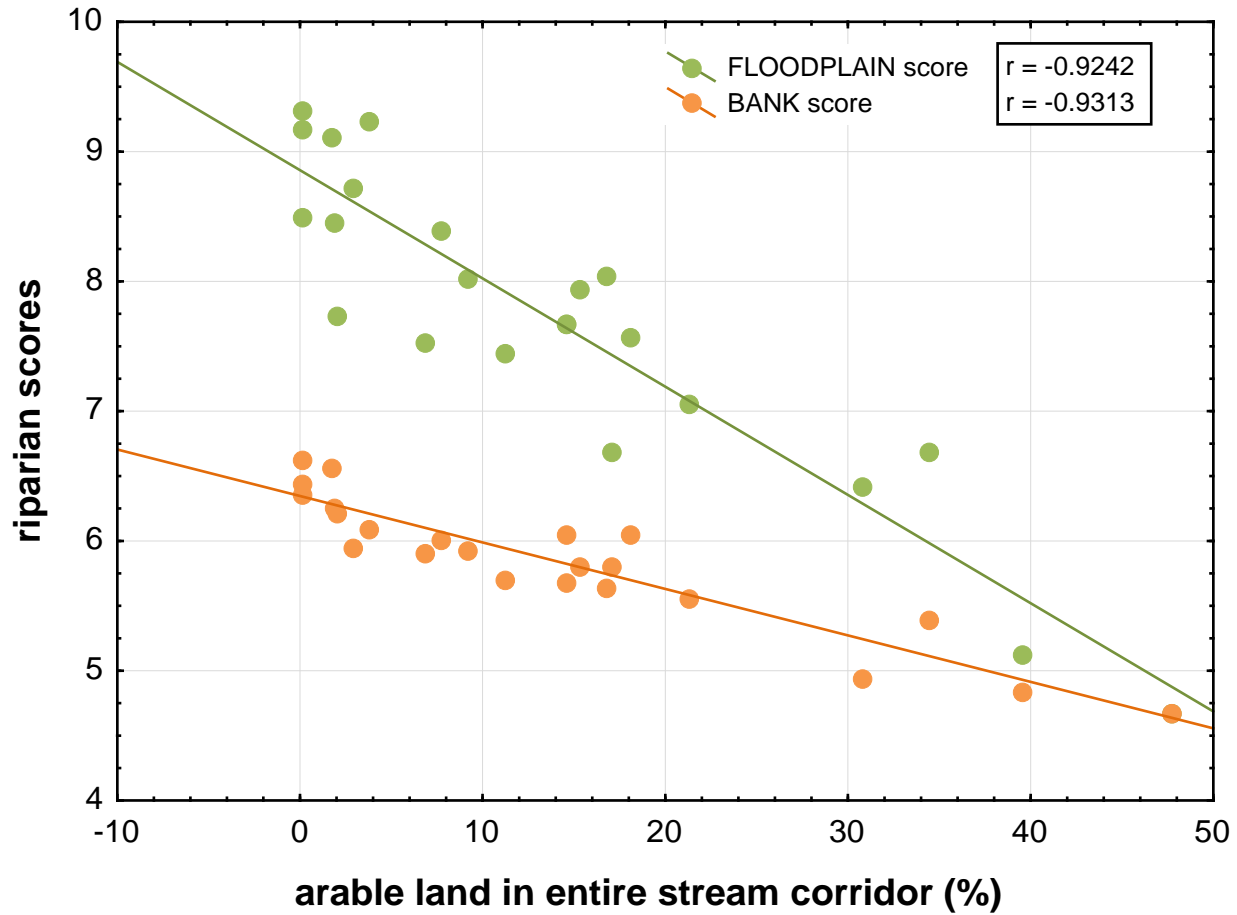
RIP scores vs. CORINE



F



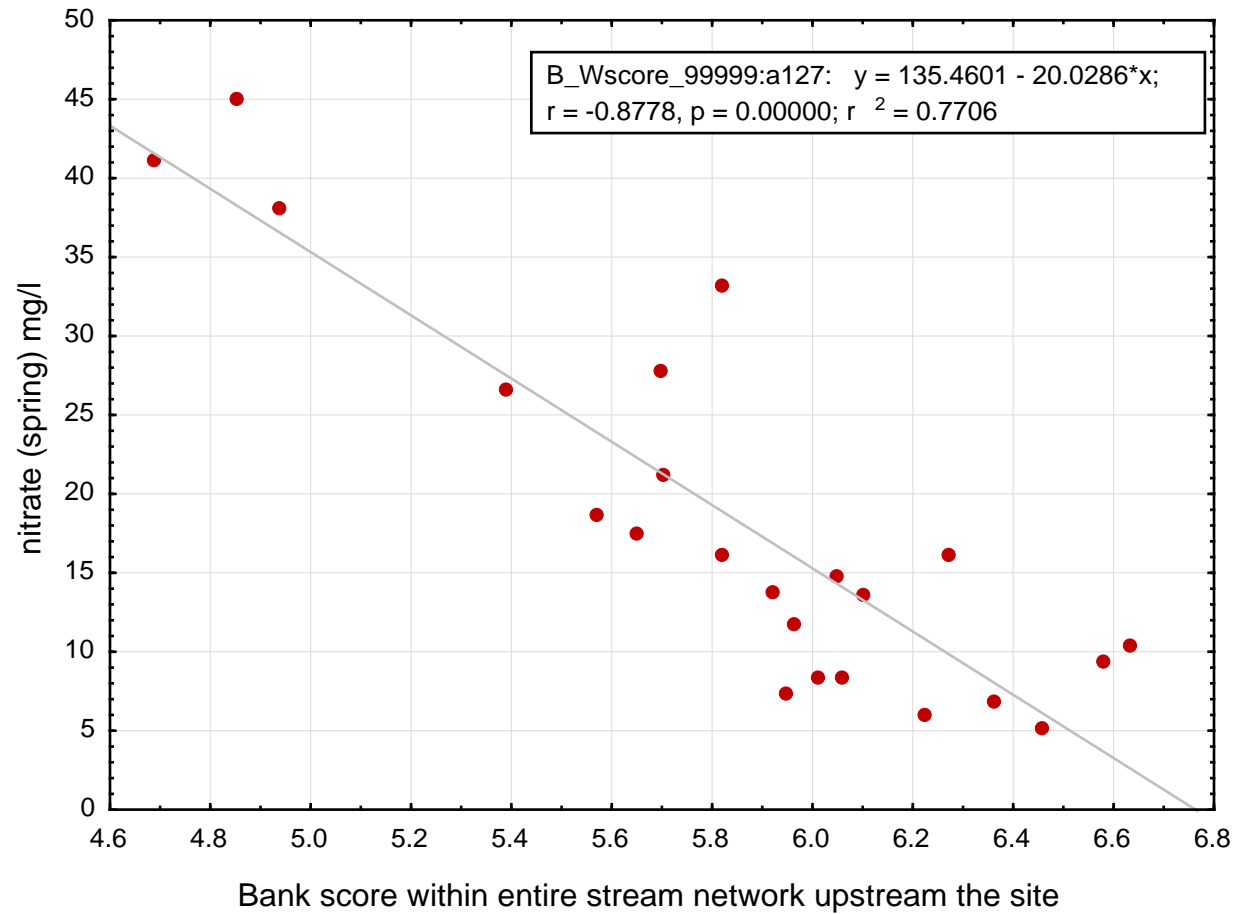
B



WATER CHEMISTRY

variable	score	corridor extent upstream (km)							
		0.1	0.2	0.5	1	2	5	10	all
chloride	Bank						-0.66	-0.77	-0.74
	Floodplain				-0.50	-0.47	-0.62	-0.72	-0.70
BOD5	Bank					-0.42	-0.66	-0.70	-0.65
	Floodplain				-0.49	-0.52	-0.62	-0.57	-0.53
amonium	Bank						-0.58	-0.50	-0.46
	Floodplain	-0.43	-0.46	-0.57	-0.54	-0.52	-0.67	-0.58	-0.52
nitrite	Bank					-0.49	-0.74	-0.71	-0.67
	Floodplain	-0.64	-0.63	-0.68	-0.75	-0.72	-0.78	-0.81	-0.77
nitrate	Bank						-0.57	-0.82	-0.83
	Floodplain						-0.50	-0.67	-0.71
ortho-phosphate	Bank						-0.51	-0.60	-0.60
	Floodplain			-0.48	-0.48	-0.46	-0.55	-0.77	-0.74
phosphate	Bank						-0.61	-0.69	-0.67
	Floodplain				-0.44	-0.49	-0.59	-0.68	-0.65

Bank score x nitrate concentration in water



MACROINVERTEBRATES vs. RIP scores

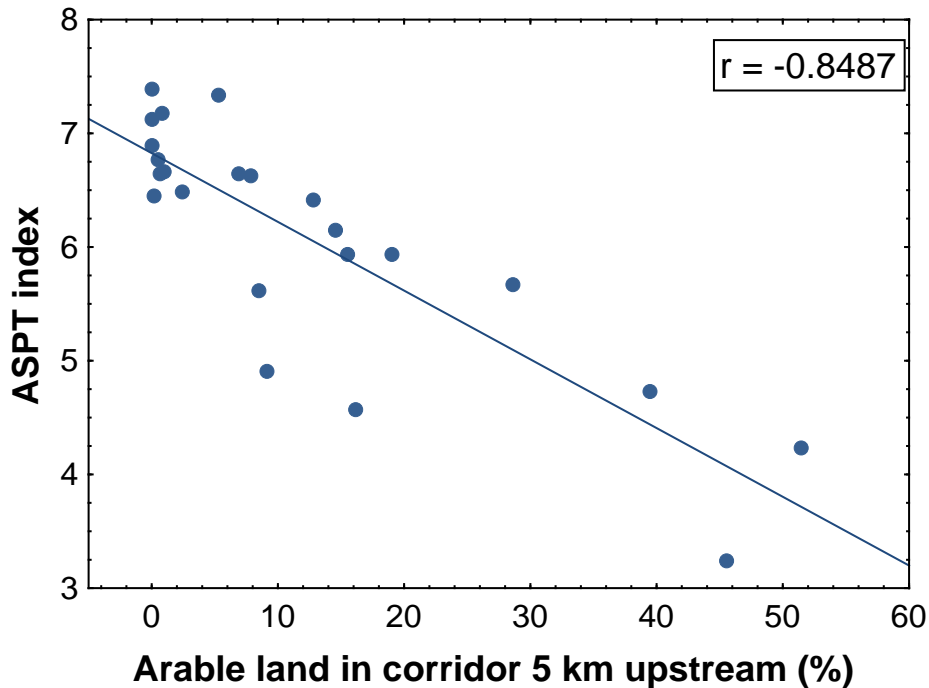
Spearman rank correlation (r_s , N=23)

variable	score	corridor extent upstream (km)							
		0.1	0.2	0.5	1	2	5	10	all
Saprobic index	Bank					-0.57	-0.70	-0.57	-0.52
	Floodplain	-0.53	-0.49	-0.55	-0.66	-0.74	-0.73	-0.62	-0.53
ASPT	Bank					0.59	0.78	0.67	0.61
	Floodplain	0.47	0.49	0.60	0.68	0.74	0.79	0.65	0.56
number of sensitive taxa	Bank	0.58	0.59	0.42	0.56	0.79	0.86	0.70	0.64
	Floodplain	0.65	0.65	0.68	0.77	0.86	0.86	0.69	0.59
Gathering collectors	Bank					-0.56	-0.73	-0.56	-0.49
	Floodplain	-0.57	-0.56	-0.60	-0.71	-0.76	-0.79	-0.58	-0.48
EPT-taxa (%)	Bank					0.52	0.64	0.48	0.43
	Floodplain			0.54	0.62	0.69	0.69	0.51	0.45
Oligochaeta (%)	Bank	-0.51	-0.54		-0.46	-0.59	-0.69	-0.43	
	Floodplain	-0.51	-0.54	-0.58	-0.65	-0.73	-0.71		
Chironomidae (%)	Bank					-0.42			
	Floodplain	-0.44	-0.44		-0.49	-0.47		-0.43	
number of EPT taxa	Bank	0.54	0.54		0.54	0.70	0.80	0.64	0.58
	Floodplain	0.66	0.63	0.64	0.76	0.84	0.78	0.56	0.47
number of Coleoptera taxa	Bank	0.48	0.48		0.46	0.69	0.77	0.74	0.73
	Floodplain	0.47	0.46	0.48	0.56	0.70	0.76	0.72	0.67
number of chironomid taxa	Bank	-0.47	-0.44			-0.52	-0.53	-0.43	
	Floodplain	-0.65	-0.70	-0.73	-0.76	-0.73	-0.59	-0.61	-0.53

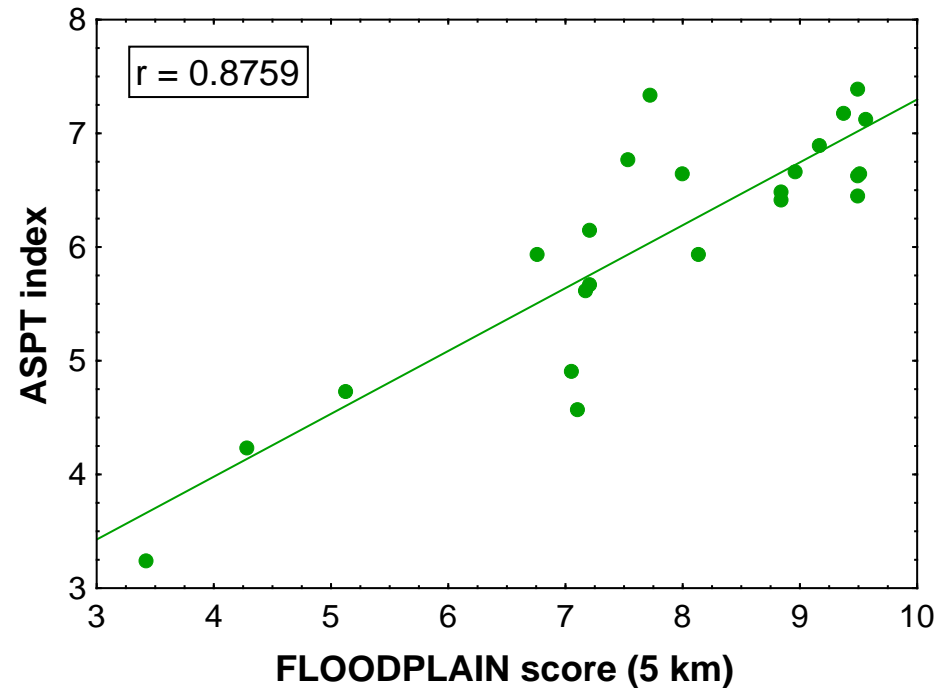
MACROINVERTEBRATES vs. RIP scores

ASPT

CORINE



Floodplain RIP-score



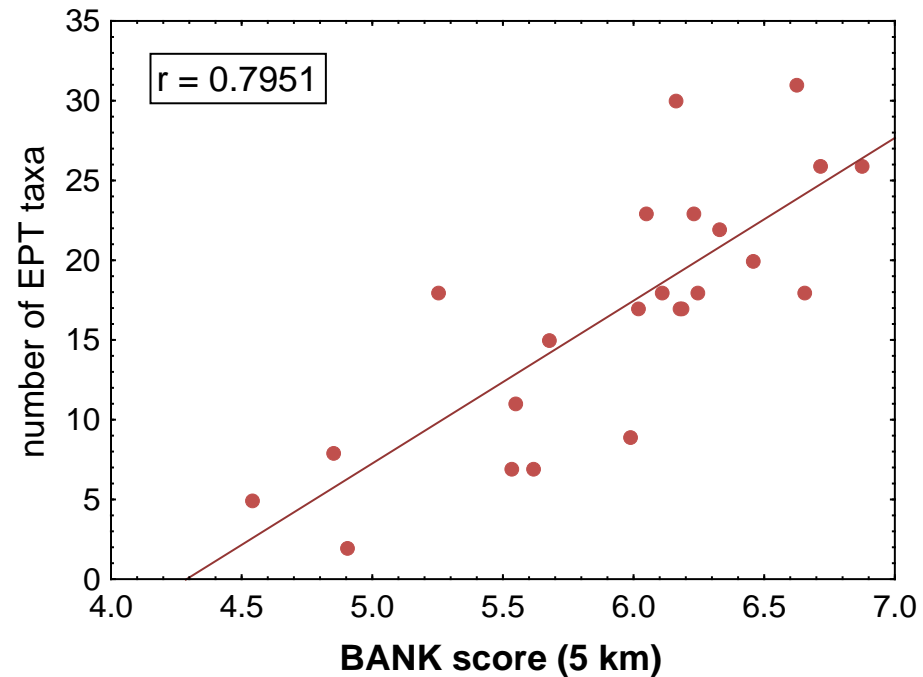
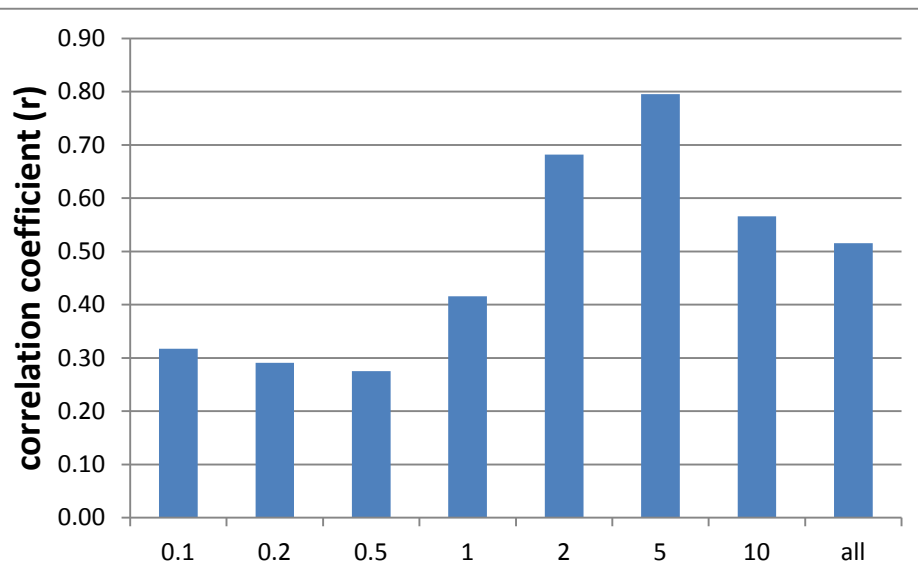
MACROINVERTEBRATES vs. RIP scores

EPT taxa richness

(similar pattern was found for Stone-dwelling taxa index – Braukmann)

EPT taxa richness and BANK score (5 km)

(r , $N=23$)



Conclusions

- **newly developed scoring system** of stream corridors based on aerial maps (RIP)
- **water chemistry** is predominantly linked to large scale characteristics of stream corridor (10 km or entire stream network buffer)
(F-score combines agriculture and urban pressures)
- most of studied **macroinvertebrate** parameters was related to corridor characteristics within 2 or 5 km upstream the site
- **combination** of both methods for corridors classification can result in efficient explanation of chemical and biological characteristics of fluvial ecosystems (e.g. first 2 km of RIP combined with large scale CORINE)



ACKNOWLEDGEMENTS

Data collection started in STAR project (FP5)
This study was supported by REFORM project (FP7)

and the Ministry of Education of the Czech Republic
(LM2011028 and LO1214).

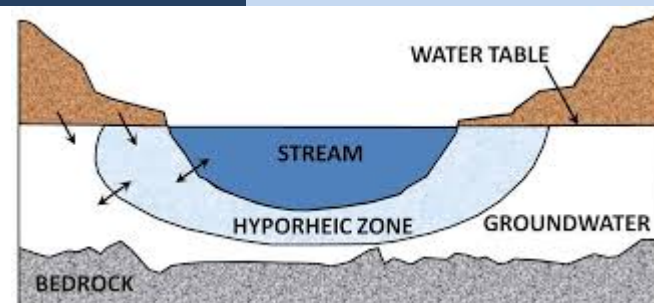


WWW.REFORMRIVERS.EU



Research centre
for toxic compounds
in the environment

- *downwelling a upwelling zóny toku*
- *kyslíkové poměry*
- *živiny a další minerální látky*
- *DOM, POM*
- *biota (pronikání do substrátu, komunikace s podzemními vodami, refugia)*



<http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.858.218&rep=rep1&type=pdf>

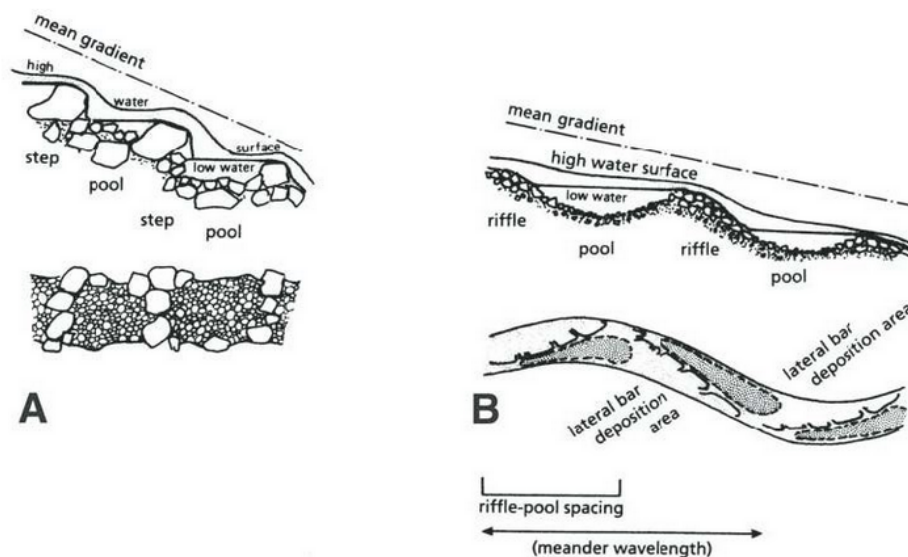



Figure 2. Step-pool and pool-riffle morphologies (from Church, 1992, *Channel morphology and typology*, in Calow, P., and Petts, G.E., eds., *The rivers handbook: hydrological and ecological principles*; Malden, Blackwell Scientific Publications. Reproduced with permission of Blackwell Publishing Ltd.).

- *downwelling a upwelling zóny toku*

 *Hydrobiologia* 444: 183–195, 2001.
© 2001 Kluwer Academic Publishers. Printed in the Netherlands.

Biological, chemical and physical characteristics of downwelling and upwelling zones in the hyporheic zone of a north-temperate stream

Rob J. M. Franken¹, Richard G. Storey & D. Dudley Williams

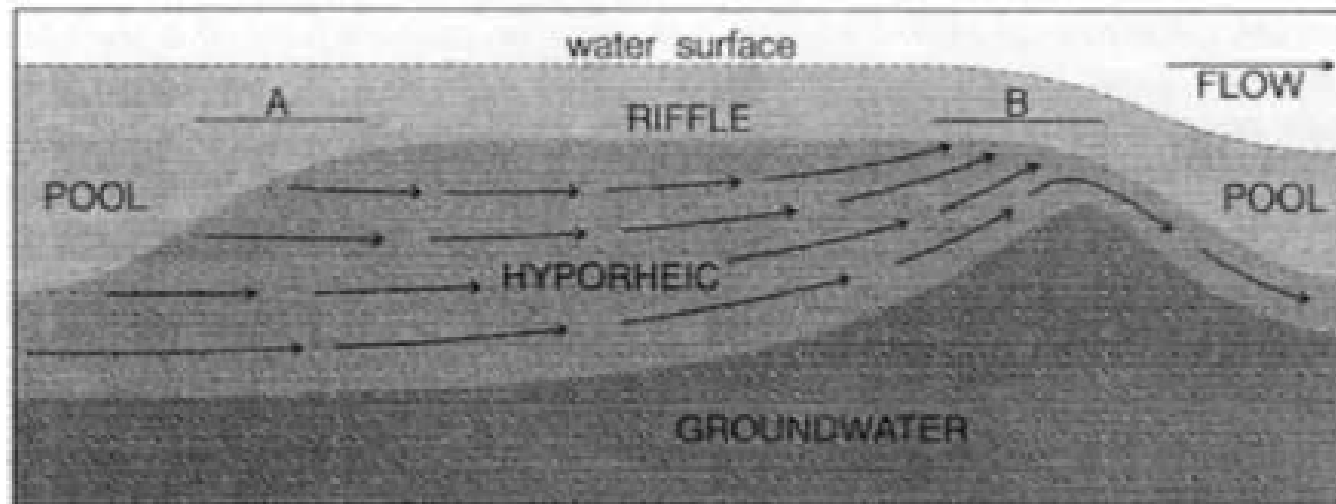
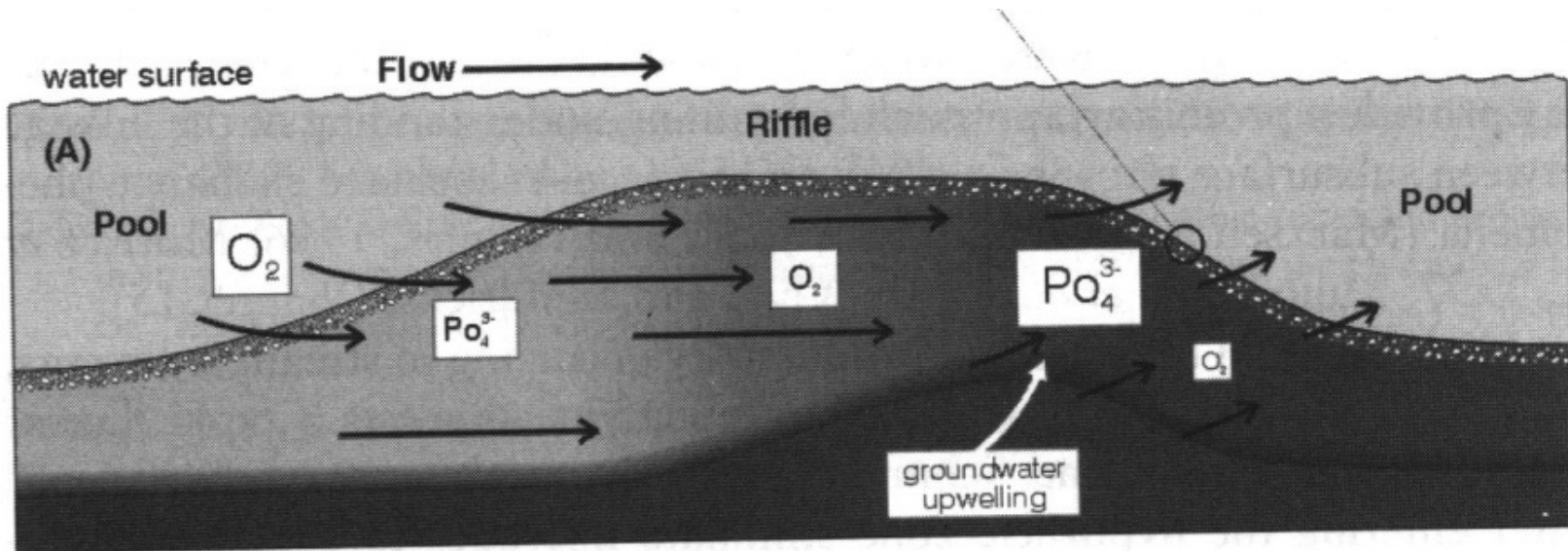



Figure 1. Conceptual diagram of surface-water advective flow through the hyporheic zone of a stream bed riffle-pool sequence and the relationship to groundwater distribution. Line A represents the region of surface water infiltration (downwelling) and line B represents the region of expected underflow return (upwelling) to the surface (by permission of Hendricks, 1993, and J. N. Am. Benthol. Soc.).

- downwelling a upwelling zóny toku

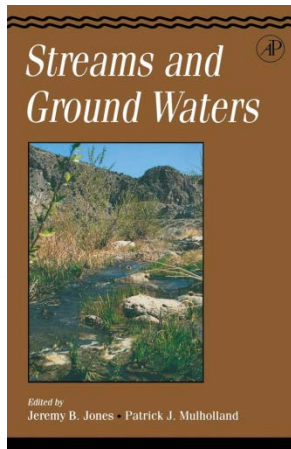


aerobic downwelling zone $\xrightarrow{\text{gradient}}$ less aerobic/more anaerobic upwelling zone

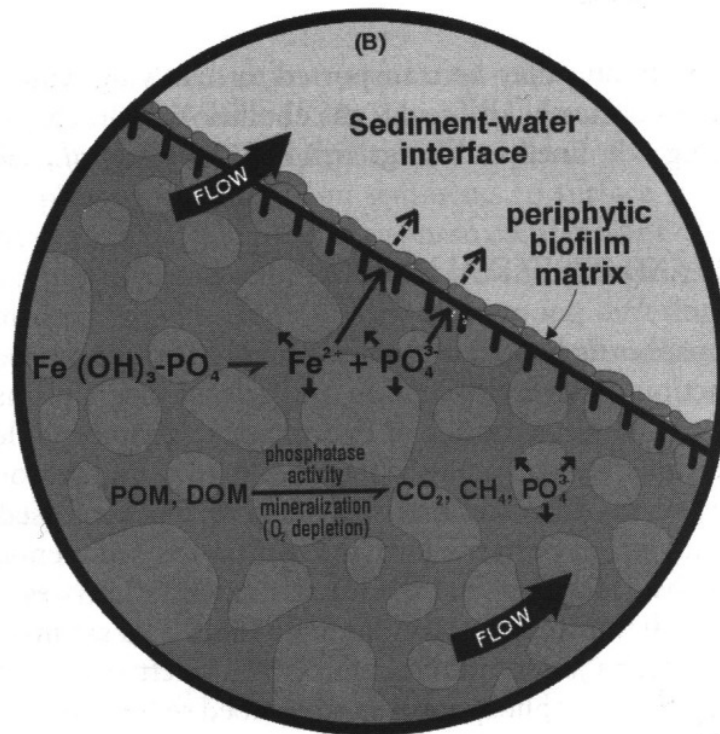
\rightarrow arrows indicate underflow path



 more oxidizing environment

 more reducing environment



- *downwelling a upwelling zóny toku*



 indicates interstitial advective flow
 oxidized microzone at sediment-water interface

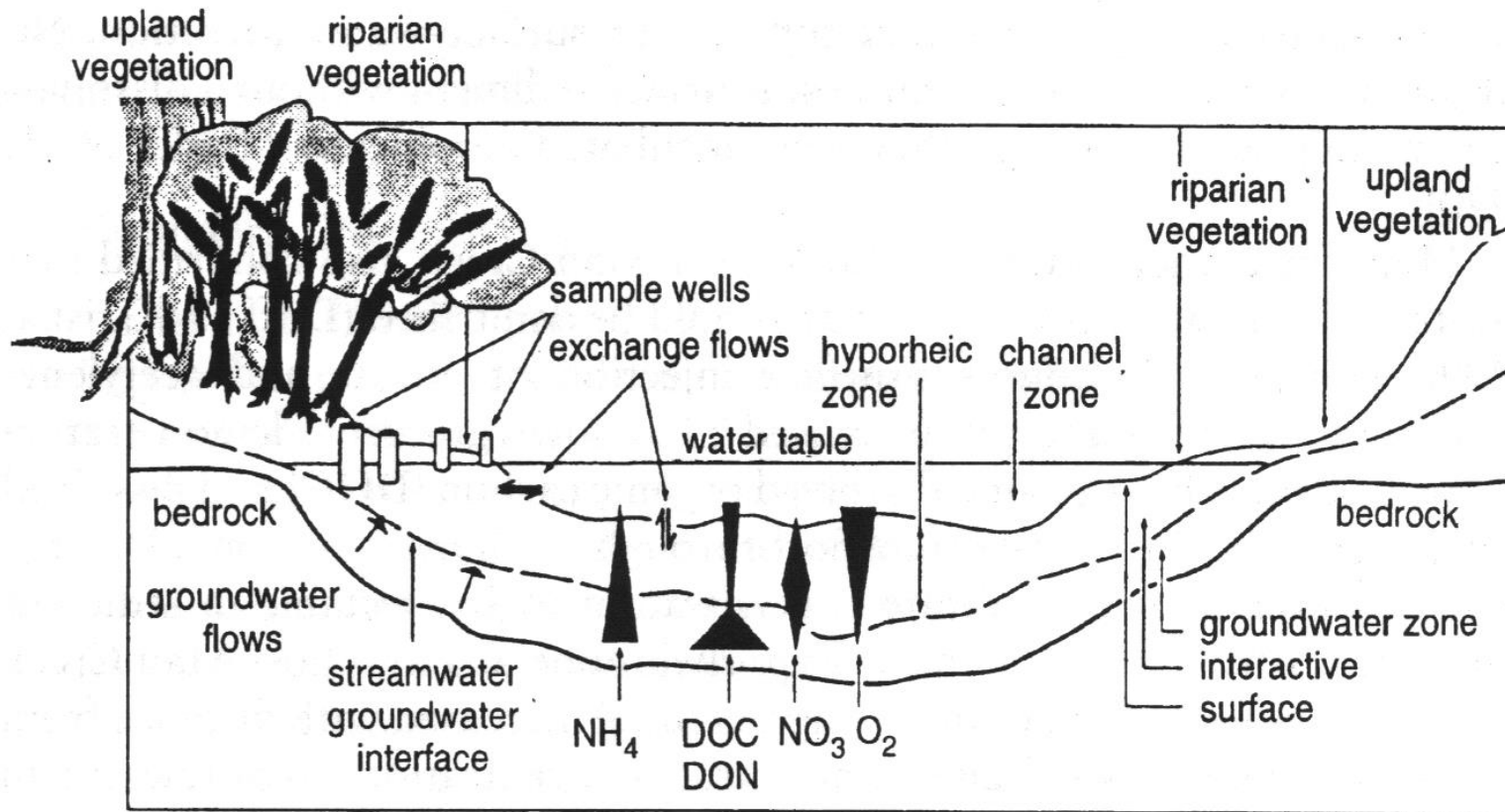
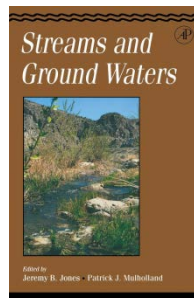
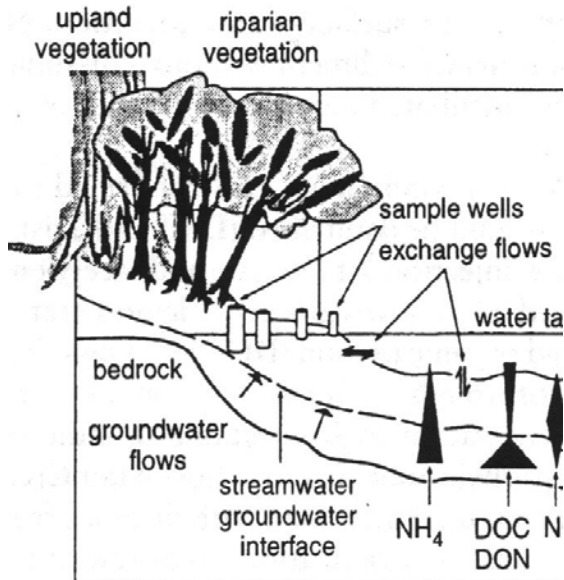
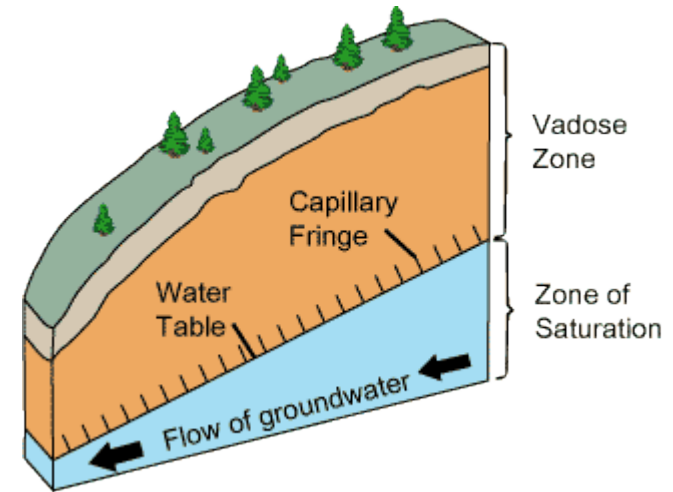
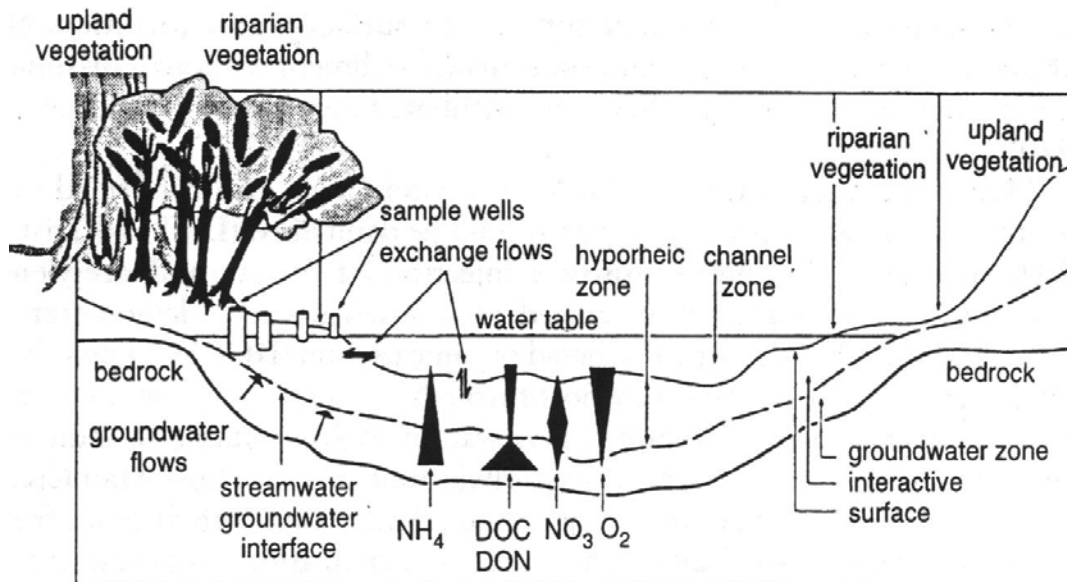


FIGURE 2 Conceptual model of hyporheic exchange and nutrient linkage in Little Lost Man Creek, California. Adapted from Triska *et al.* (1989b), *Ecology* 70:1893–1905, copyright by the American Geophysical Union.





- *20 dnů vypouštěny roztoky chloridu a dusičnanu do povrchové vody*
- *pozorování v sondách na břehu*
- *chlorid >90% říční vody v sondách <4m od koryta*
- *0% v sondách 10m od koryta*
- *dusičnany – vyšší i nižší koncentrace než by odpovídalo konzervativním chloridům*
- *zvýšené koncentrace – nitrifikace v podpovrchovém transportu*
- *snížené koncentrace – denitrifikace během transportu*



laterální promíchávání prokysličené vody

- *rozsáhlé na jaře, pokles na podzim (pokles průtoku, mikrobiální respirace a nitrifikace)*

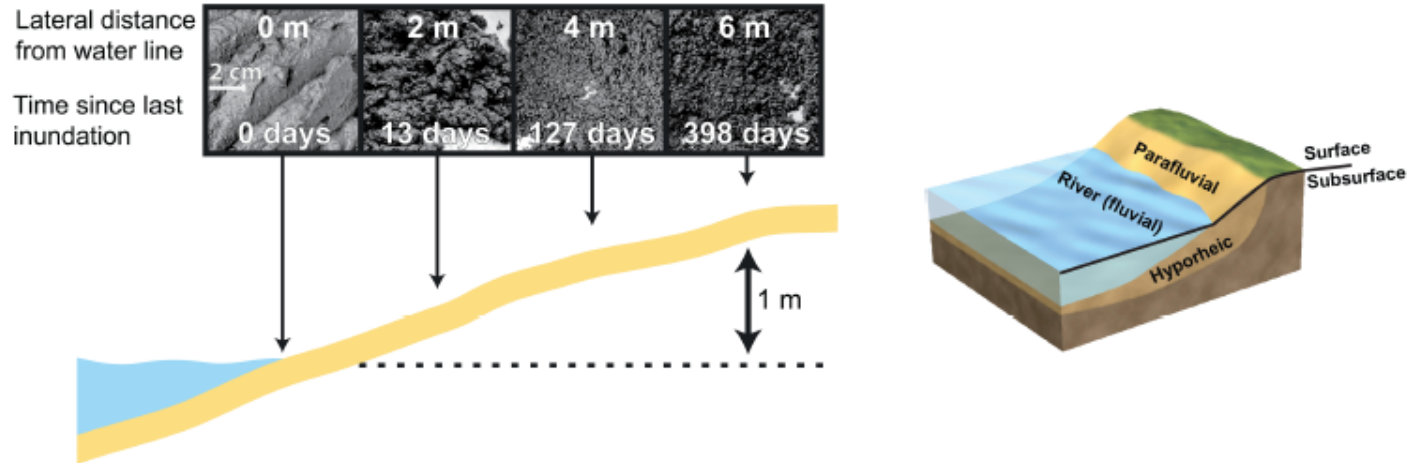


Figure 1. Diagram of parafluvial hyporheic zone and of sampling design with photographs of sieved sediment sampled. The four locations were spaced laterally at 2 m intervals beginning at the water line and encompassed 1 m of elevation change. Note changes in sediment moisture and texture with changes in inundation history.

Biogeochemical cycling at the aquatic–terrestrial interface is linked to parafluvial hyporheic zone inundation history

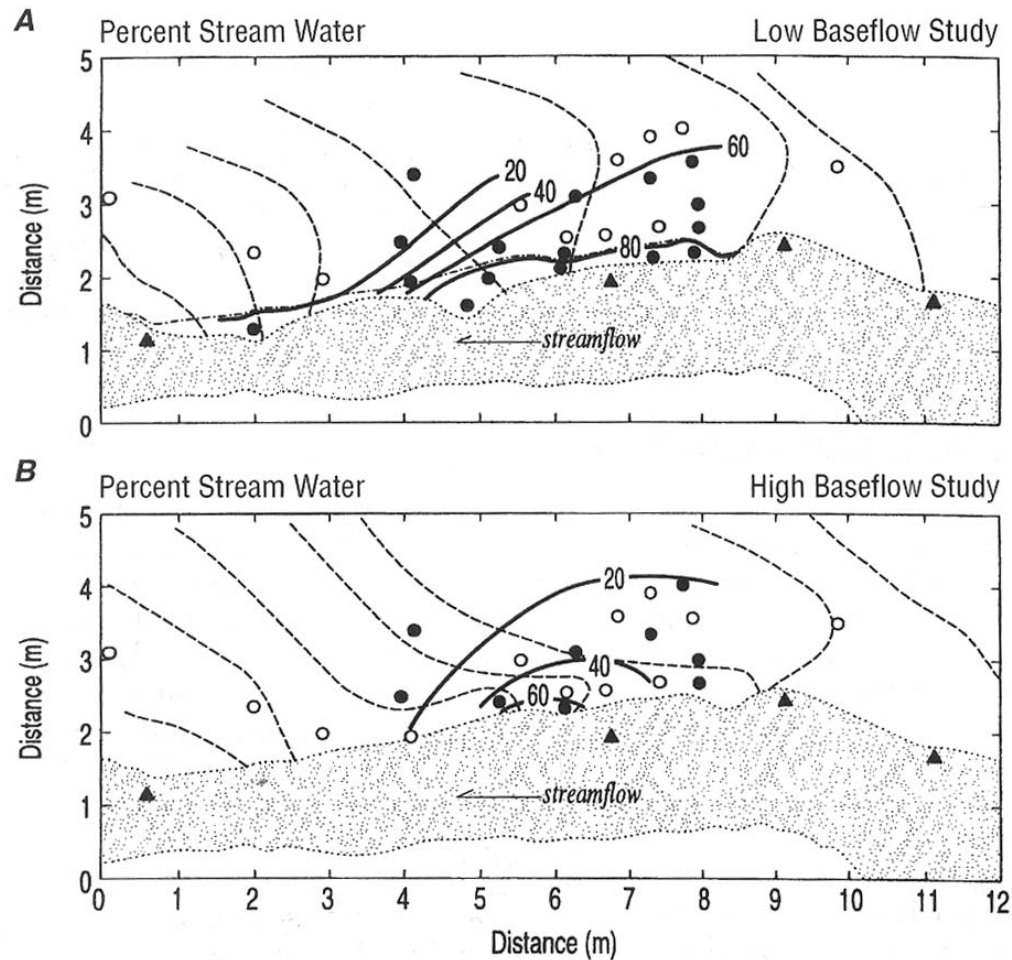


FIGURE 4 Identification of hyporheic flowpaths using chemical tracers. In this plan-view map of the stream, solid contours are percent stream water, dashed contours are hydraulic head, closed circles are wells sampled for chemistry, and triangles are staff gages. Note the less extensive penetration of stream water into hyporheic flowpaths during the higher baseflow study, when higher groundwater levels oppose stream-water inputs to the subsurface. (Modified from Harvey *et al.*, 1996.)

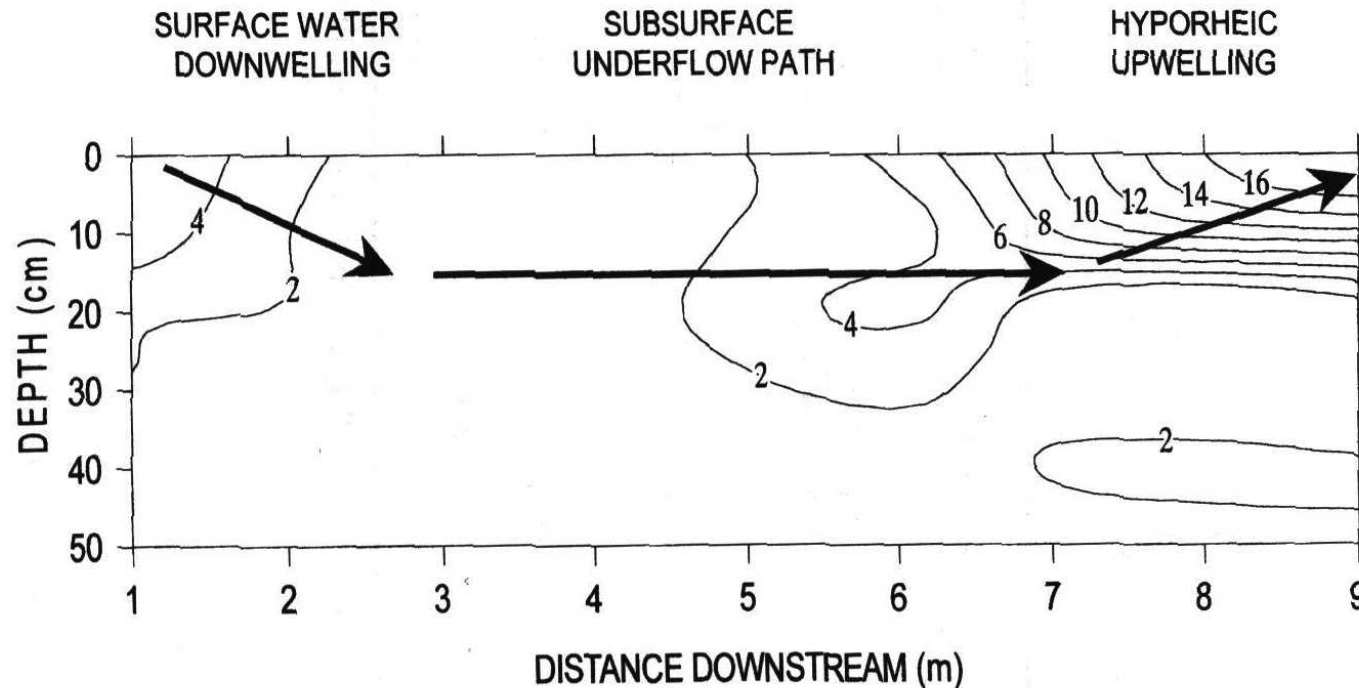
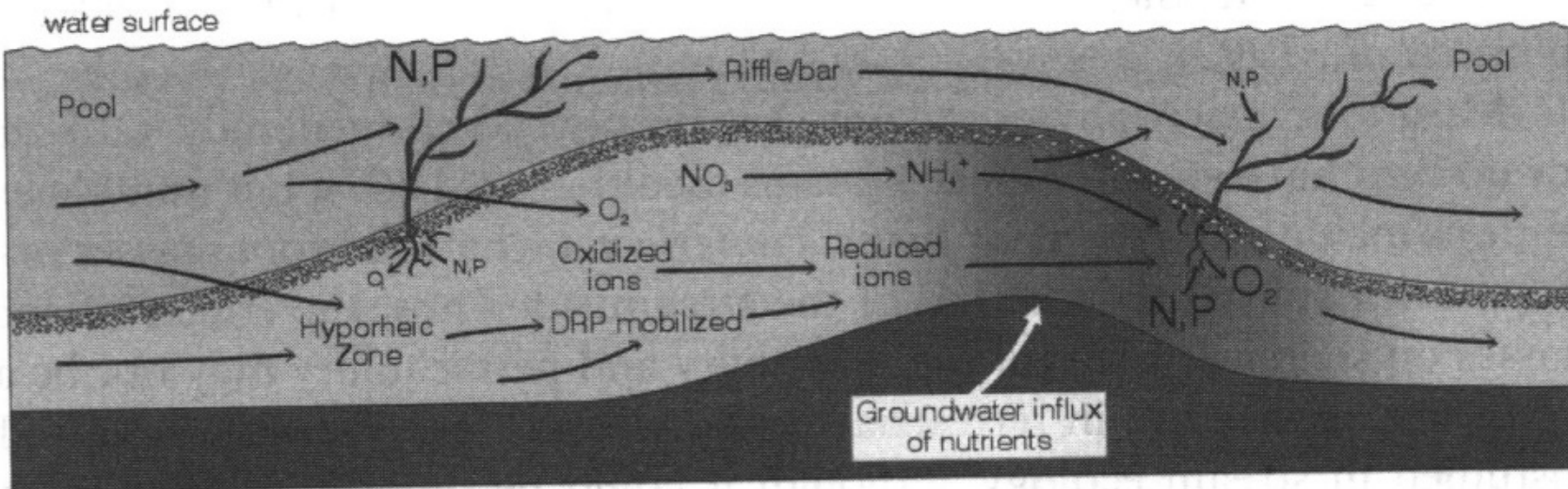
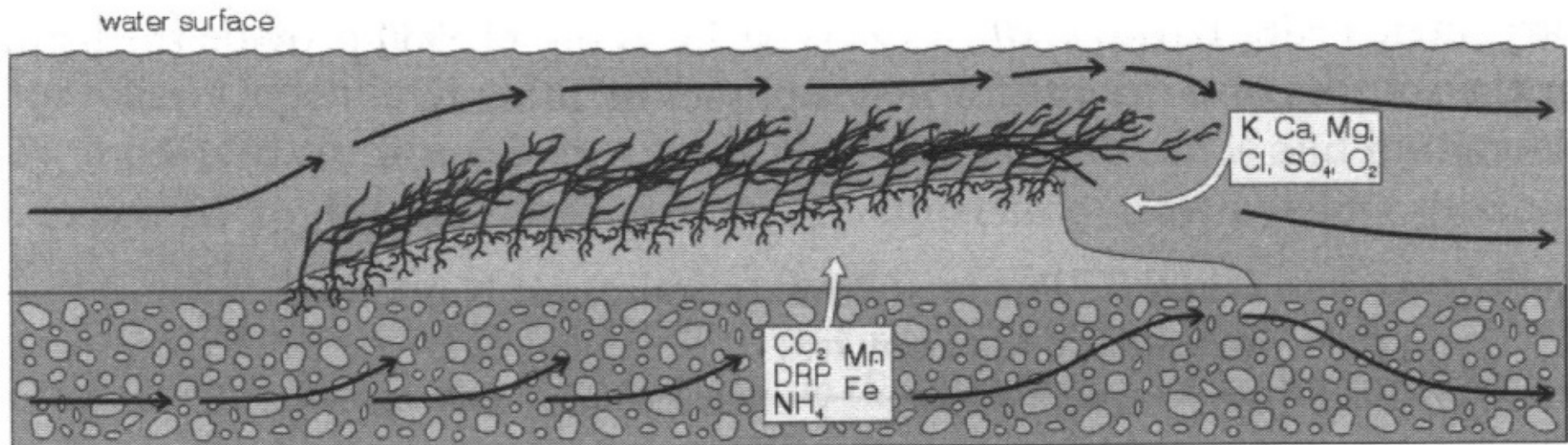


FIGURE 1 Isopleth contours of hyporheic soluble reactive phosphorus (SRP; $\mu\text{gP L}^{-1}$) patterns along a longitudinal transect beneath a riffle pool on July 16, 1989, in a northern Michigan stream. Isopleths are based on 135 determinations for SRP; $n = 3$ at each depth (5) at each meter (9) along the transect. Surface water SRP concentration was $<2 \mu\text{gP L}^{-1}$. Depth is magnified relative to distance in order to illustrate detail of the phosphorus contours. Depth 0 (y-axis) is the streambed surface. Meter 1–2 (x-axis) represent a downwelling zone. Meters 3–7 represent a subsurface flowpath. Meters 7–9 represent an upwelling zone. (From Hendricks and White, 1995, with permission.)

- *pokles rychlosti proudění na dolním konci vytváří nepříznivé podmínky pro rostliny (usazování písku a jemných sedimentů)*
- *zakořenění na horním konci pahorku (hummock) a vegetativní část splývá po proudu (tímto směrem také přirůstá)*



- *přední část struktury – prokysličená voda vstupuje do sedimentu, rostliny využívají především rozpuštěný fosfor a dusík z povrchové vody, uvolňují málo kyslíku do sedimentů*
- *podél struktury mikrobiální aktivita – redukční podmínky, mobilizace rozpuštěného reaktivního fosforu a amoniaku*
- *rostliny rostoucí na dolním konci struktury využívají především N a P ze sedimentů (uvolňují více kyslíku v rhizosféře)*



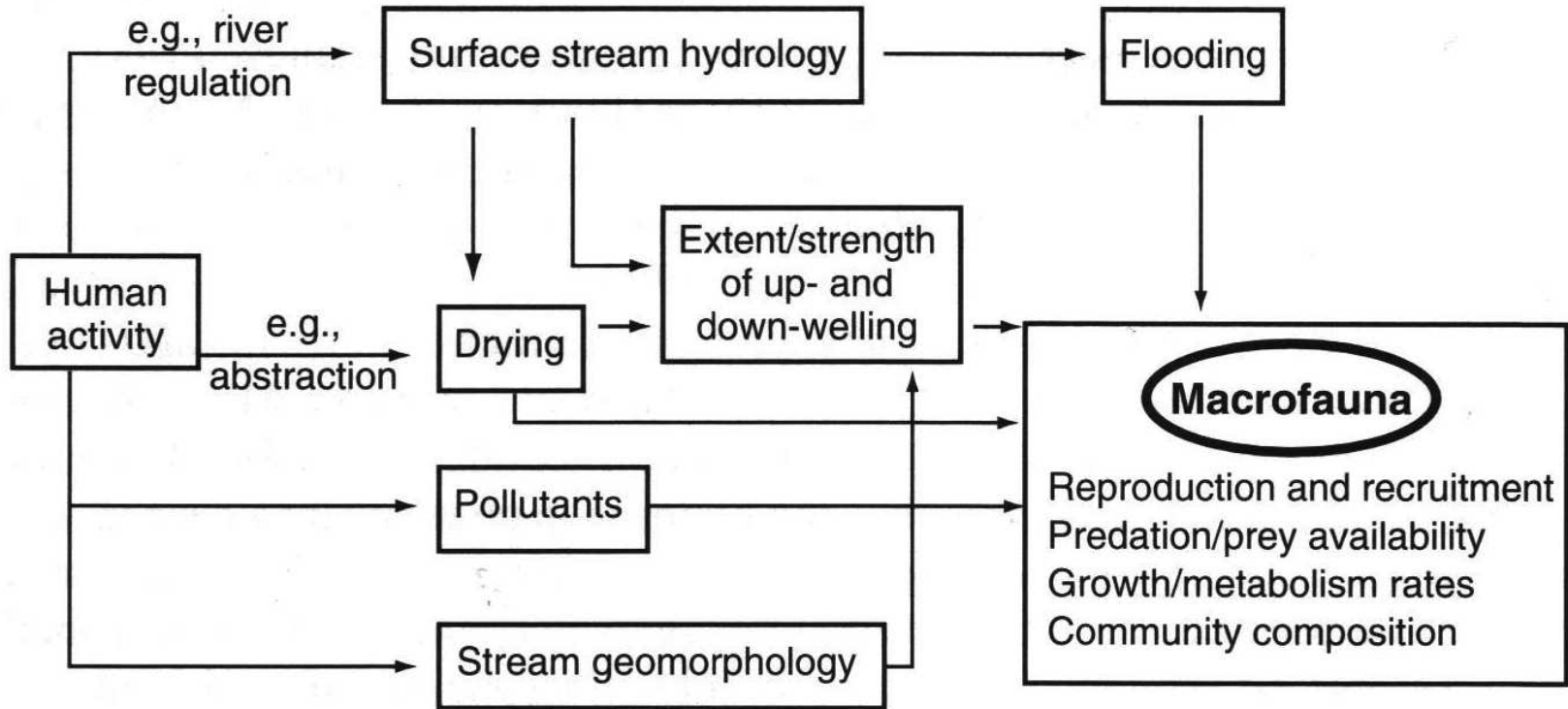


FIGURE 2 Mesoscale variables influencing the distribution of subsurface macrofauna in streams. See text for detailed explanation of impacts of pollution, flooding, and drying.

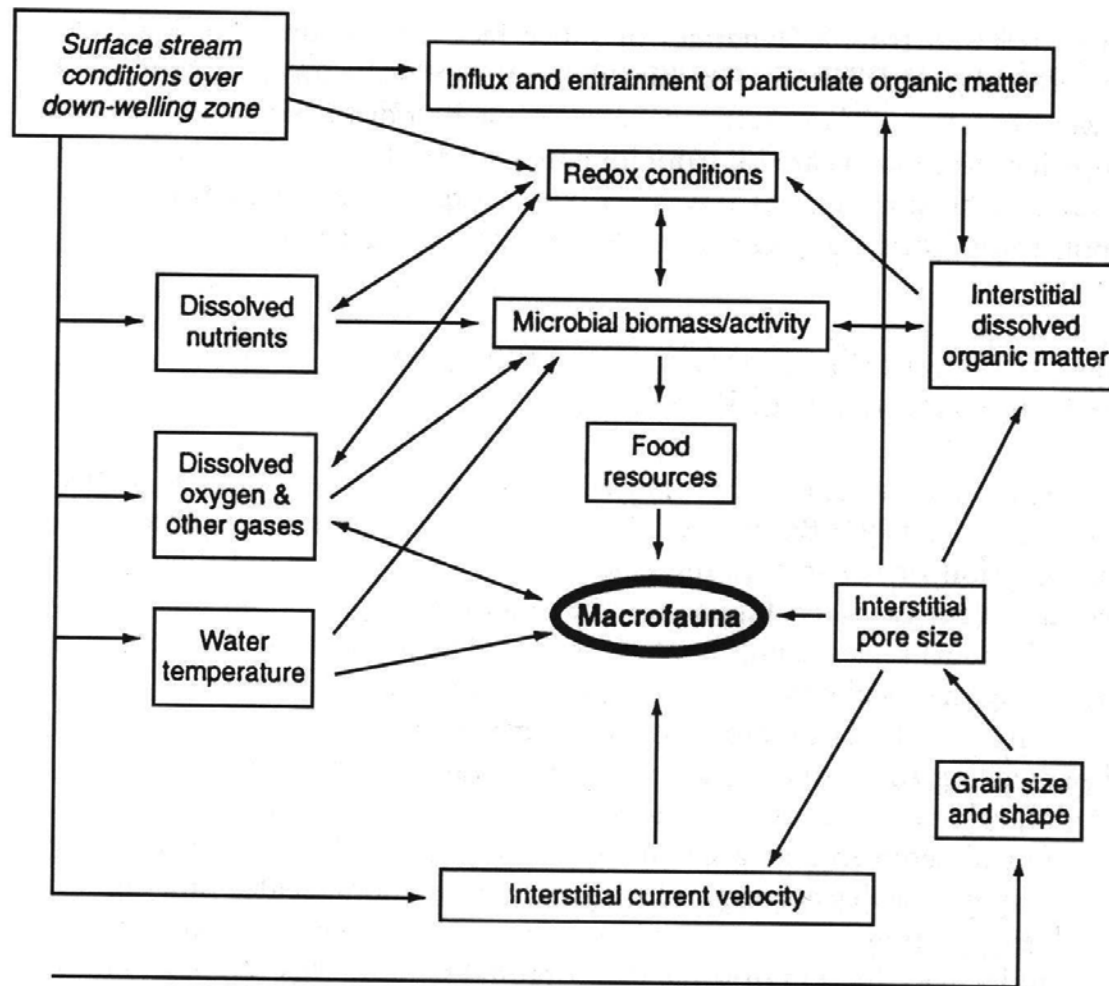


FIGURE 1 Microscale variables influencing the distribution of subsurface macrofauna in streams. Biotic interactions such as predation and competition are not included. Double-headed arrows signify that the interactions may occur in both directions. Some interactions have been omitted for clarity of the diagram.

- *meiofauna (50-1000 μm)*
- *makrofauna (> 1000 μm)*
- *vířníci, korýši, máloštětinatí červi, larvy hmyzu*



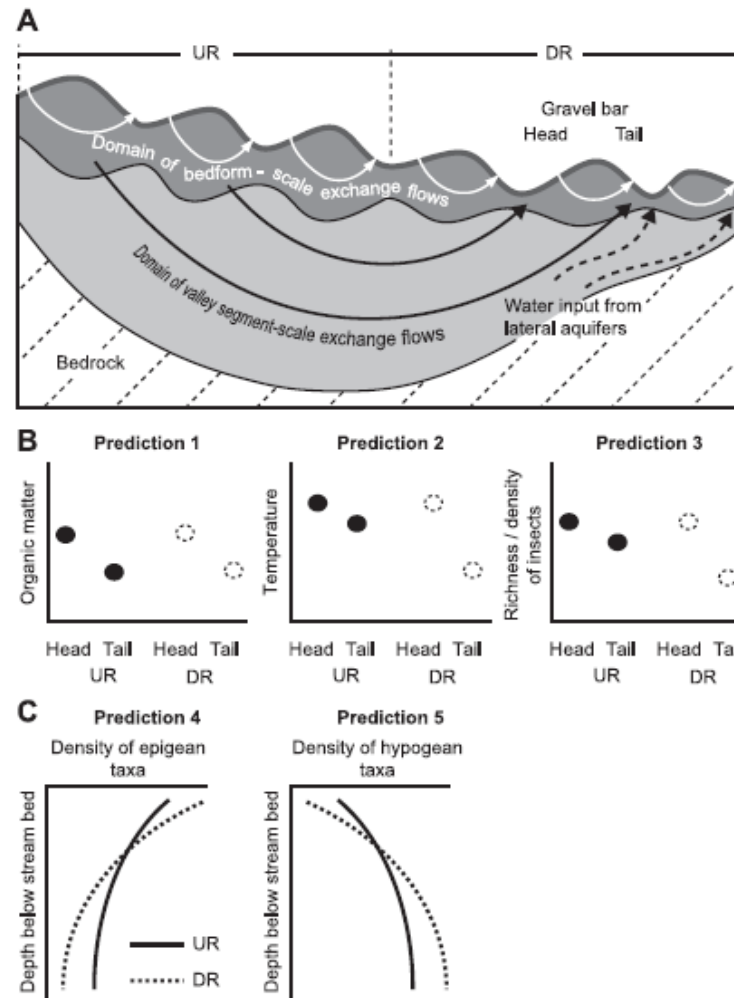
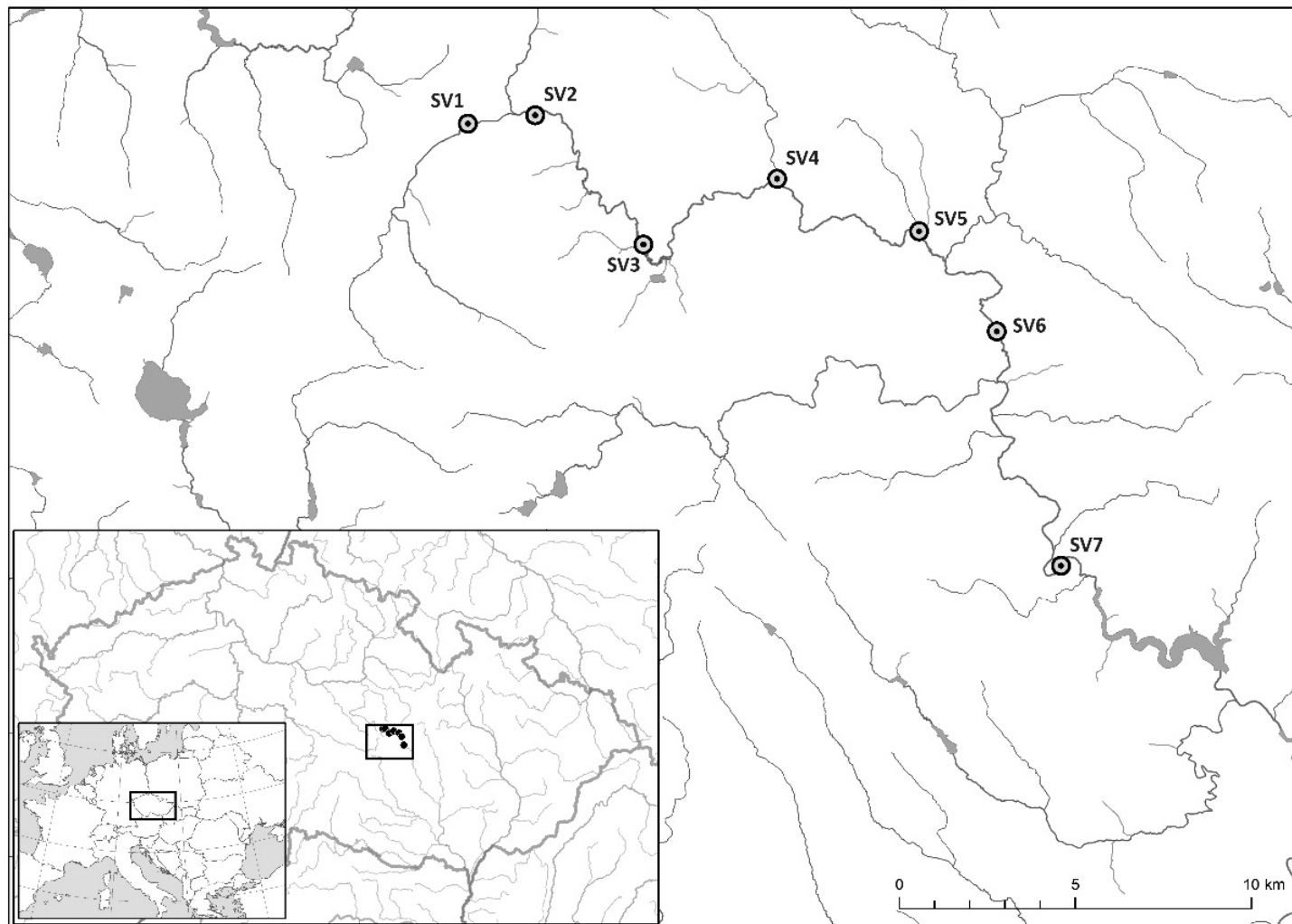


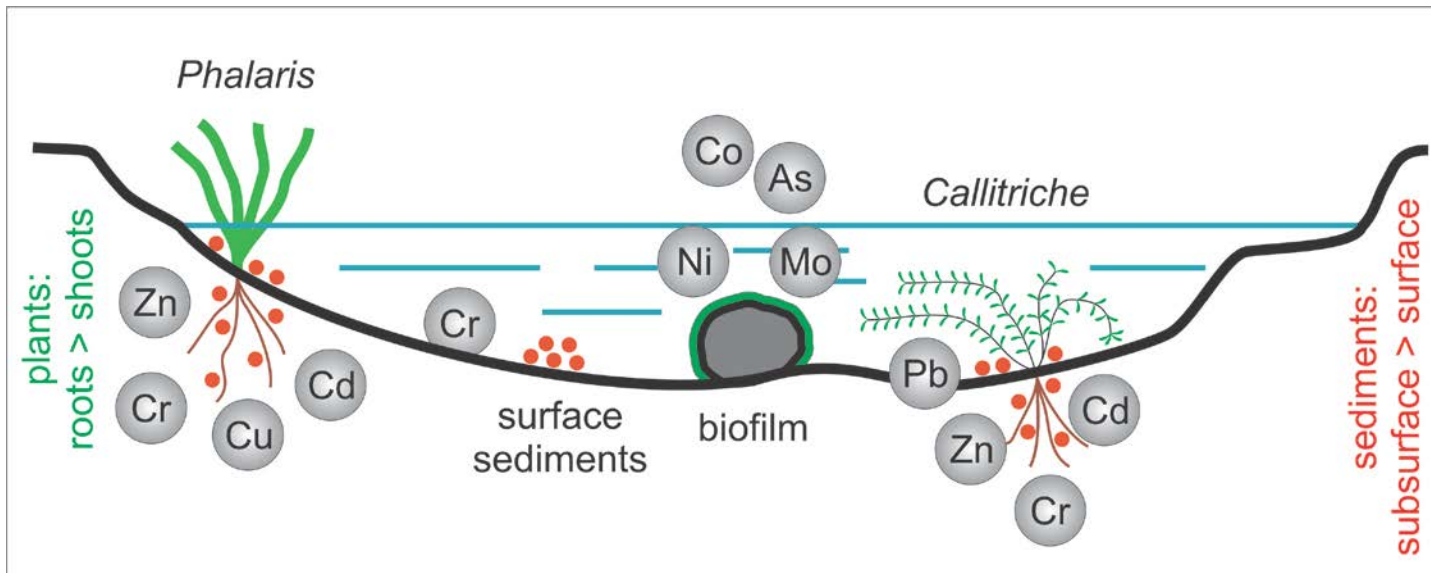
FIG. 1. A.—Theoretical organization of surface-subsurface water exchanges in a downstream bounded unconfined valley segment. B.—Predicted distribution patterns of organic matter (prediction 1), temperature (prediction 2), and insects (prediction 3) in the hyporheic zone along the longitudinal dimension of valley segments. C.—Predicted vertical distribution patterns of epigeal (prediction 4) and hypogean (prediction 5) taxa at the tails of bars in downstream and upstream reaches of valley segments. DR = downstream reach, UR = upstream reach.

- *injektáž nereagující látky*
- *čerpání vody ze sond*
- *odběr sedimentů (freeze core)*
- *instalace logerů, gelové náplně*

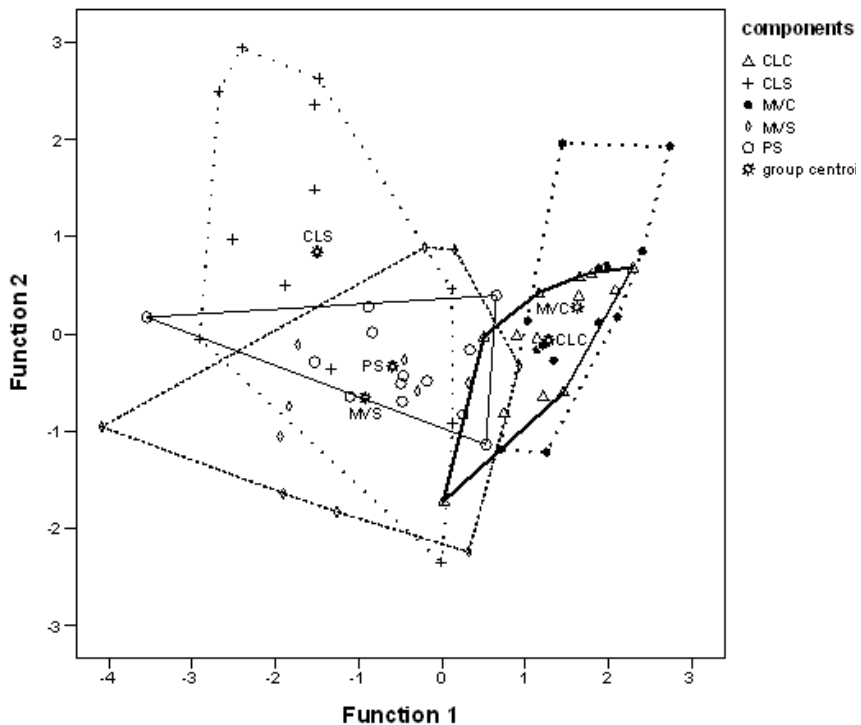




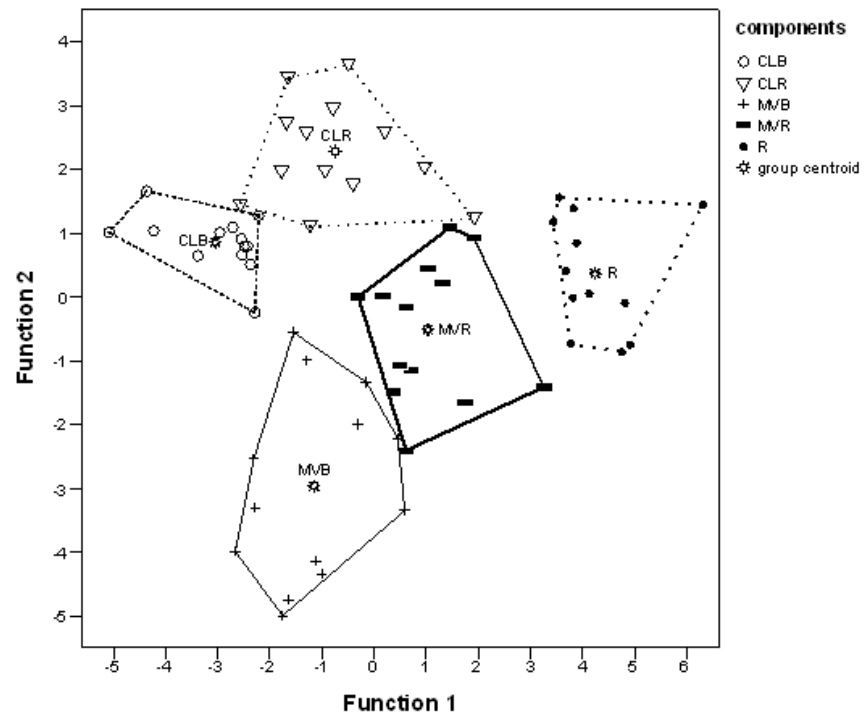
Location of study sites at Svatka River

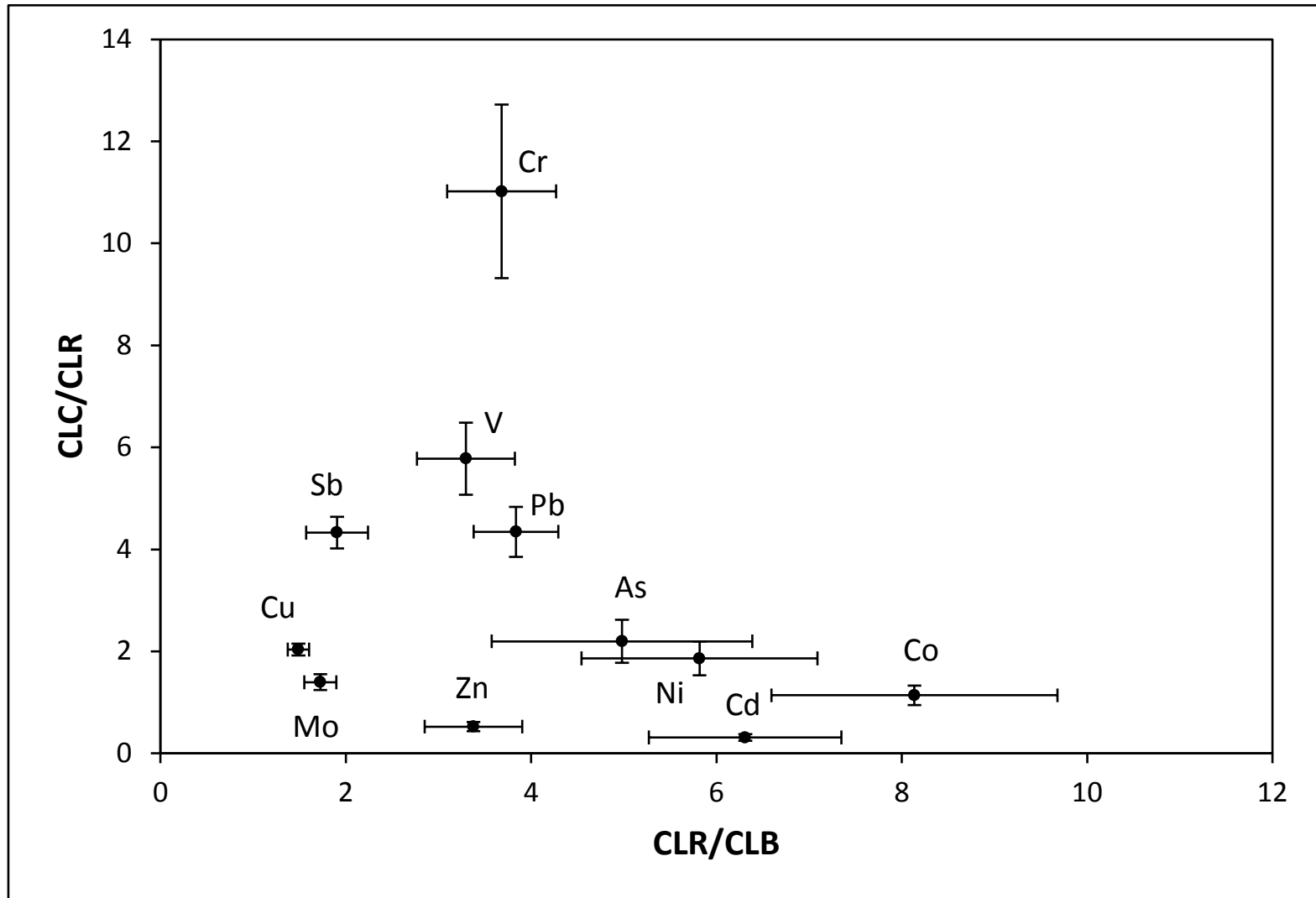


SEDIMENTS

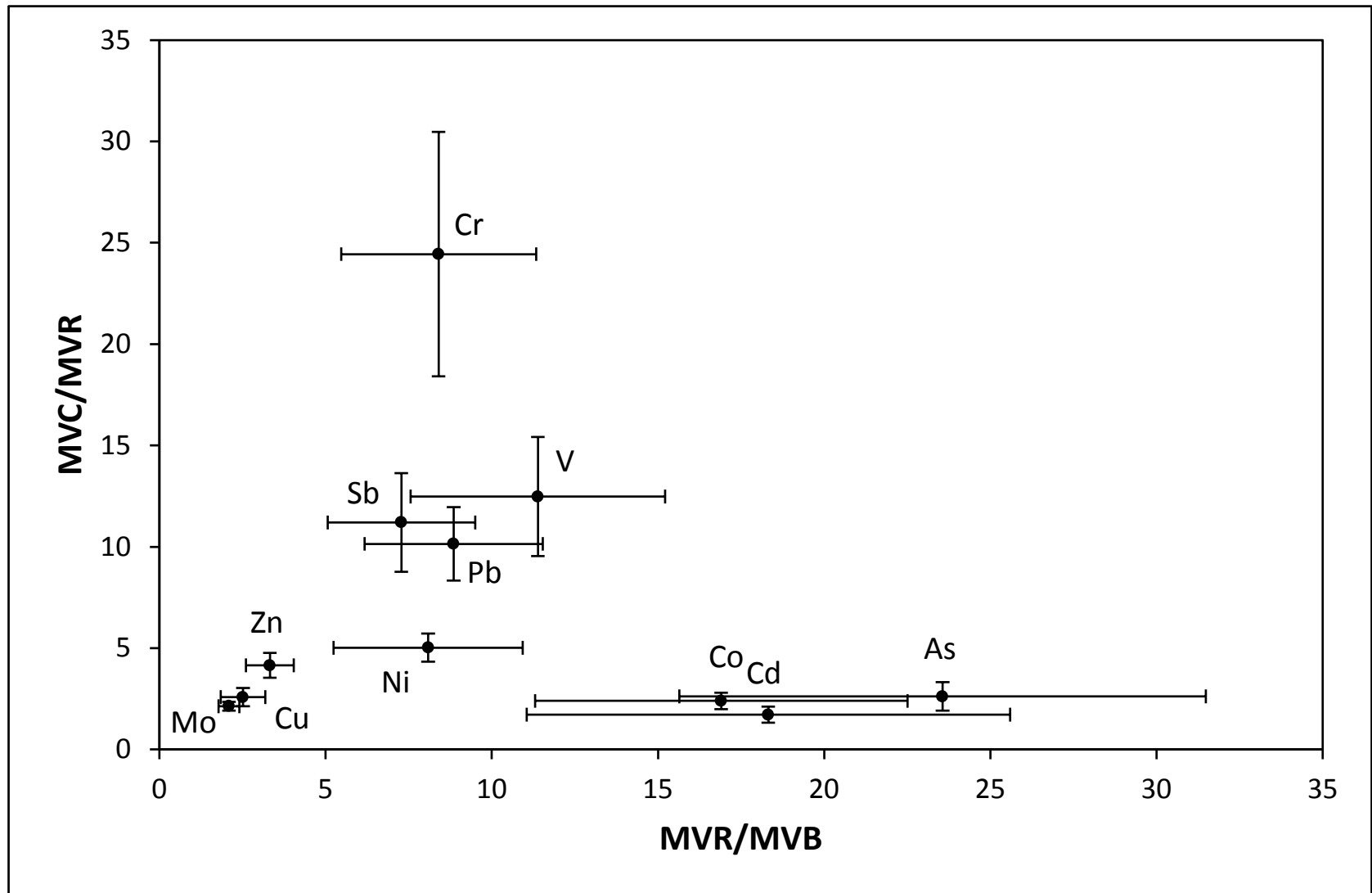


BIOLOGICAL COMPONENTS





Phalaris translocation factor between root and shoot (MVR/MVB) displayed against bioconcentration factor between subsurface sediments and *Phalaris* roots (MVC/MVR) – mean \pm standard error.



Callitriche translocation factor between root and shoot (CLR/CLB) displayed against bioconcentration factor between subsurface sediments and *Callitriche* roots (CLC/CLR) – mean \pm standard error.

Significant correlations (Pearson r , $N=13$; $p<0.05$) among metal concentrations in different submatrices related to plants (B = plant shoots, R = plant roots, S = plant-associated surface sediments, C = subsurface sediments washed from plant roots).

Metal	Phalaris	Callitriche
As	B x R	B x C; S x all
Cd	R x S	-
Co	R x C	B x R
Cr	-	B x C; B x R
Cu	B x R	R x C; S x all
Mo	-	R x S; R x C
Ni	-	-
Pb	-	B x R; B x C; R x C
Sb	R x C	B x C; R x S
V	-	R x S
Zn	B x S	B x R; C x S