Vybrané kapitoly z říční ekologie

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Náplň kurzu

- Teorie a hypotézy popisující říční systémy
- Hyporheal
- Tropické toky
- Zvláštní typy lotických habitatů
- Velké řeky – ekologie a biologie

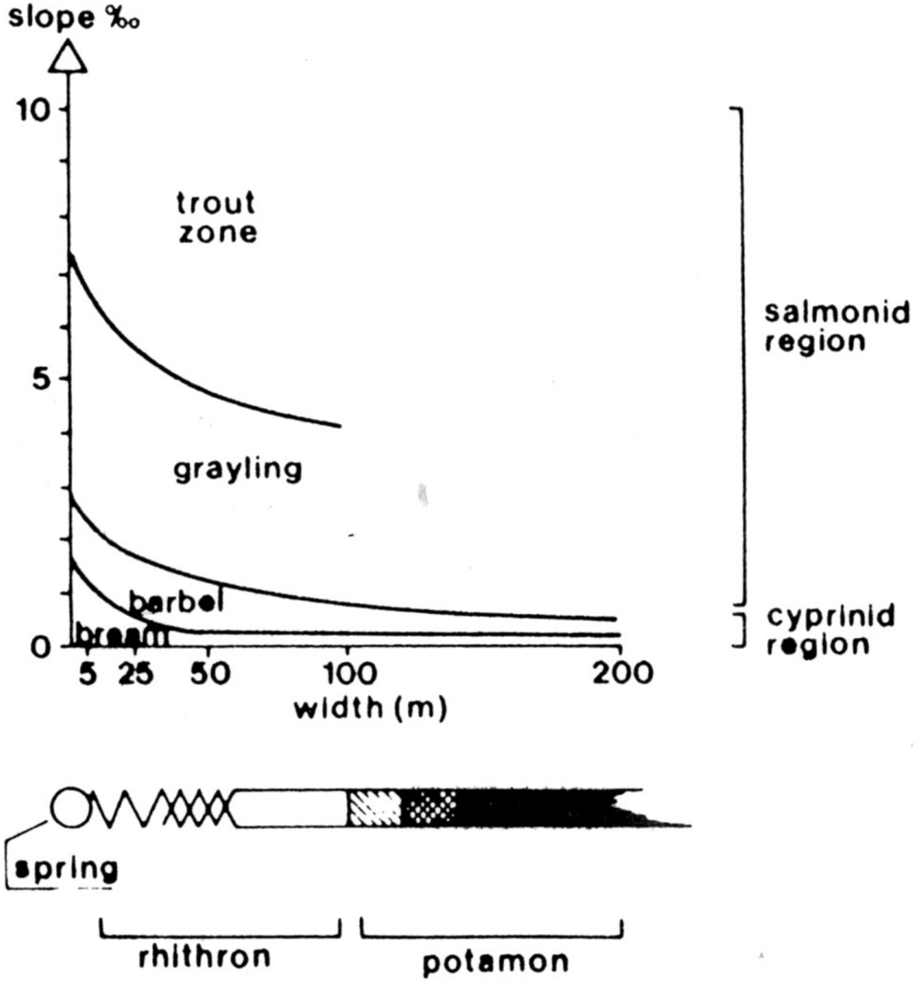
Říční ekosystémy a jejich klasifikace

- Zonačně-prostorový koncept
- Prostorově klinální koncept
- Časový koncept
- Časově prostorový koncept

Zonačně-prostorový koncept

- Zonační schéma
  - Rybí pásma
    - Frič (1872), Hawkes (1975)
  - Organismy
    - Thienemann (1921) dle pakomárů
    - Zelinka (1953) dle jepic
  - Organismy a podmínky
    - Ilies (1961), Ilies & Botosaneanu (1963)

ILLIES a BOTOSANEANU 1963		FRIČ 1872 (doplněno)	Zóny jepic (ZELINKA 1953)	Fyziografické členění	Průměrný spád v promile	Maximální teploty vody ve °C
KRENON	Eukrenon	Pramen	-	Pramen	-	-
	Hypokrenon	Pramenná stružka	Ameletová	Stružka	nad 3 (ale i méně)	do 14
RHITHRON	Epirhithron	Pstruhový potok	Rhithrogenová	Bystřina	nad 3 (blíže k prameni i méně)	do 16
	Metarhithron	Pstruhová říčka	Ecdyonurová	Potok	do 3	do 18 (20)
	Hyporhitron	Lipanové pásmo	Ecdyonurová	Říčka	1,5 - 3,0	do 20 (22)
POTAMON	Epipotamon	Parmové pásmo	Oligoneuriellová	Řeka	0,8 - 1,5	do 25 (27)
	Metapotamon	Cejnové pásmo	Ephoronová	Veletok	do 0,8	až 28
	Hypopotamon	Pásmo vody brakické	-	-	-	-


slope ‰
10
5
0
trout zone
grayling
barbel
bream
5
25
50
100
200
width (m)
salmonid region
cyprinid region
spring
rhithron
potamon

Prostorově – klinální koncept

- Struktura společenstva
  - Objektivní klasifikace a ordinace (Townsend 1983)
  - Po proudový vývoj související s teplotou vody, hydraulikou atd. (Vannote & Sweeney 1980; Statzner & Higler 1986 ………….)

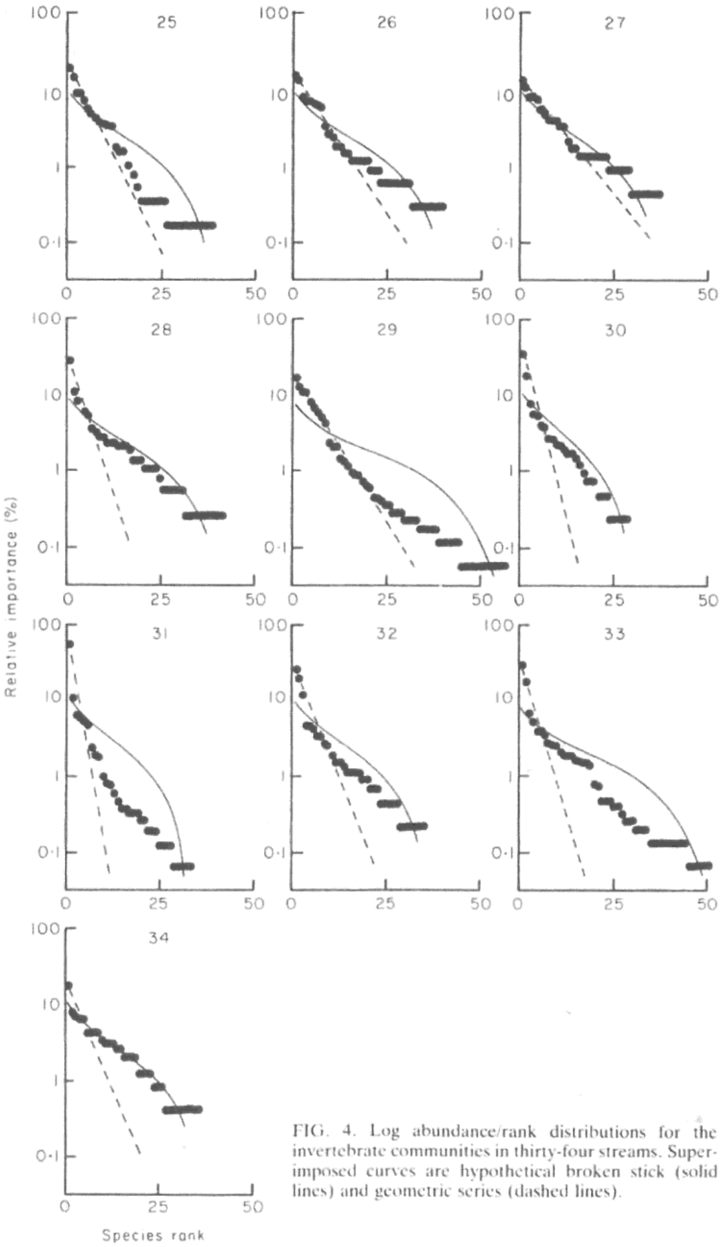


FIG. 4. Log abundance/rank distributions for the invertebrate communities in thirty-four streams. Superimposed curves are hypothetical broken stick (solid lines) and geometric series (dashed lines).

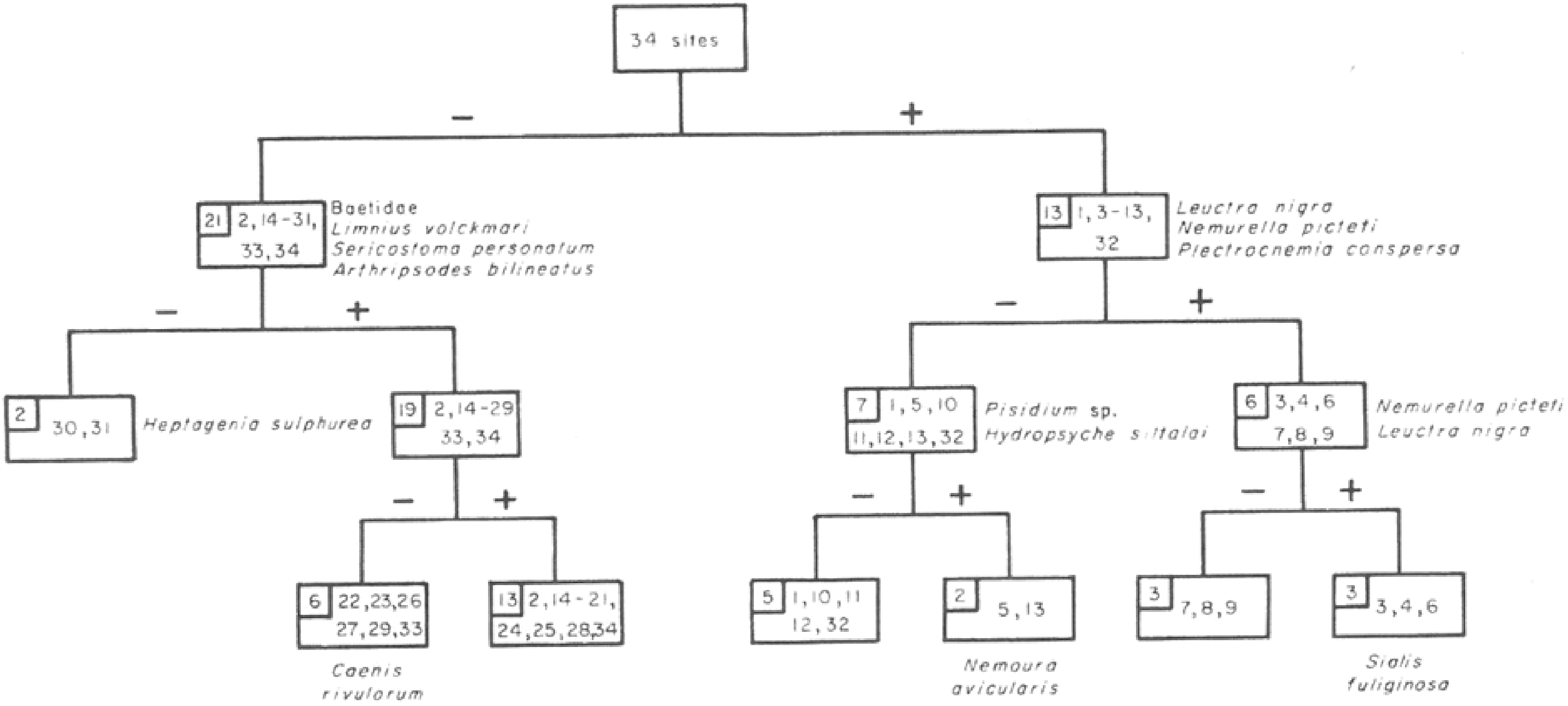
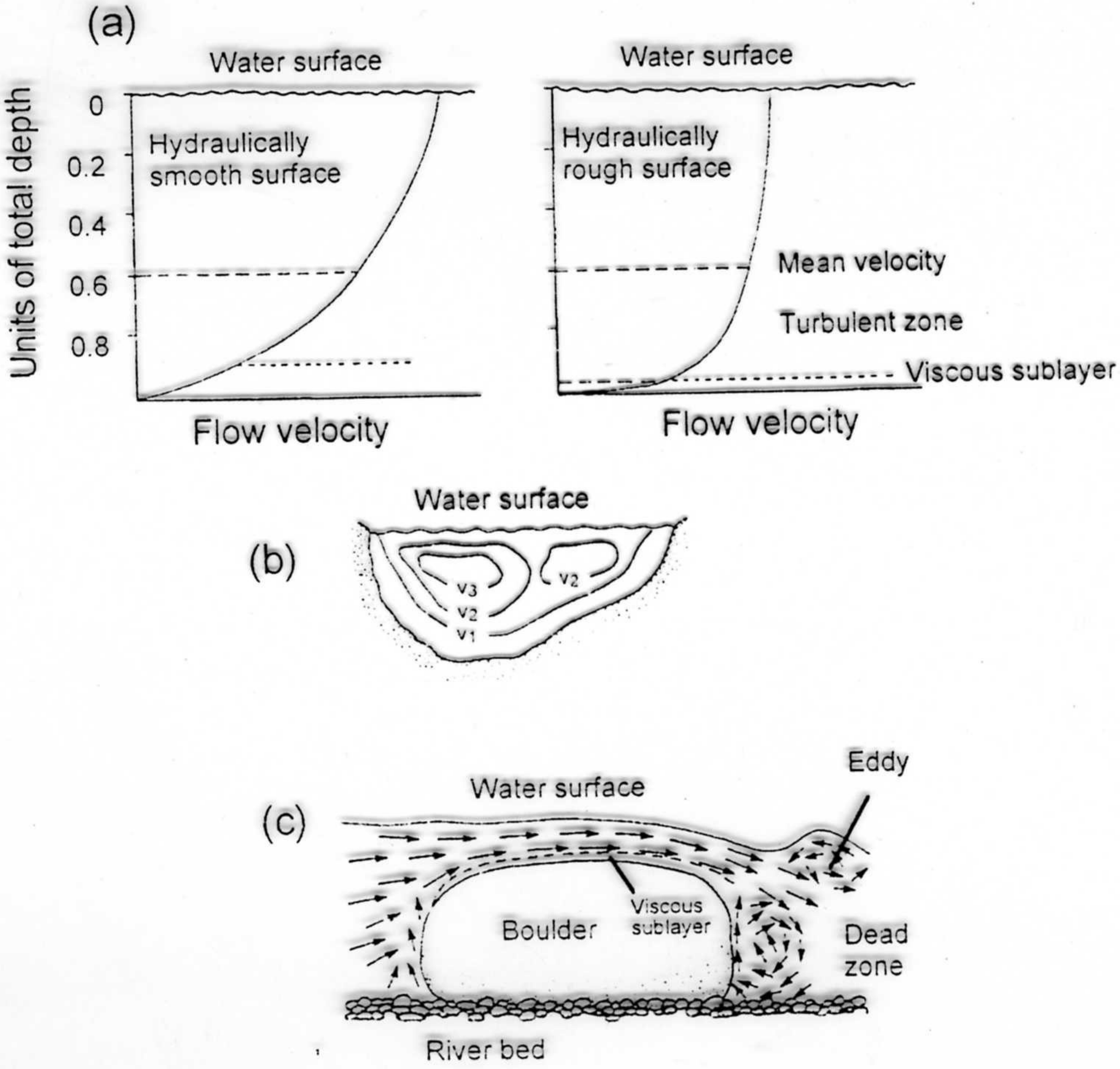
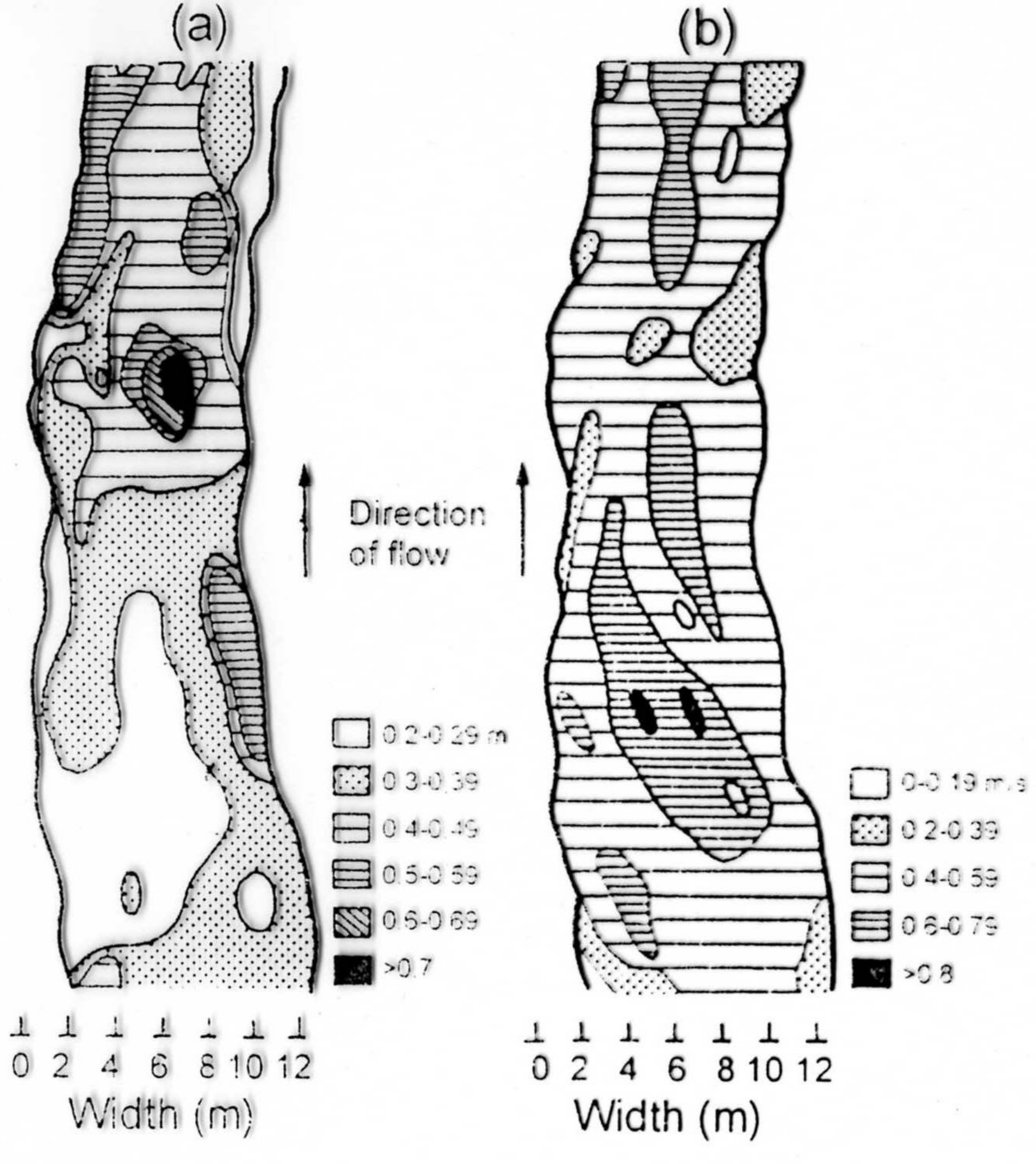


FIG. 6. Classification of thirty-four stream communities as revealed by indicator species analysis. The technique progressively divides the set of communities into smaller sub-sets according to the closeness of similarity in species composition. At each division, 'indicator' species are shown.

TABLE 3.2 Some terms and equations useful in describing streamflow (Adapted from Davis and Barmuta, 1989; and Carling, 1992)

Terms			
$\bar{U}$	Mean velocity	Measured at 0.6 depth from surface or from velocity profile	
U_*	Shear velocity	Estimated from fine-scale velocity *versus* log depth profile at nearbed depths	
D	Water depth	Total depth, surface to bottom	
k	Height of surface roughness elements	Difficult to quantify; methods described in text	
ν	Kinematic viscosity	$1.004 \times 10^{-6}\,\mathrm{m}^2\,\mathrm{s}^{-1}$ at 20°C	
g	Acceleration due to gravity	$9.8\,\mathrm{m}^2\,\mathrm{s}^{-1}$	
Equations			
Re	Bulk flow Reynolds number		
		$\mathrm{Re} < 500$	⇒ laminar flow
	$\mathrm{Re} = \bar{U}D/\nu$	$500 < \mathrm{Re} < 10^3\text{–}10^4$	⇒ transitional flow
		$\mathrm{Re} > 10^3\text{–}10^4$	⇒ turbulent flow
Fr	Froude number		
		$\mathrm{Fr} < 1$	⇒ sub-critical flow
	$\mathrm{Fr} = \bar{U}\sqrt{(gD)}$	$\mathrm{Fr} = 1$	⇒ critical flow
		$\mathrm{Fr} > 1$	⇒ super-critical flow
D/k	Relative roughness	Height of roughness elements relative to water depth; influences flow type	
Re_*	Roughness Reynolds number	Describes flow near streambed	
		$\mathrm{Re}_* < 5$	⇒ hydraulically smooth flow
	$\mathrm{Re}_* = U_*k/\nu$	$5 < \mathrm{Re}_* < 70$	⇒ transitional flow
		$\mathrm{Re}_* > 70$	⇒ hydraulically rough flow
δ	Thickness of laminar sublayer	Describes region of viscous flow	
	$\delta = 11.5\nu/U_*$	$\delta/\mathrm{k} < 1$	⇒ hydraulically smooth flow
		$\delta/\mathrm{k} > 1$	⇒ hydraulically rough flow


(a)
Water surface
Units of total depth
0
0.2
0.4
0.6
0.8
Hydraulically smooth surface
Flow velocity
Water surface
Hydraulically rough surface
Mean velocity
Turbulent zone
Viscous sublayer
Flow velocity
Water surface
(b)
v3
v2
v1
v2
Eddy
Water surface
(c)
Viscous sublayer
Boulder
Dead zone
River bed


(a)
(b)
Direction of flow
0.2-0.29 m
0.3-0.39
0.4-0.49
0.5-0.59
0.6-0.69
>0.7
0-0.19 m/s
0.2-0.39
0.4-0.59
0.6-0.79
>0.8
0 2 4 6 8 10 12
Width (m)
0 2 4 6 8 10 12
Width (m)

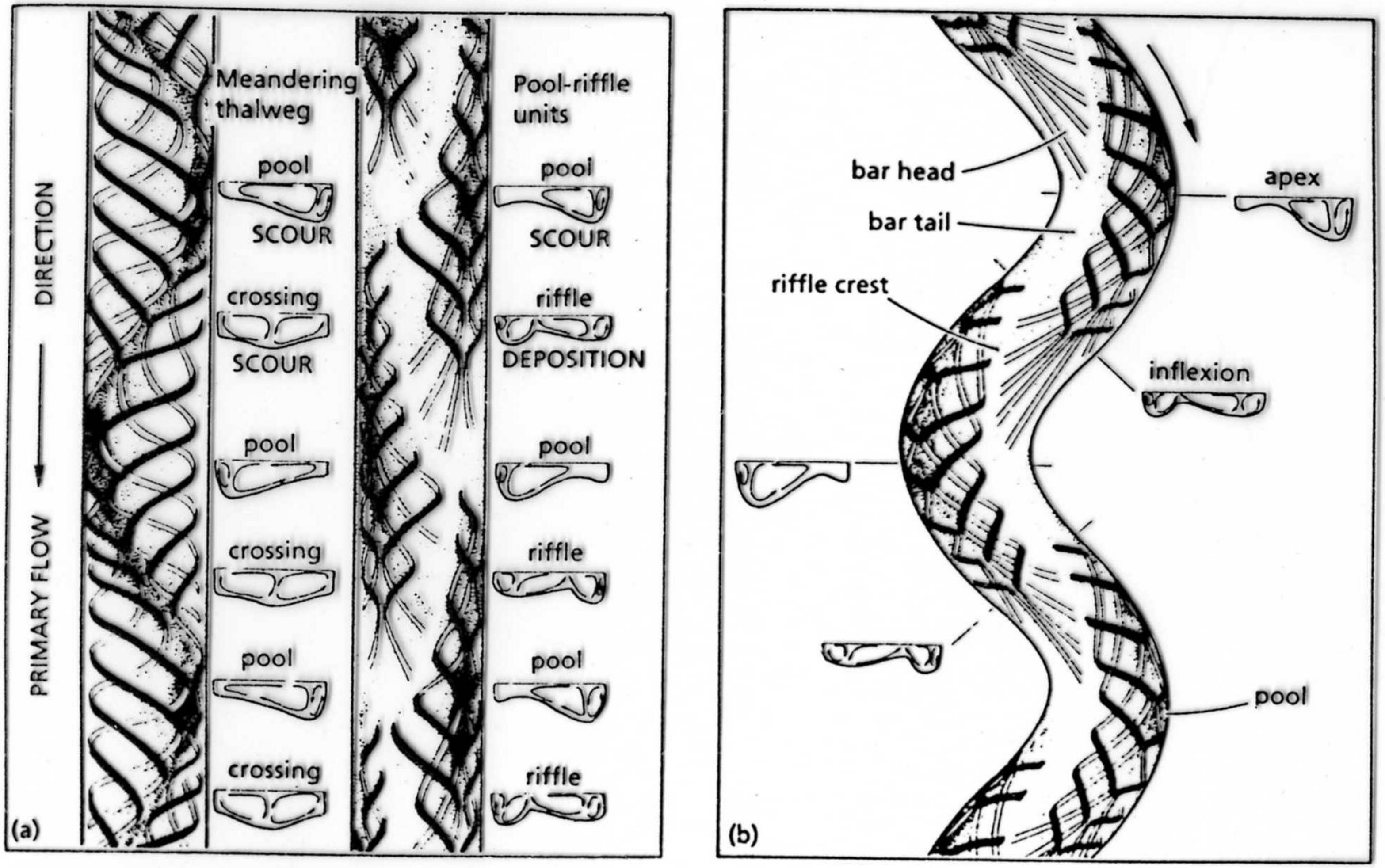
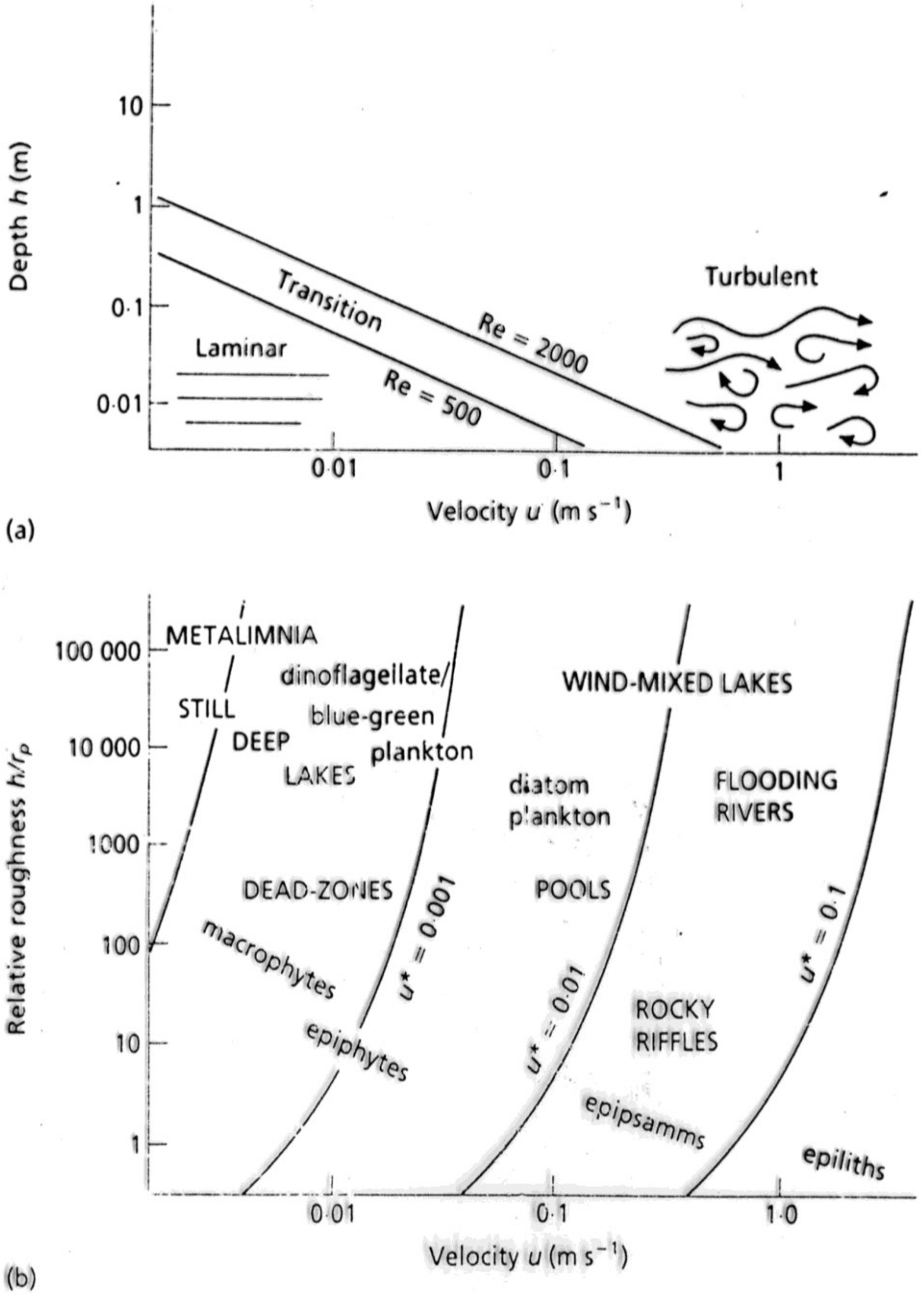


FIGURE 7-5 Models of flow structure in (a) straight and (b) meandering channels. (From Carling, 1992, after Thompson, 1986. Secondary flows and the poolriffle unit: a case study of the processes of meander development. Earth Surface Processes and Landforms *11*:631–641, © John Wiley & Sons Limited. Reproduced


10
1
0·1
0·01
Depth h (m)
Laminar
Transition
Re = 500
Re = 2000
Turbulent
0·01
0·1
1
Velocity u (m s^{-1})
(a)
100 000
10 000
1000
100
10
1
Relative roughness h/r_p
METALIMNIA
STILL
DEEP
LAKES
dinoflagellate/
blue-green
plankton
WIND-MIXED LAKES
diatom
plankton
FLOODING
RIVERS
DEAD-ZONES
POOLS
macrophytes
epiphytes
$u^* = 0.001$
$u^* = 0.01$
$u^* = 0.1$
ROCKY
RIFFLES
epipsamms
epiliths
0·01
0·1
1·0
Velocity u (m s^{-1})
(b)

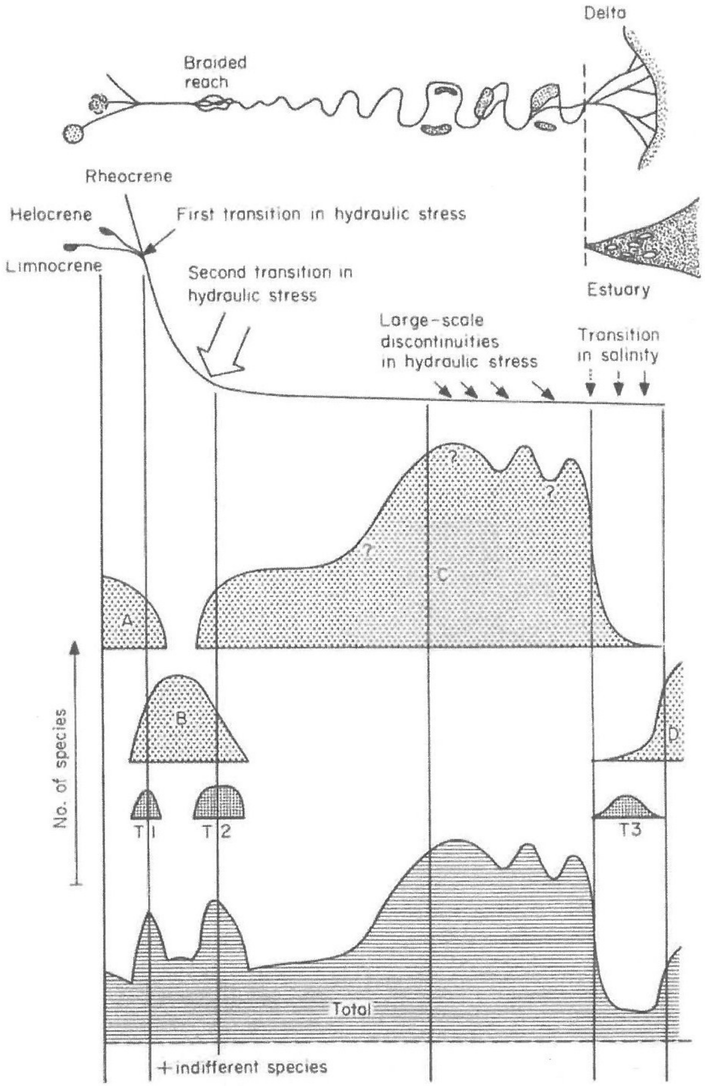
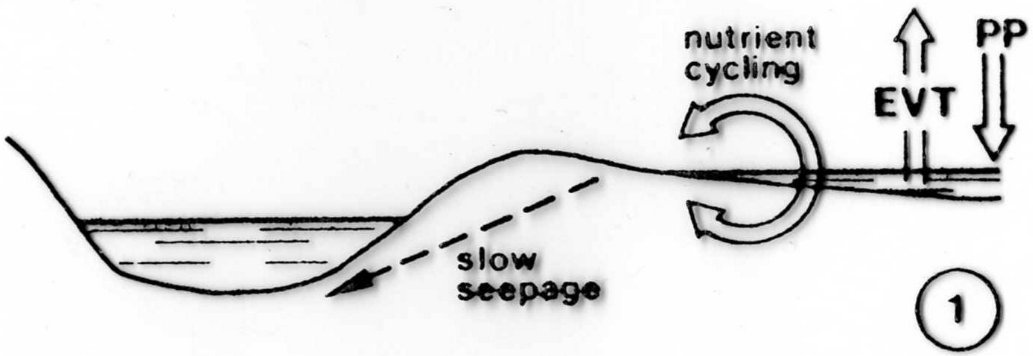


FIG. 8. Proposal for a general faunistic zonation pattern of the benthos in pristine streams (aerial view and slope) with 'standard' flow characteristics. Source types: rheocrene—source discharges directly into a channel; helocrene: source discharges into a marshy pond; limnocrene—source discharges into a pond. Not all of the components shown here can be or must be present in a stream. The species distribution in a running water that starts with a helocrene and ends with an estuary is indicated in our example. Species occurring in the spring (A) and in the reach of high slope (B) overlap at the first transition in hydraulic stress. Species of group B and species occurring in the stream after it has entered the flood-plain (C) overlap at the second transition in hydraulic stress, where pristine streams are frequently braided. Patterns in the large river are rather speculative due to sparse information. In the brackish zone a third overlap is found between species of group C and the marine fauna (D). In all three zones of species overlap few species occur which are solely found in these reaches of transition (T1, T2, T3). Species which do not characterize a zone are omitted.

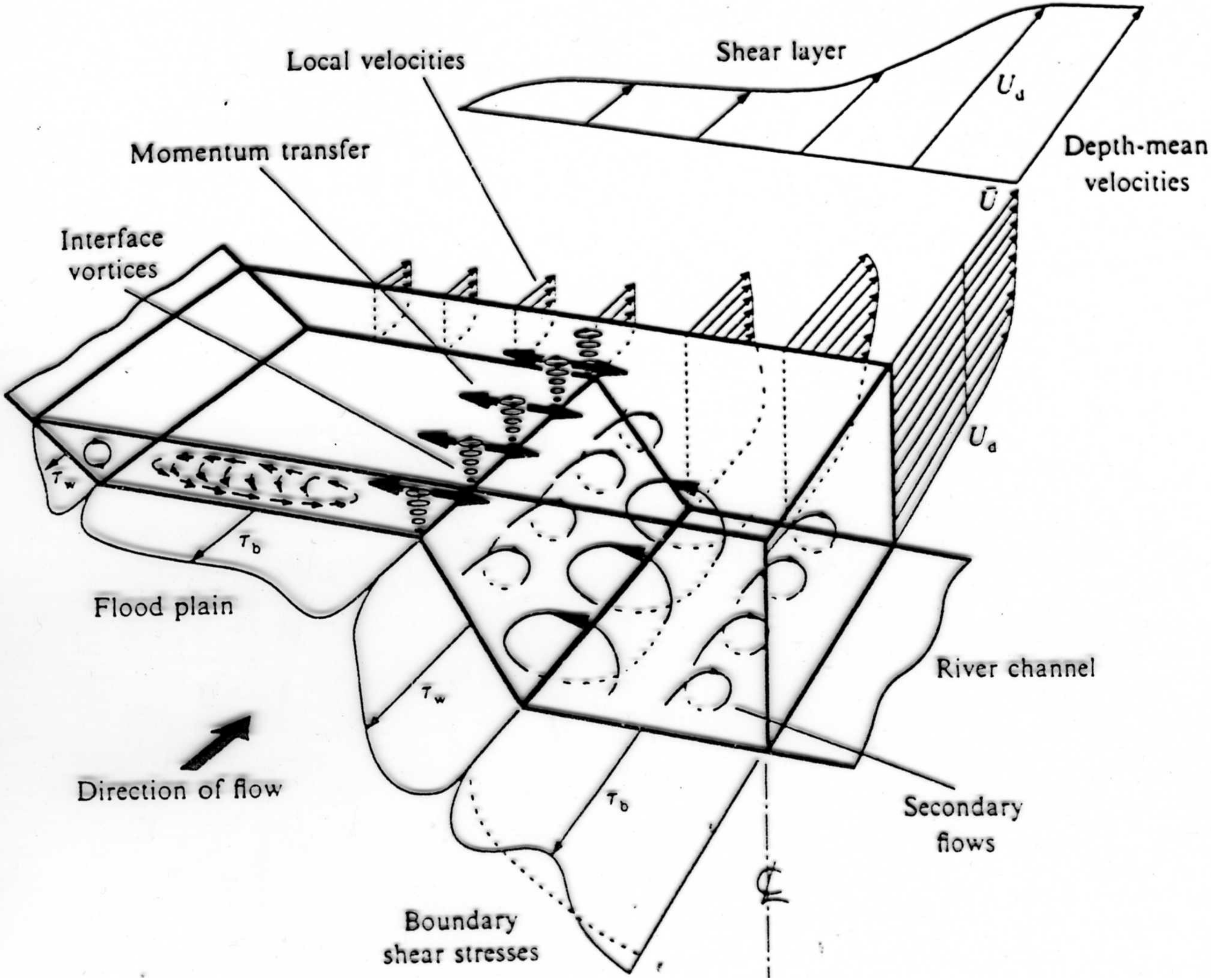
Prostorově – klinální koncept

- Laterální (boční) propojení (komunikace)
  - Koloběh materiálu (hmoty) v systému břeh / koryto a záplavové území (niva)/koryto (Sedell et al. 1990; Wetzel & Ward 1992)


nutrient cycling
EVT
PP
slow seepage
①

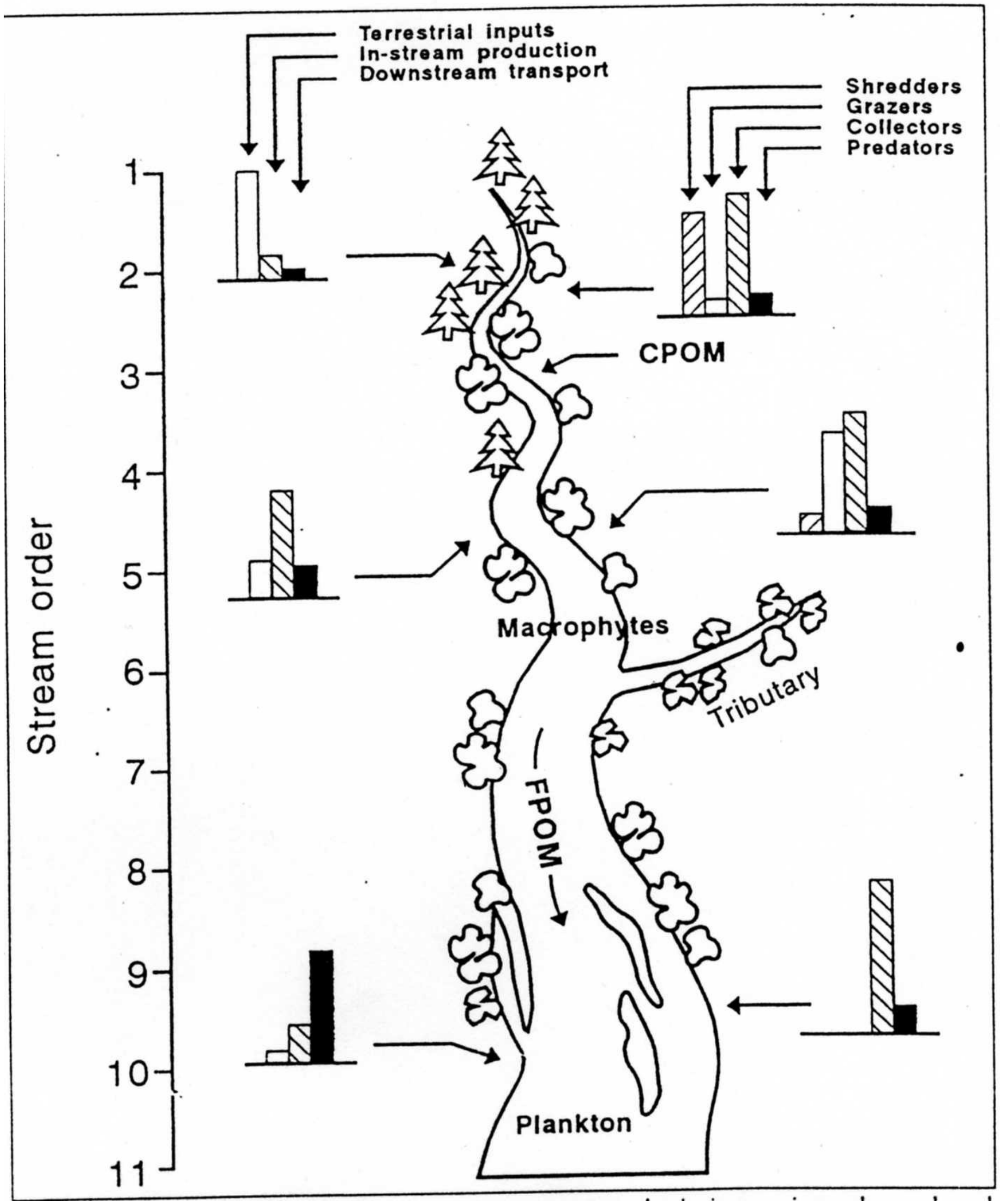

rapid overflow
②


slow drainage
③


Local velocities
Shear layer
U_d
Momentum transfer
Depth-mean velocities
$\bar{U}$
Interface vortices
U_d
τ_w
τ_b
Flood plain
River channel
τ_w
Direction of flow
τ_b
Secondary flows
℄
Boundary shear stresses

Prostorově – klinální koncept

- Podélné propojení (komunikace) toku
  - Proti/poroudový koloběh hmoty a organismů (Vannote et al 1980, Newbold 1992)


Terrestrial inputs
In-stream production
Downstream transport
Shredders
Grazers
Collectors
Predators
Stream order
1
2
3
4
5
6
7
8
9
10
11
CPOM
Macrophytes
Tributary
FPOM
Plankton

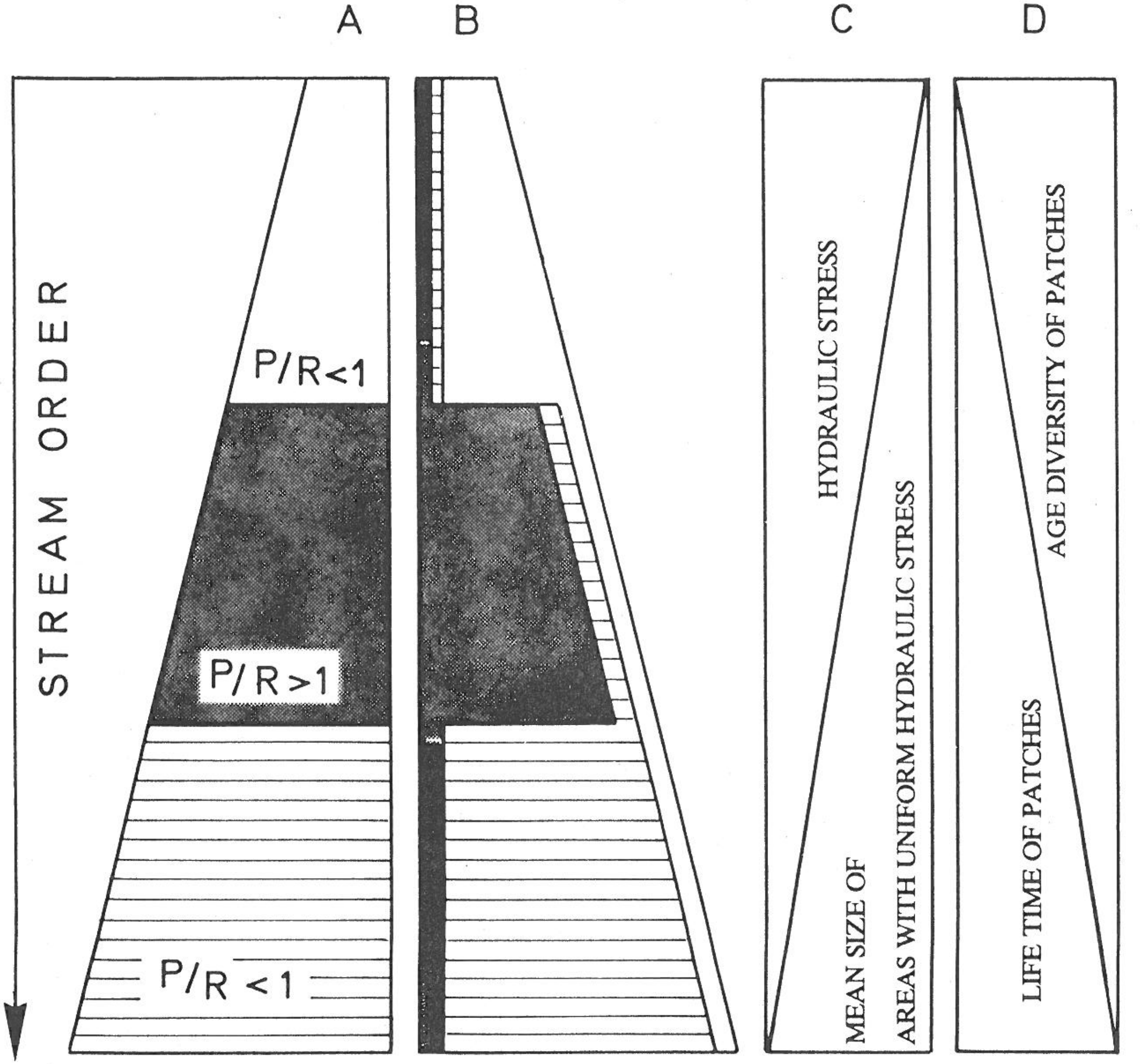
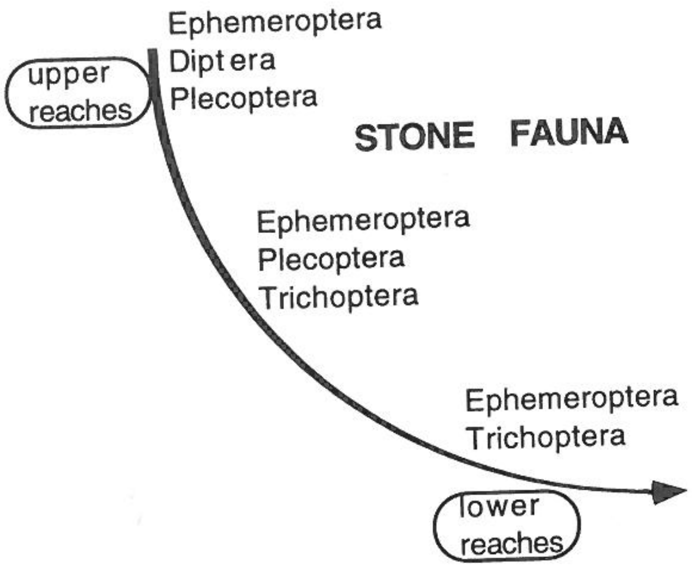
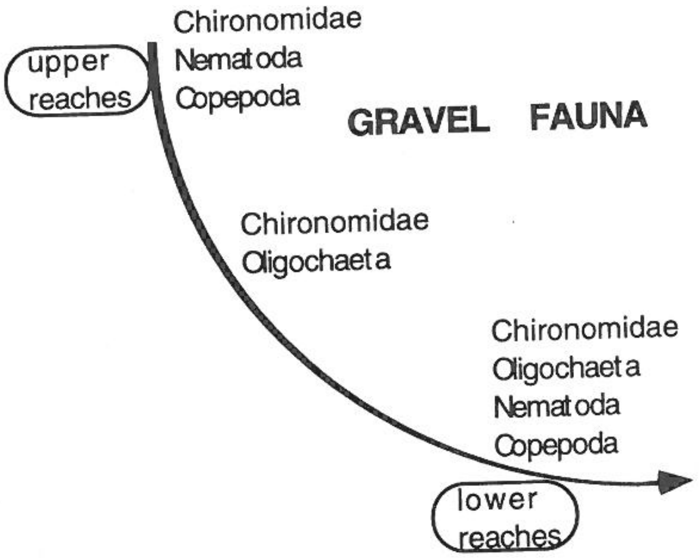


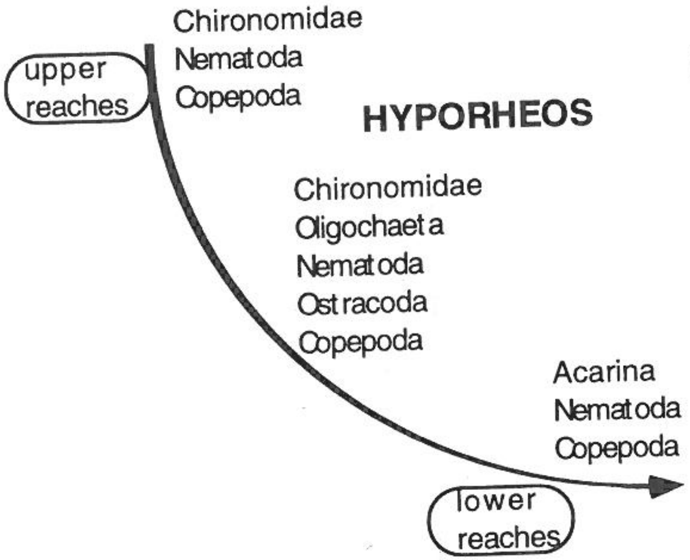
Fig. 2. A: The classical RCC configuration. B: Modification of the classical RCC to include habitat heterogeneity. C: Hydraulic regulation and size of physical habitats. D: Temporal responses to hydraulics and streamsize.

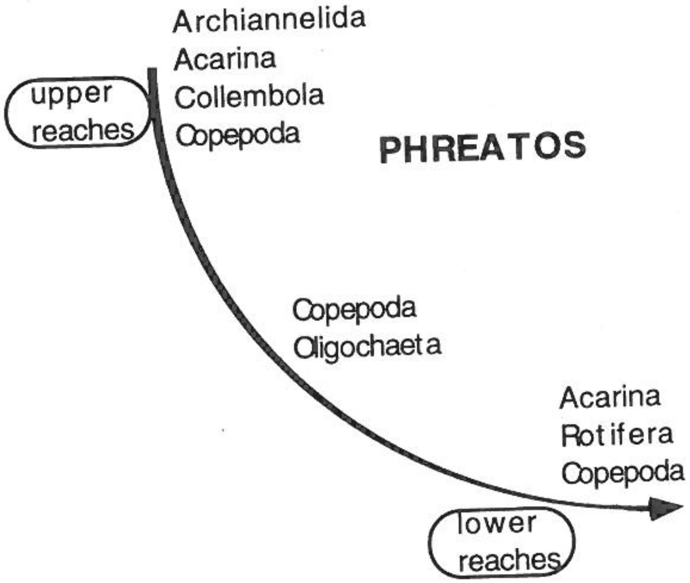
Prostorově – klinální koncept

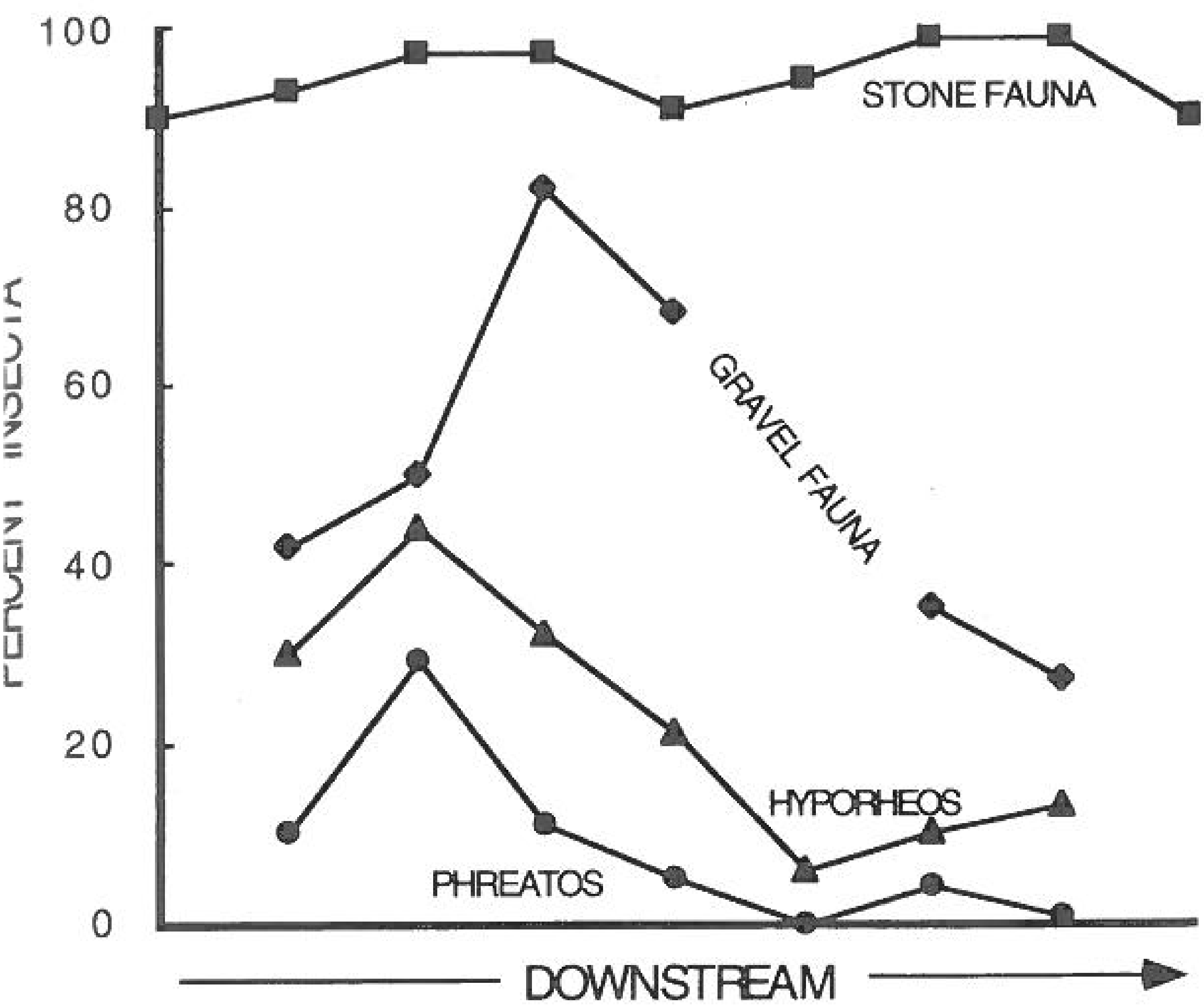
- Vertikální propojení – koloběh
  - Hyporeal/řečiště, hyporeos/bentos
  - Koloběh organizmů a hmoty (Pennak&Ward 1986; Ward 1989; Triska et al 1996 ……)


upper reaches
Ephemeroptera
Diptera
Plecoptera
STONE FAUNA
Ephemeroptera
Plecoptera
Trichoptera
Ephemeroptera
Trichoptera
lower reaches


upper reaches
Chironomidae
Nematoda
Copepoda
GRAVEL FAUNA
Chironomidae
Oligochaeta
Chironomidae
Oligochaeta
Nematoda
Copepoda
lower reaches


upper reaches
Chironomidae
Nematoda
Copepoda
HYPORHEOS
Chironomidae
Oligochaeta
Nematoda
Ostracoda
Copepoda
Acarina
Nematoda
Copepoda
lower reaches


upper reaches
Archiannelida
Acarina
Collembola
Copepoda
PHREATOS
Copepoda
Oligochaeta
Acarina
Rotifera
Copepoda
lower reaches


100
80
60
40
20
0
PERCENT INSECTA
STONE FAUNA
GRAVEL FAUNA
HYPORHEOS
PHREATOS
DOWNSTREAM

Časové modely

- Průběžná redistribuce benthosu
  - Drift a kolonizační dynamika
    - Townsend & Hildrew (1976)
  - Proudová distribuce – časová různorodost v různých podmínkách
    - Vliv nově příchozích populací, interakce a vytěsňování netolerantních druhů
      - Hemphill & Cooper 1983
      - Power & Stewart 1987

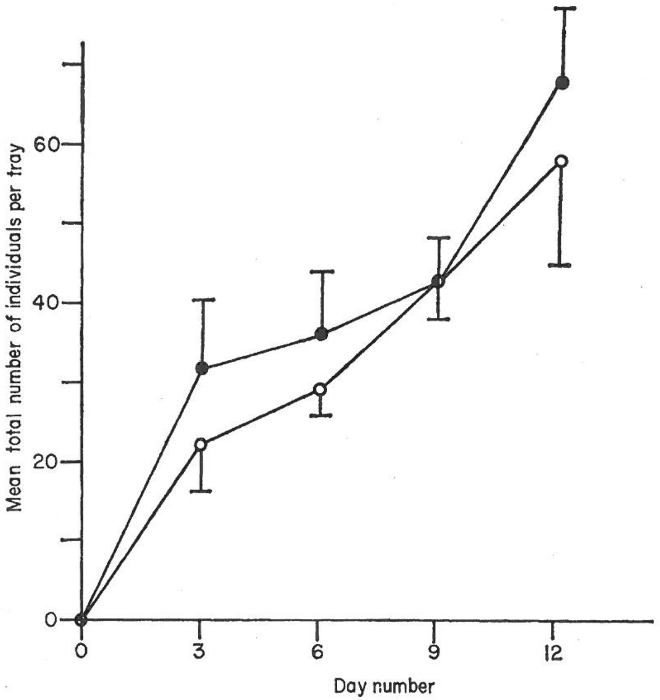


FIG. 1. Relationship between mean numbers of individuals (+ or − standard error) colonizing bottom trays (●) or suspended trays (○) and length of experiment (days).

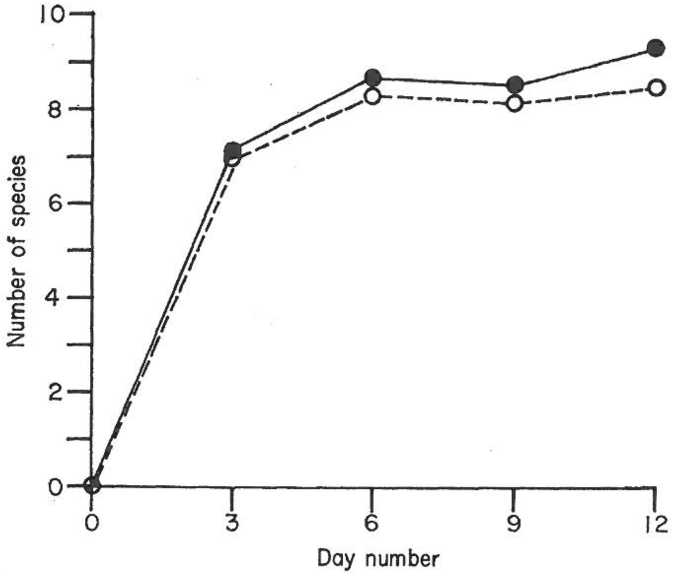


FIG. 2. Species colonization of bottom (●) and suspended trays (○).

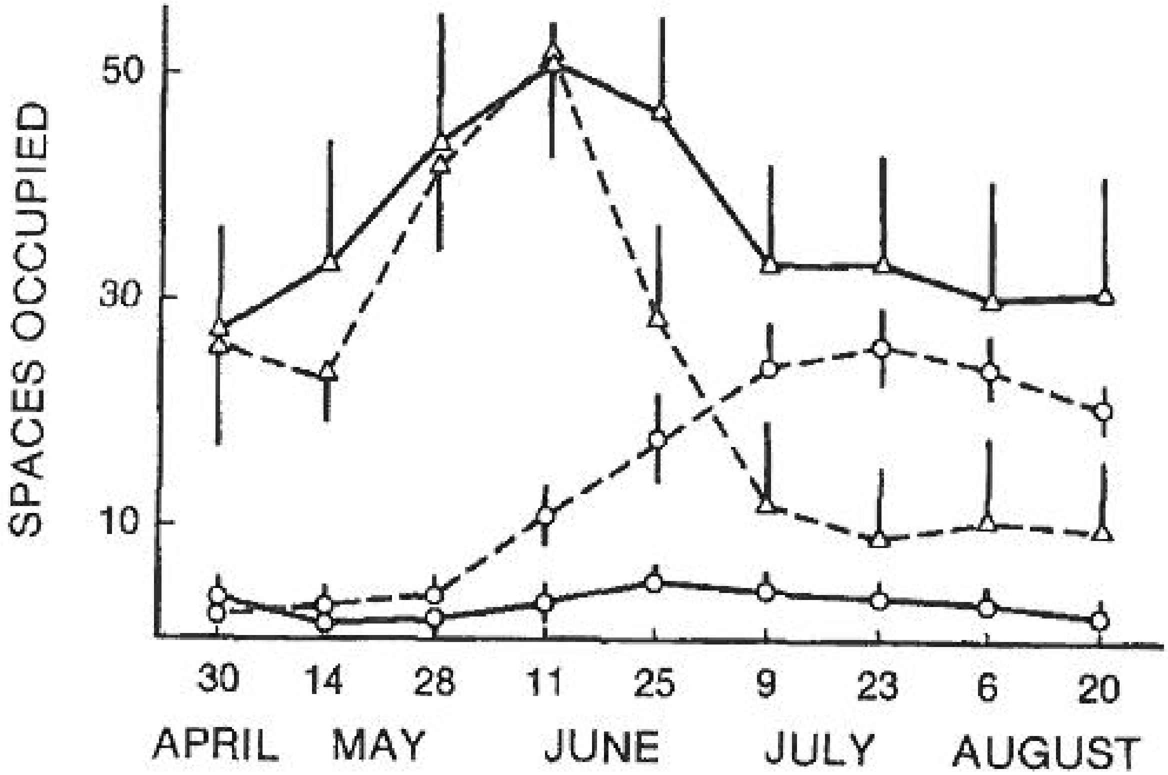


Fig. 2. Temporal changes in the amount of space occupied by *Simulium* (triangles) and *Hydropsyche* (circles) in quadrats which were disturbed every two weeks (solid line) or were left undisturbed (controls, dashed line). Quadrats disturbed every 4 weeks or every 8 weeks occupied intermediate positions between the 2 week and control lines. Bars represent standard errors

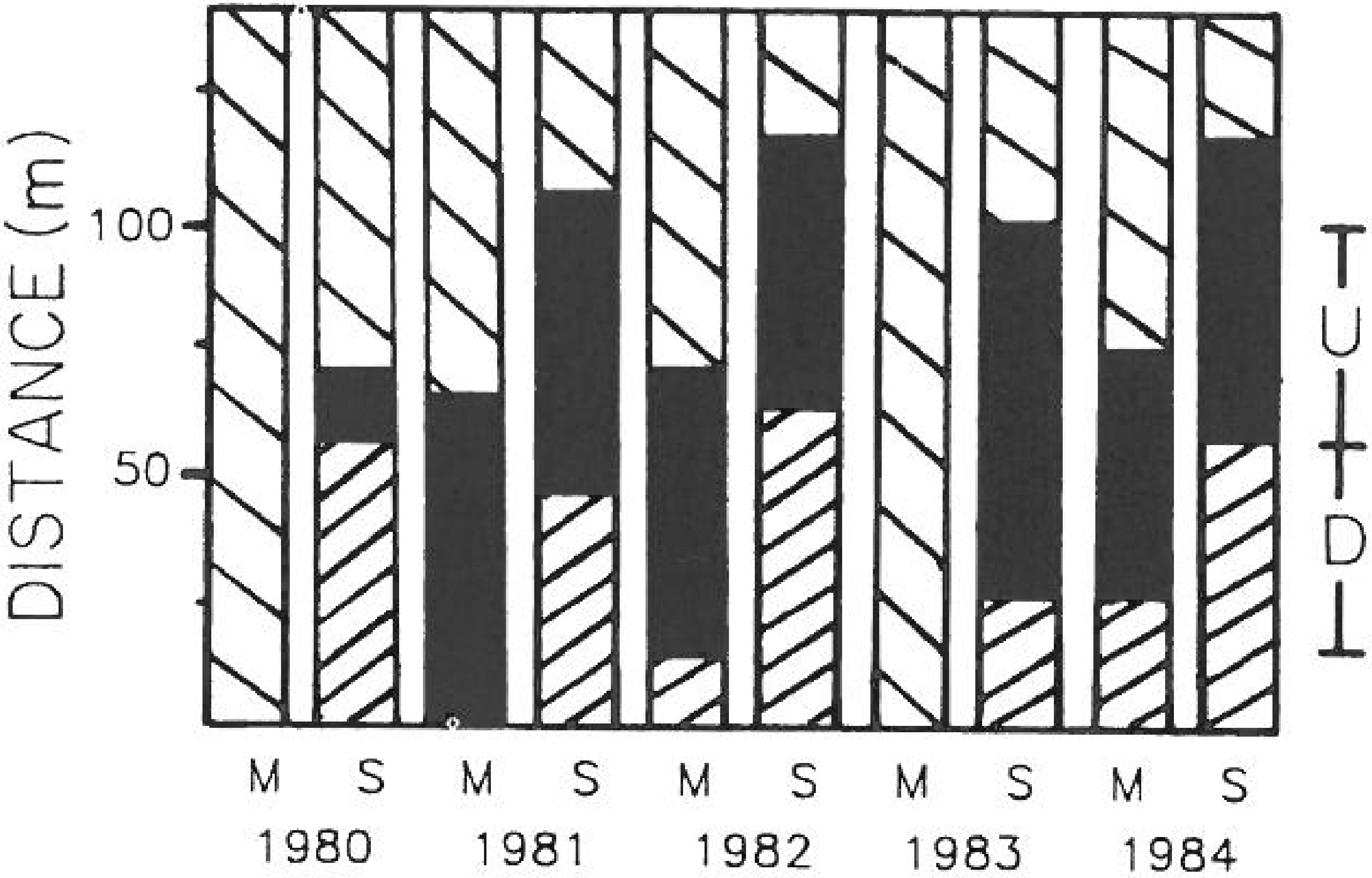
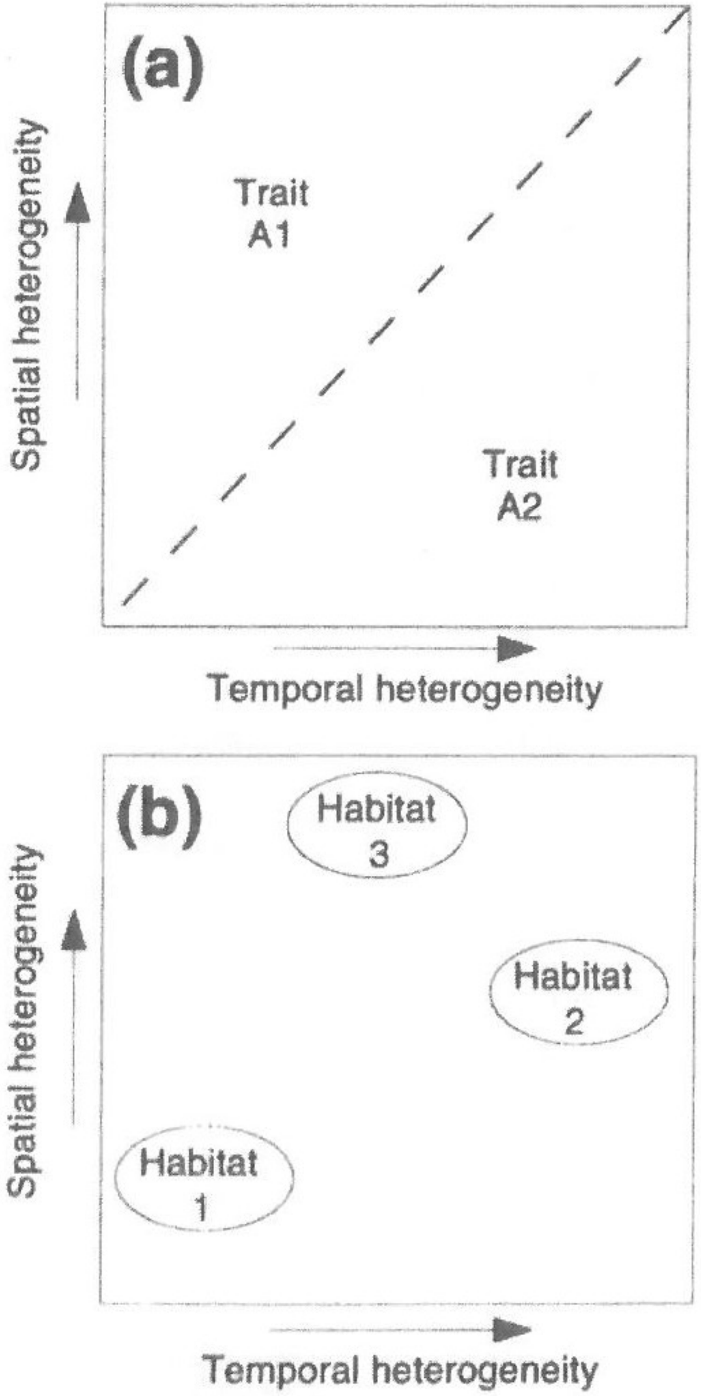


FIG. 3. Year-to-year variation in spatial distribution of *Hydropsyche* ▨ and *Simulium* ▧ in early (May) and late (September) summer in Refugio Creek. The zone of overlap between the two taxa is indicated by ■. The bar to the right indicates the upstream (U) and downstream (D) reaches of the stretch of stream studied in this experiment.

Časově – prostorové modely

- Habitat templet concept
  - Southwood 1977, Townsend & Hildrew 1994, Statzner at al. 1994 ……
- Refugia concept
  - Seddell et al. 1990, Townsend & Hildrew 1994
- Patch-dynamics concept
  - Townsend 1989, 1991


(a)
Trait A1
Trait A2
Spatial heterogeneity
Temporal heterogeneity
(b)
Habitat 3
Habitat 2
Habitat 1
Spatial heterogeneity
Temporal heterogeneity

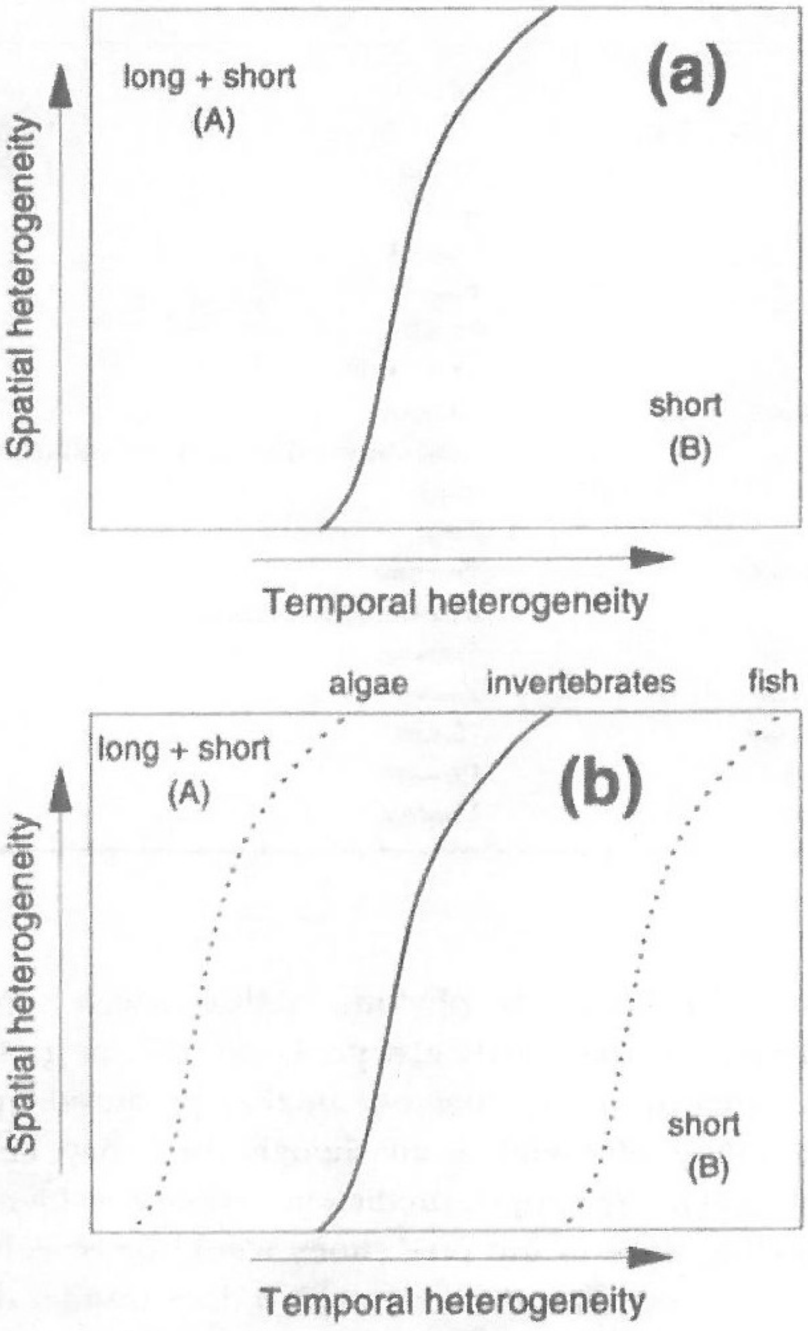

(a)
long + short
(A)
short
(B)
Spatial heterogeneity
Temporal heterogeneity
algae
invertebrates
fish
(b)
long + short
(A)
short
(B)
Spatial heterogeneity
Temporal heterogeneity

Table 1 Species traits predicted in areas A and B of the habitat templet in Fig. 4

Species trait	Area A	Area B
Minimum age at reproduction	Old–young	Young
Descendants per reproductive cycle	Few–many	Many
Reproductive cycles per year	<1–several	Several
Potential life span	Long–short	Short
Potential size	Large–small	Small
Total reproductive cycles per individual	Many–one	Few–one
Parental care	Present–absent	Absent
Reproductive technique	Diverse	Single individual produces offspring
Annual P/B ratio	Low–high	High
Attachment	None–firm	Firm
Body flexibility	Inflexible–flexible	Flexible
Body form	Diverse	Streamlined–flattened
Inundation tolerance	Absent–present	Present
Desiccation tolerance	Absent–present	Present
Mobility	Immobile–mobile	Mobile
Relatively invulnerable life stages	Absent–present	Present
Potential for regeneration	Absent–present	Present

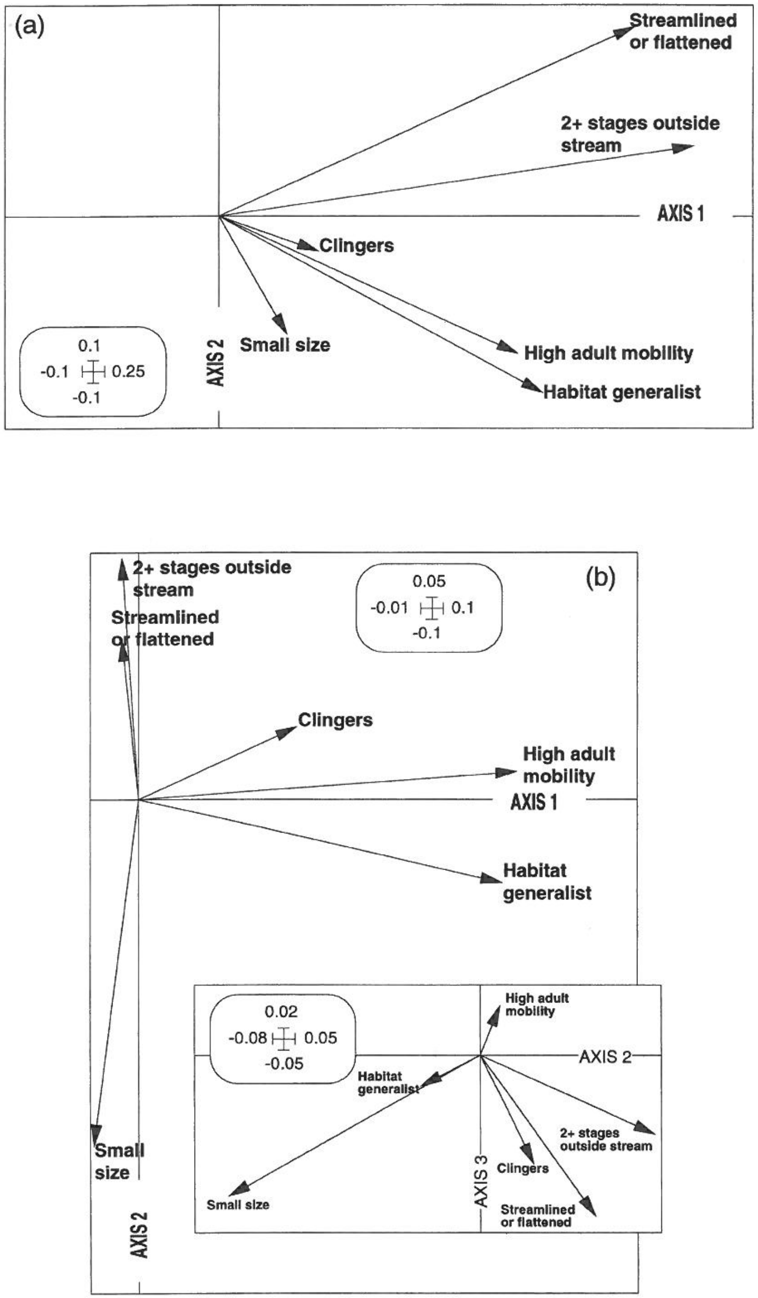


Fig. 3 Typologies of species traits produced using a centred principal components analysis: (a) according to the percentage of individuals per site that possess the traits; (b) according to the percentage of taxa per site that possess the traits (arrangement of traits according to axis 2 *v* 3 is inset).

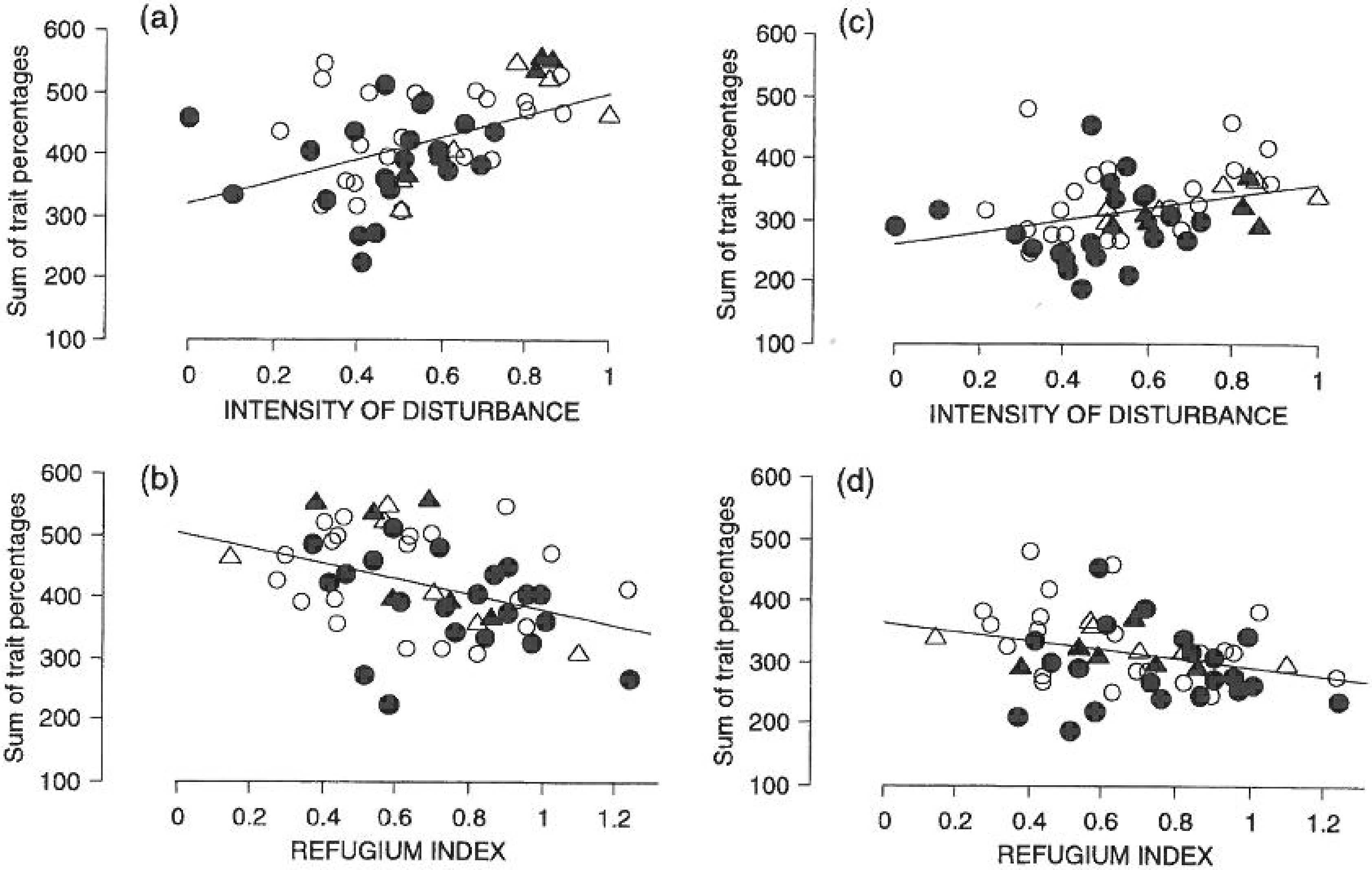
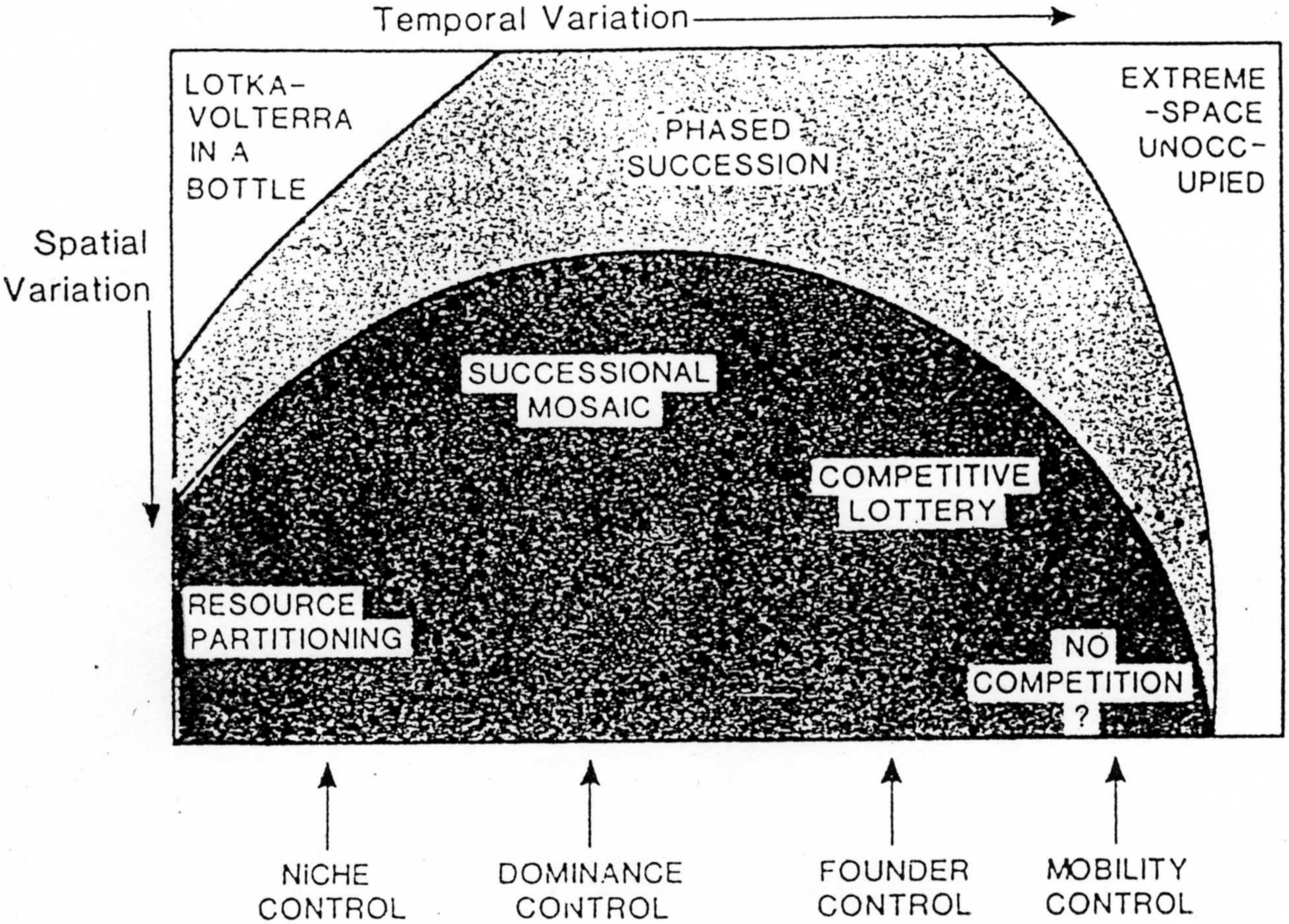
(a)
Sum of trait percentages
600
500
400
300
200
100
0
0.2
0.4
0.6
0.8
1
INTENSITY OF DISTURBANCE
(c)
Sum of trait percentages
600
500
400
300
200
100
0
0.2
0.4
0.6
0.8
1
INTENSITY OF DISTURBANCE
(b)
Sum of trait percentages
600
500
400
300
200
100
0
0.2
0.4
0.6
0.8
1
1.2
REFUGIUM INDEX
(d)
Sum of trait percentages
600
500
400
300
200
100
0
0.2
0.4
0.6
0.8
1
1.2
REFUGIUM INDEX

Table 5 Relationships between the percentage of taxa per site that possess each of six traits and intensity of disturbance. R^2, percentage of variation explained; *P*, probability that slope of the relationship is different from zero; s, sign of the best fit regression line

	Intensity of disturbance			Refugia index		
Species traits	R^2	*P*	s	R^2	*P*	s
Small size	0.044	0.126	+	0.008	0.510	–
High adult mobility	0.078	0.041	+	0.129	0.008	–
Habitat generalist	0.137	0.006	+	0.198	0.001	–
Clingers	0.021	0.300	+	0.006	0.567	+
Streamlined or flattened	0.000	0.954	–	0.011	0.448	+
Two+ stages outside stream	0.000	0.998	+	0.006	0.574	+


Temporal Variation
Spatial Variation
LOTKA-VOLTERRA IN A BOTTLE
PHASED SUCCESSION
EXTREME -SPACE UNOCCUPIED
SUCCESSIONAL MOSAIC
COMPETITIVE LOTTERY
RESOURCE PARTITIONING
NO COMPETITION ?
NICHE CONTROL
DOMINANCE CONTROL
FOUNDER CONTROL
MOBILITY CONTROL

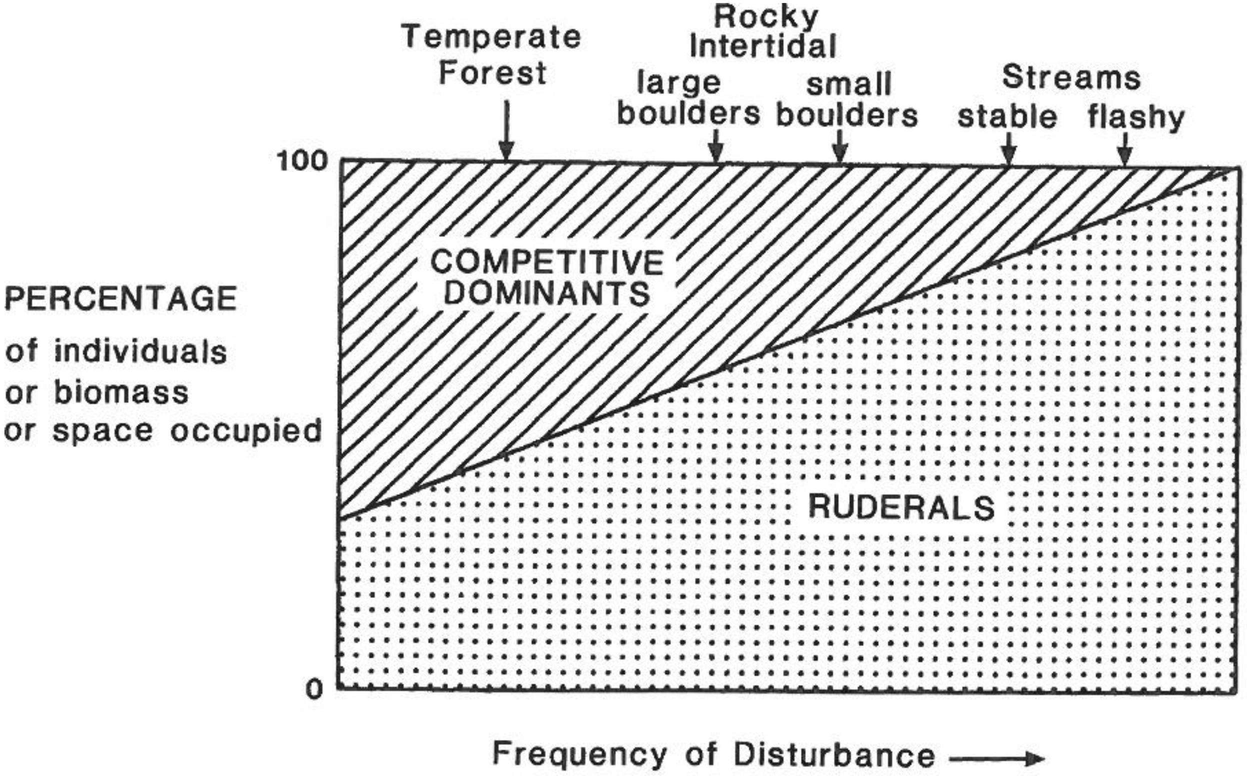


FIG. 5. Hypothetical relationship between frequency of disturbance and the relative representation of species that can be described as competitive dominants or ruderals.

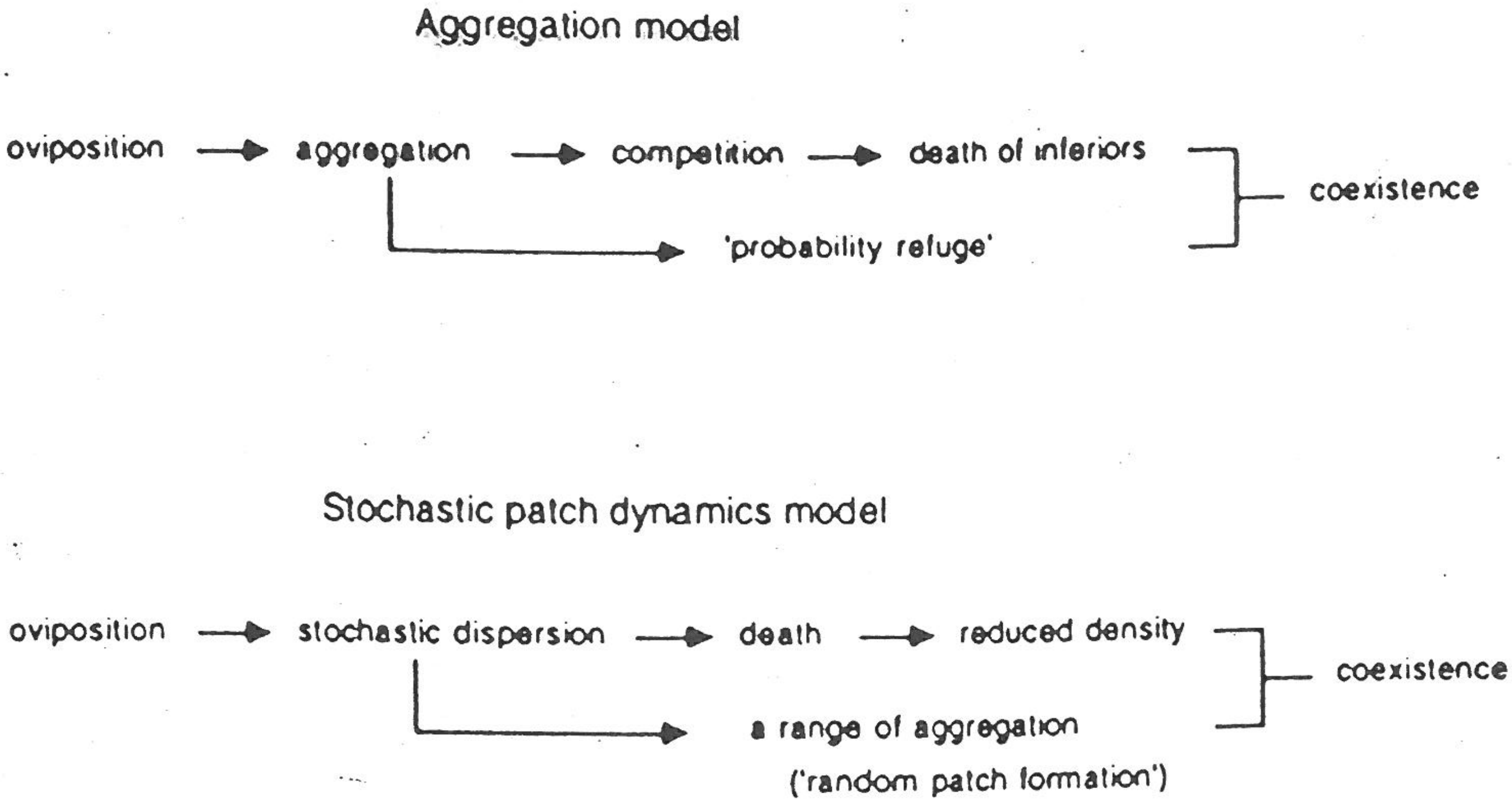


Fig. 6. Components of the "aggregation" model and the "stochastic patch dynamics" model for coexistence of species (see the text for details). (After TOKESHI 1995)

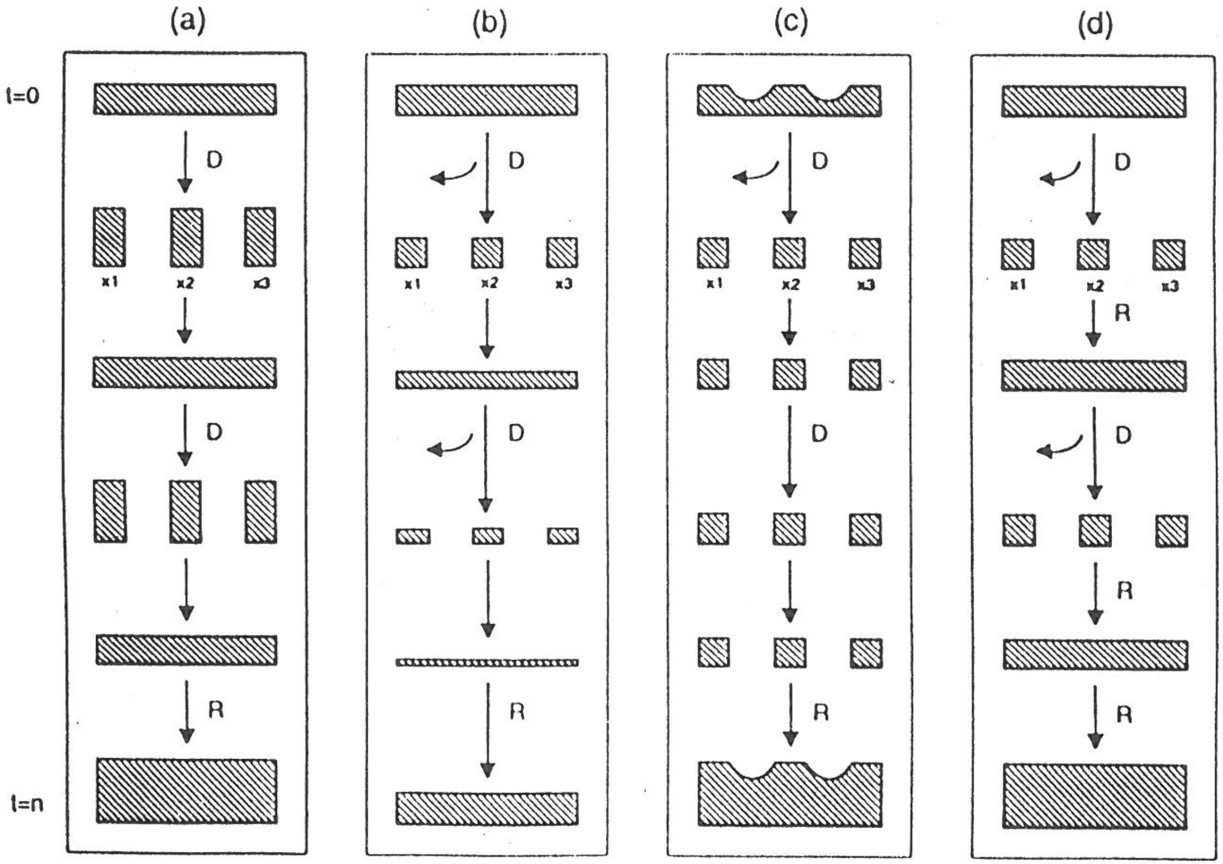


Fig. 4. Sequences of events through time t = 0 to t = n, in different models of "refugia" (a) – (d). At each stage of a sequence, the total block area (cross-hatched) represents population size while the arrangement of blocks represents spatial distribution. Disturbance events "D" are brief and punctuate longer periods of benign conditions. Horizontal arrows indicate when population numbers are reduced by disturbance. Recruitment "R" occurs only at t = n in models (a) – (c), but is frequent in model (d). (a) "catastrophe avoided", entire population is concentrated into refugia (x1, x2, x3 …) during disturbance events and redisperses subsequently to occupy the entire habitat when conditions are benign; (b) "incomplete catastrophe", population suffers high mortality from disturbance except for the fraction already in refugia (x1, x2, x3 …); this fraction subsequently disperses throughout the habitat, after the disturbance; (c) "refugia equals habitat", only that fraction of the population already in refugia survives disturbance and no dispersal occurs between events, except that some individuals may temporarily move into intervening habitat patches, particularly when the population is high and the conditions benign. In models (a) – (c) there are several to many disturbances per generation, recruitment occurs only at the end of a disturbance sequence (t = n). In model (d) there is "incomplete catastrophe" as in model (b), but recruitment is frequent. (Redrawn from Robertson et al. 1995).

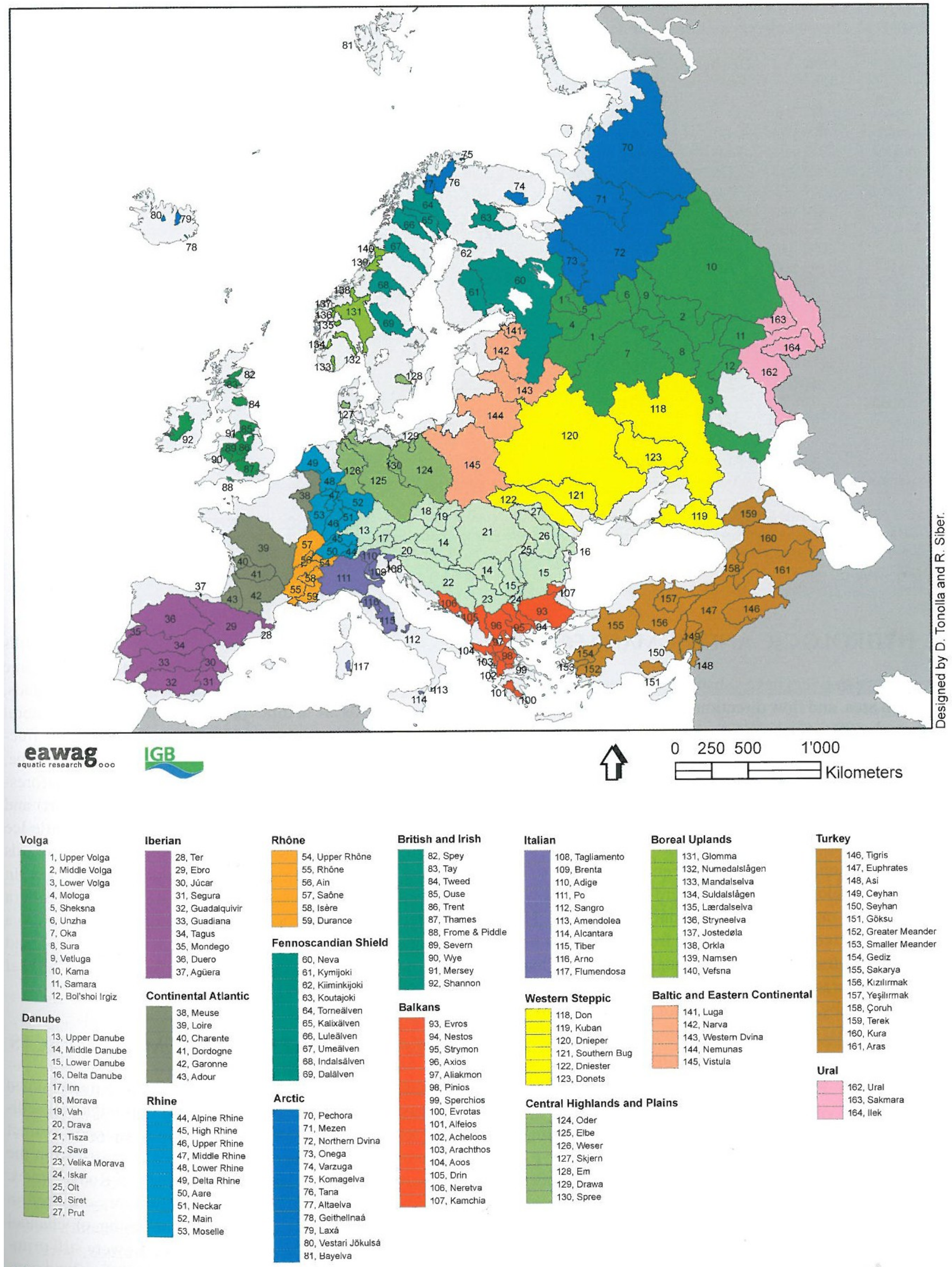


FIGURE 1.2 Spatial distribution of European catchments in 17 different geographic regions (different colors), including subcatchments of the Volga, Danube, Rhine, and Rhone Basins. Data sources: see Appendix.

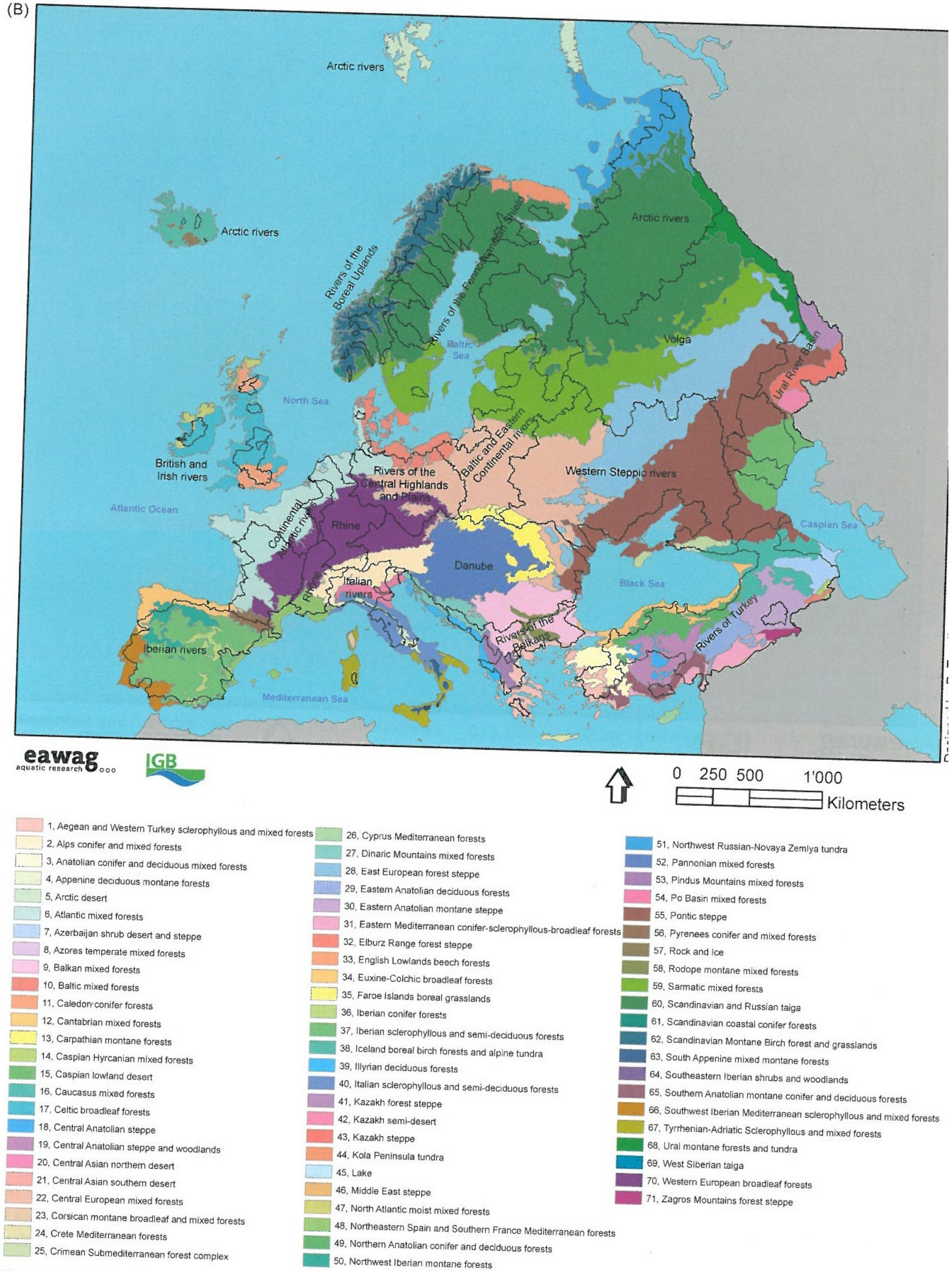
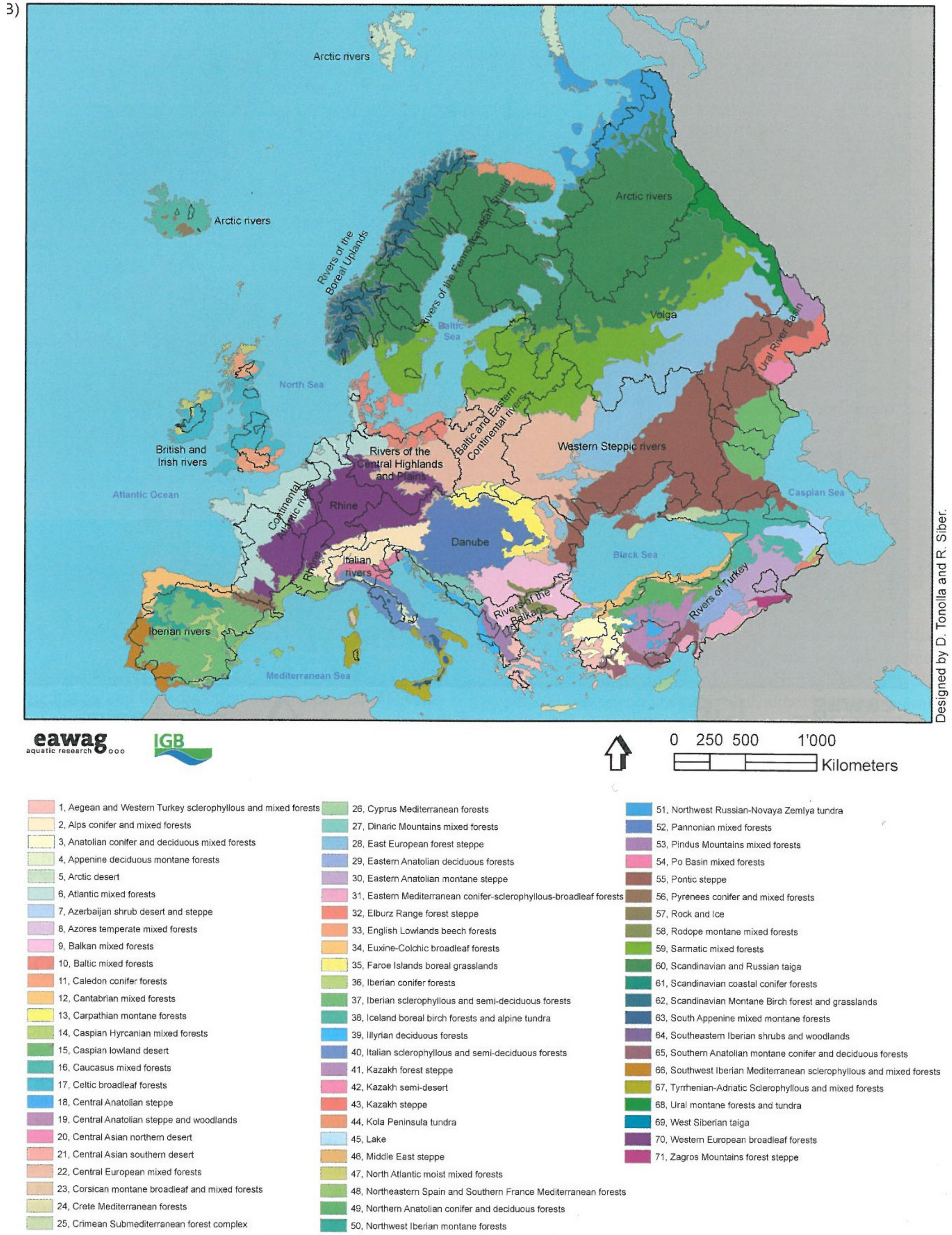


FIGURE 1.3 *(Continued)*.



GURE 1.3 *(Continued).*

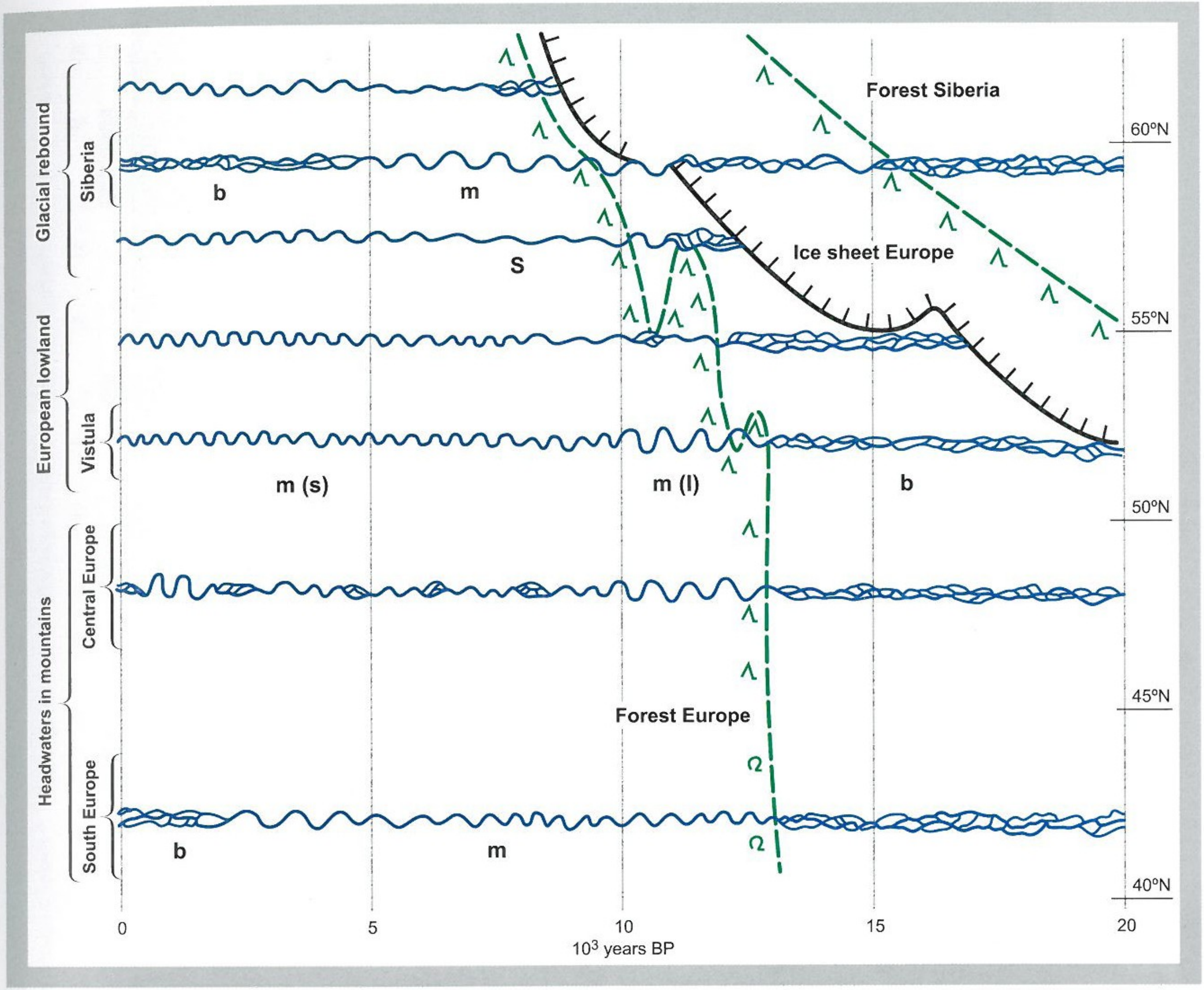


FIGURE 1.4 Changes in fluvial systems in a north–south cross-section through Europe: (b) braided (bed-load river); (m) meandering (suspended-loaded river); (m(s)): small meanders; (m(l)): large meanders. The diagram also includes the probable sequence of channel patterns for Siberian rivers. Redrawn from Starkel (1991).

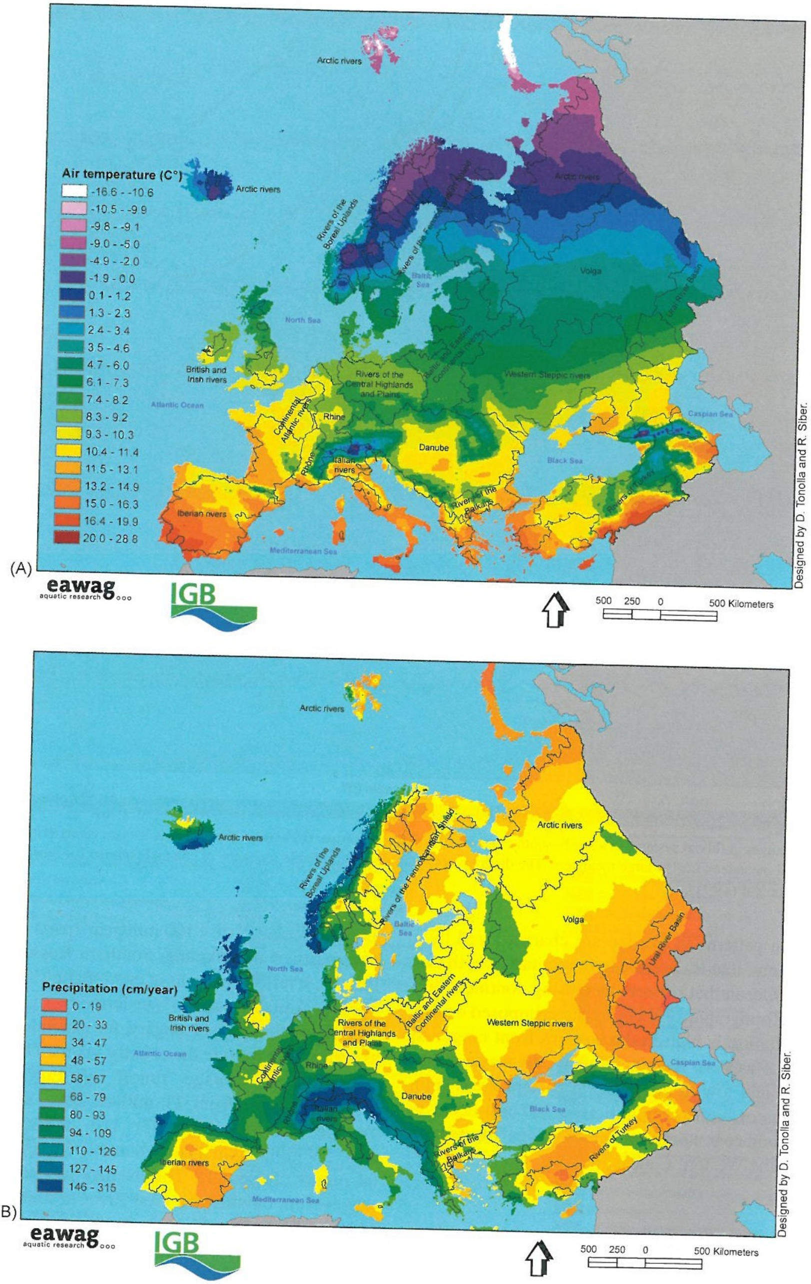


FIGURE 1.5 Mean annual air temperature (A) and mean annual precipitation (B) across Europe. Locations of the geographic regions covered in the book are indicated. Data sources: see Appendix.

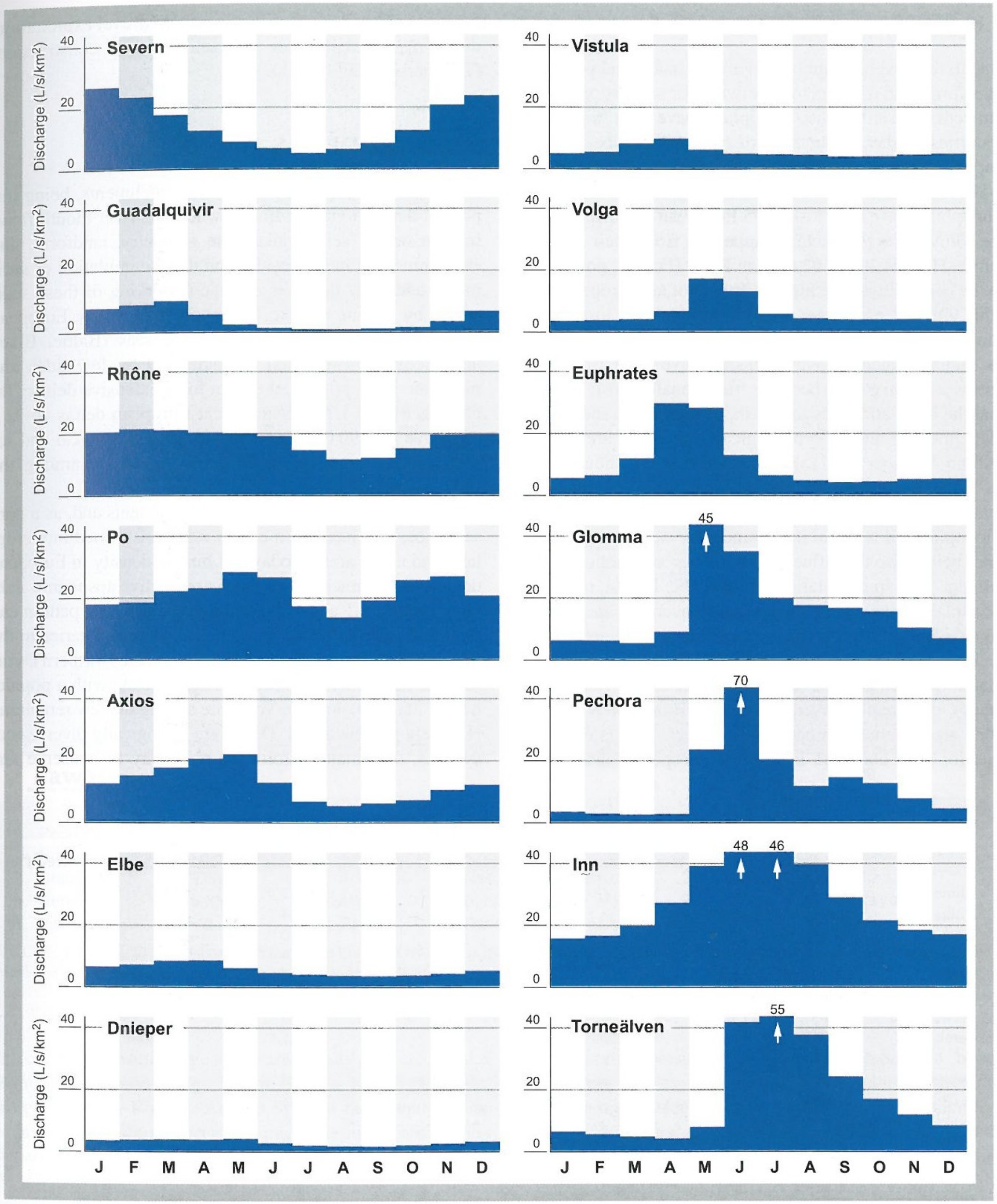
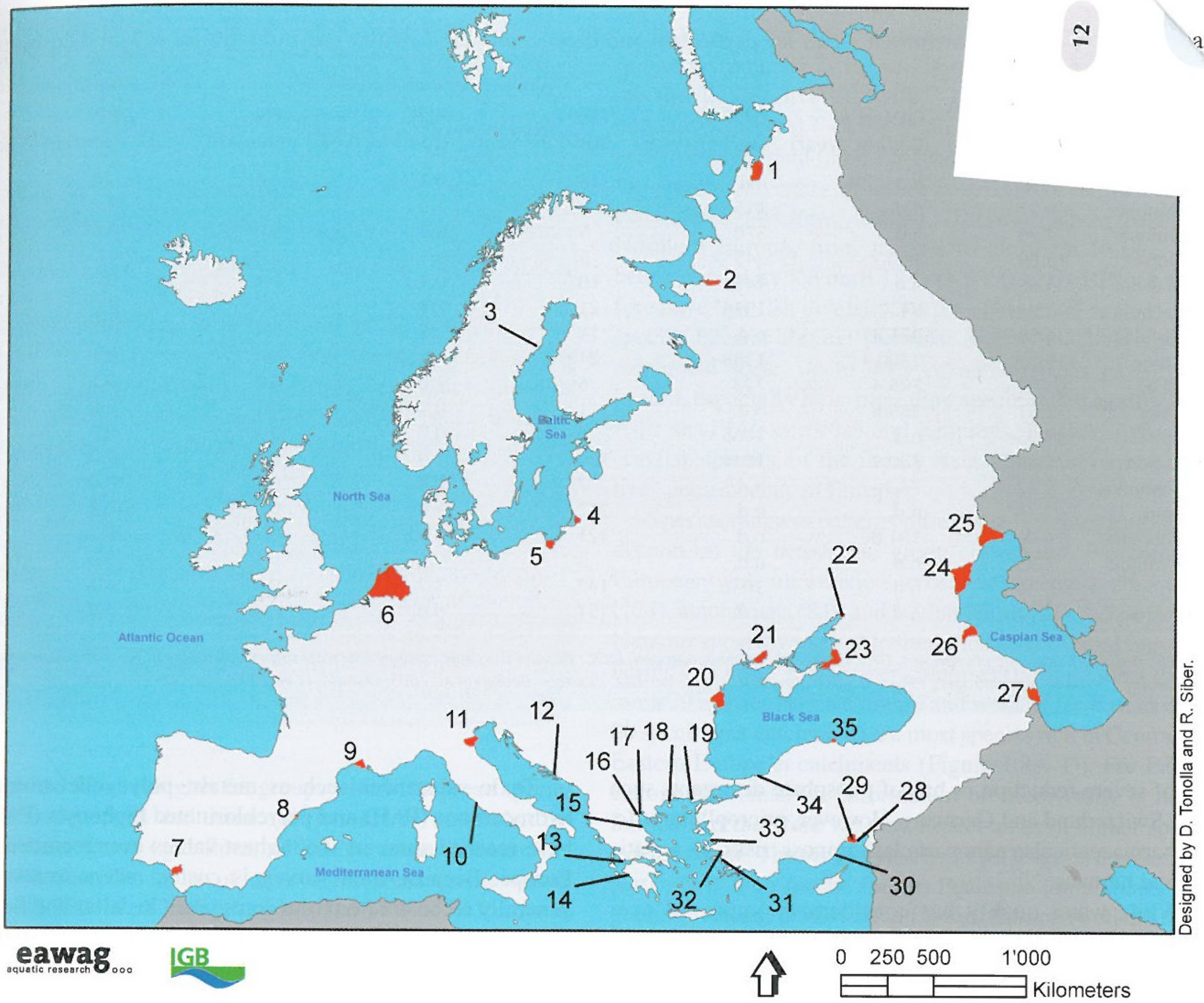


FIGURE 1.6 Seasonal distribution in catchment runoff (L/s/km^2) for selected rivers distributed across Europe. Runoff includes the difference between precipitation, evapotranspiration and catchment topography (Data source: Global Water Runoff Data Center, GRDC, http://grdc.bafg.de/servlet/is/2781/?lang=en).



1, Pechora
2, Northern Dvina
3, Umeälven
4, Nemunas
5, Vistula
6, Rhine
7, Guadalquivir
8, Ebro
9, Rhône
10, Tiber
11, Po
12, Neretva
13, Acheloos
14, Alfeios
15, Pinios
16, Aliakmon
17, Axios
18, Nestos
19, Evros
20, Danube
21, Dnieper
22, Don
23, Kuban
24, Volga
25, Ural
26, Terek
27, Kura
28, Ceyhan
29, Seyhan
30, Göksu
31, Greater Meander
32, Smaller Meander
33, Gediz
34, Sakarya
35, Kızılırmak

FIGURE 1.7 Spatial distribution of 35 important European river deltas (K. Tockner et al., unpublished data). The delimitation of each delta is based on published literature, expert opinion, and a river networks DEM.

major efforts are underway to conserve and

TABLE 1.2 Twenty of the largest river deltas in Europe (including Turkey and the Caucasus).

	Area (km²)	Average temperature (°C)	Population (people/km²)	Arable and Pasture (%)	Protected (%)
Rhine	25 347	9.2	492	66.2	0.9
Volga	11 446	10.3	53	68.4	24.7
Ural	8586	9.1	24	49.0	<0.1
Pechora	5490	−4.0	<1	1.4	26.3
Kuban	5422	11.7	63	51.5	20.3
Danube	4560	10.7	34	24.0	89.1
Kura	4175	15.5	78	17.6	20.6
Terek	4026	11.6	46	76.1	3.3
Po	2878	12.8	119	83.8	10.0
Dnieper	2833	8.7	80	78.8	7.4
N Dvina	2229	0.6	118	29.5	5.9
Guadalquivir	2213	17.6	152	60.8	31.9
Seyhan	1903	17.1	116	46.8	<0.1
Vistula	1858	7.7	187	85.7	<0.1
Rhone	1783	13.5	64	56.9	59.7
Nemunas	1088	6.7	24	60.0	18.6
Don	604	10.1	541	40.9	80.8
Kızılırmak	474	11.1	126	3.8	<0.1
Ebro	331	15.9	116	82.2	22.3
Nestos	319	12.5	53	29.5	14.6

Average annual temperature (1961–1990). Human population density: people per km². Protected: National parks, Ramsar sites, National nature reserves, and other nationally protected areas.

For data sources and detailed explanation see Appendix.

TABLE 1.3 Estimated catchment yields for particulate and dissolved organic matter and nutrients for selected Europea rivers

	DIP (kg/km^2/year)	DIN (kg/km^2/year)	DOC (kg/km^2/year)	TSS (ton/km^2/year)	POC (ton/km^2/year)	PN (ton/km^2/year)	PP (ton/km^2/year
Volga	2.39	n.d.	n.d.	18	0.2	0.0	0.0
Danube	30.21	n.d.	1152	86	1.0	0.1	0.0
Dnieper	2.96	n.d.	570	5	0.2	0.0	0.0
Don	13.60	19.1	245	5	0.1	0.0	0.0
N Dvina	5.65	n.d.	1494	10	0.4	0.1	0.0
Pechora	5.94	64.7	1954	21	0.5	0.1	0.0
Vistula	36.98	371.8	n.d.	14	3.1	0.4	0.1
Rhine	119.32	2200.4	1388	21	2.4	0.4	0.1
Elbe	63.94	795.4	753	6	1.6	0.2	0.1
Oder	32.61	389.8	n.d.	1	0.4	0.1	0.0
Loire	30.95	n.d.	1065	4	0.7	0.1	0.0
Kuban	25.88	330.9	1044	120	1.0	0.2	0.0
Nemunas	9.42	74.1	n.d.	7	0.6	0.1	0.0
Ebro	2.34	n.d.	n.d.	217	1.6	0.2	0.1
Glomma	16.06	191.8	n.d.	321	1.5	0.2	0.1
Kymijoki	3.95	n.d.	n.d.	3	0.3	0.1	0.0
Po	77.18	n.d.	3046	147	3.2	0.4	0.1
Seyhan	4.21	n.d.	n.d.	151	n.d.	n.d.	n.d.

DIP: dissolved inorganic phosphorus, DIN: dissolved inorganic nitrogen, DOC: dissolved organic carbon, TSS: total suspended solids, POC: particulate organic carbon, PN: particulate nitrogen, PP: particulate phosphorus. n.d.: no data. (Sources: Beusen et al. 2005; Dumont et al. 2005; Harrison et al. 2005).

TABLE 1.4 Global and European freshwater fauna species richness (after Lévêque et al. 2005; Balian et al. 2008)

Group	World	Europe	Proportion of global (%)
Bivalvia	1000	50	5
Gastropoda	4000	163	4
Ostracoda	2000	400	20
Copepoda	2085	902	43
Amphipoda	1700	350	21
Ephemeroptera	>3000	350	<10
Odonata	5500	150	3
Plecoptera	2000	423	21
Trichoptera	>10 000	1724	<17
Hemiptera	3300	129	4
Coleoptera	>6000	1077	<18
Diptera	>20 000	4050	<20
Lepidoptera	>1000	5	<1
Hymenoptera	>130	74	<56
Megaloptera	300	6	2
Pisces	>13 000	400	<3
Amphibia	5504	74	1
Aves	1800	253	14
Total	>82 500	10 580	<13

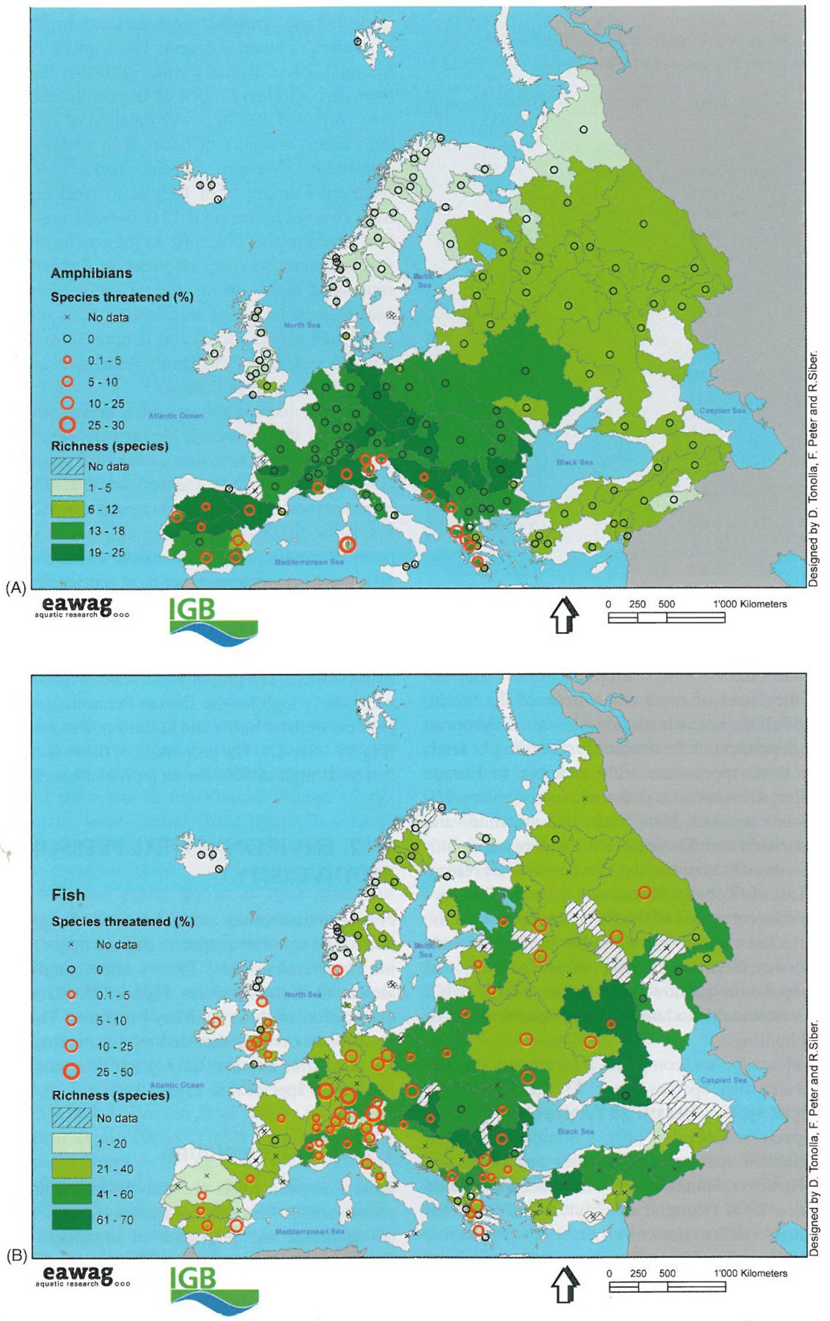
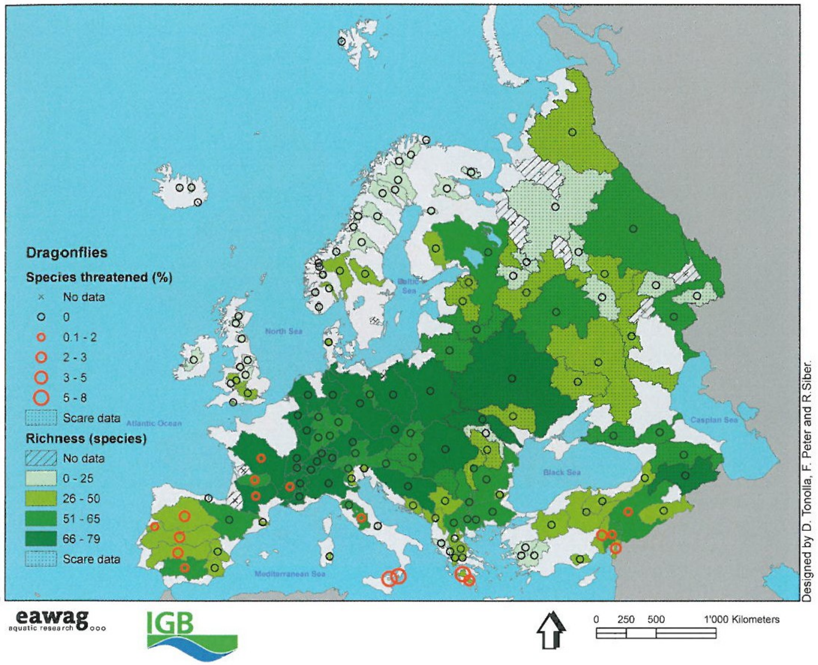


FIGURE 1.8 Species richness and relative proportions (%) of threatened species for each individual catchment: (A) Amphibians; (B) Fish; (C) Dragonflies; (D) Wetland birds. Data sources: see Appendix. Catchments are not always identical with catchments in Figure 1.2.



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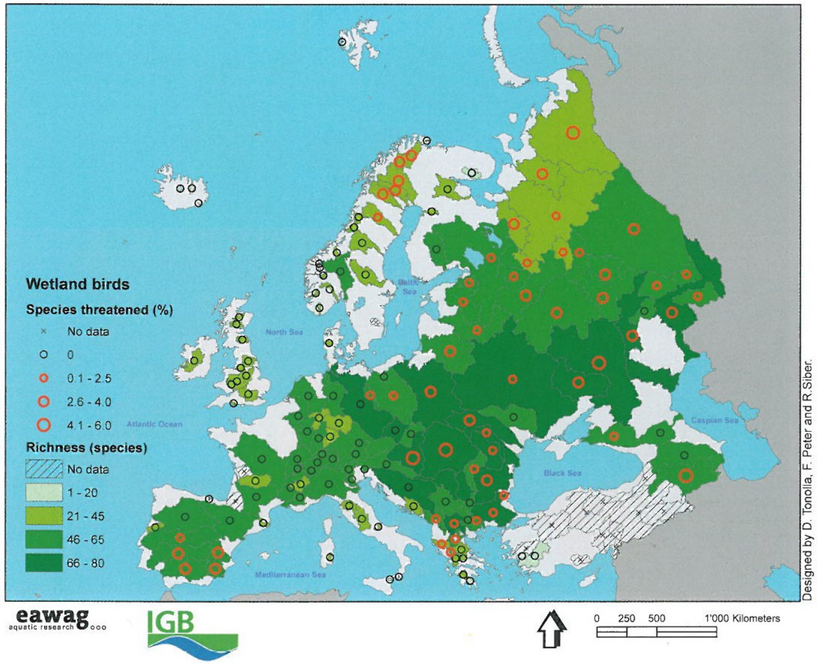
(C)



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(D)

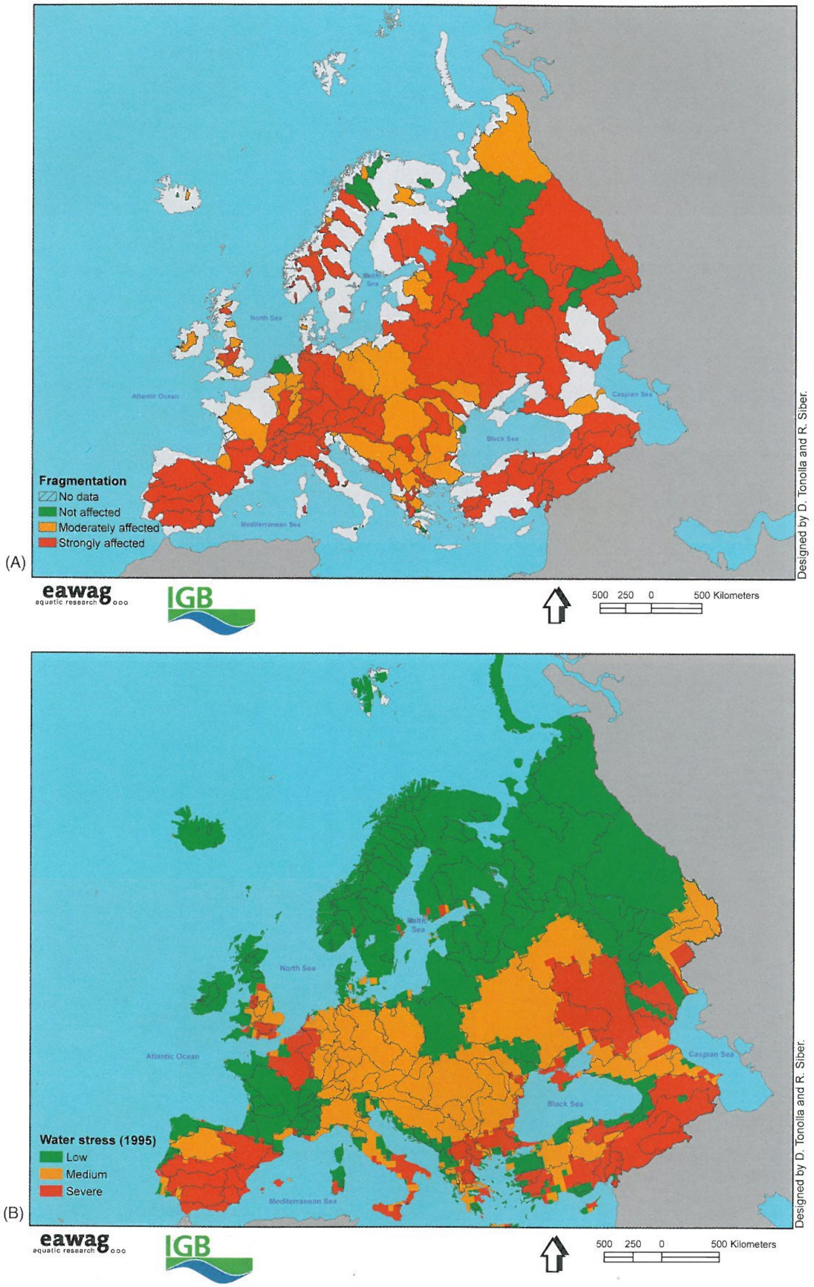
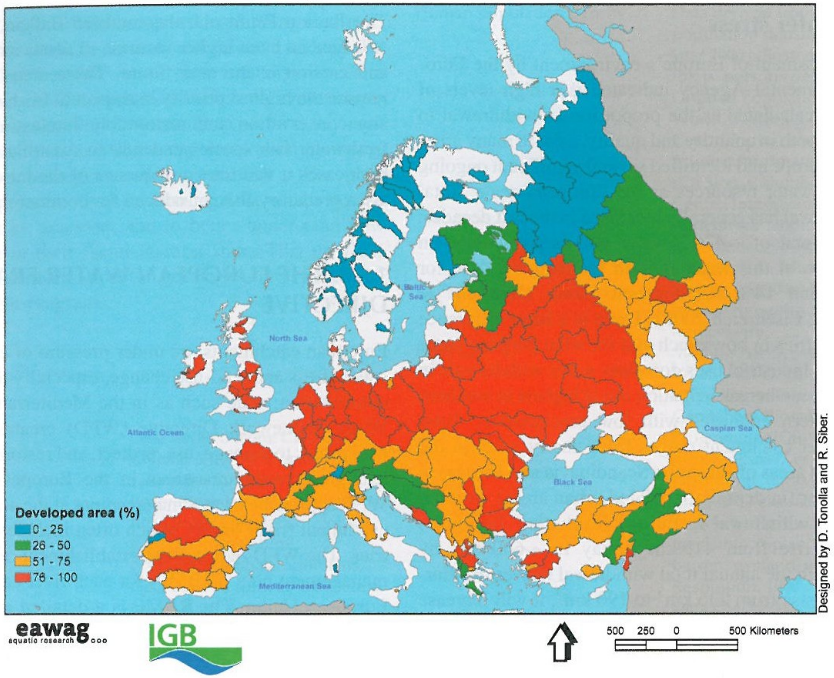
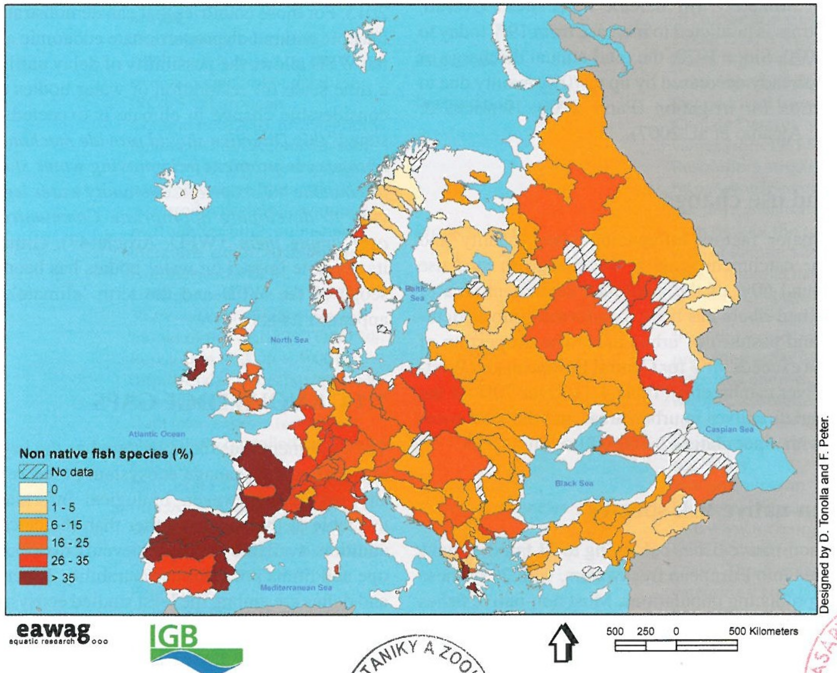


FIGURE 1.9 (A) Degree of fragmentation, (B) water stress as the proportion of withdrawal to availability, (C) developed area (urban, arable and pasture in % of the catchment), (D) relative proportion (%) of non-native fish species (Peter 2006). Data sources: see Appendix. Catchments are not always identical with catchments in Figure 1.2.


Developed area (%)
🟦 0 - 25
🟩 26 - 50
🟧 51 - 75
🟥 76 - 100
Baltic Sea
North Sea
Atlantic Ocean
Caspian Sea
Black Sea
Mediterranean Sea
eawag aquatic research
IGB
500 250 0 500 Kilometers
Designed by D. Tonolla and R. Siber.

(C)


Non native fish species (%)
▨ No data
0
1 - 5
6 - 15
16 - 25
26 - 35
> 35
Baltic Sea
North Sea
Atlantic Ocean
Caspian Sea
Black Sea
Mediterranean Sea
eawag aquatic research
IGB
500 250 0 500 Kilometers
Designed by D. Tonolla and F. Peter.

(D)

Designed by D. Tonolla and R. Siber.

Designed by D. Tonolla and R. Siber.

FIGURE 3.1 Digital elevation model (upper panel) and drainage network (lower panel) of the Danube River Basin.

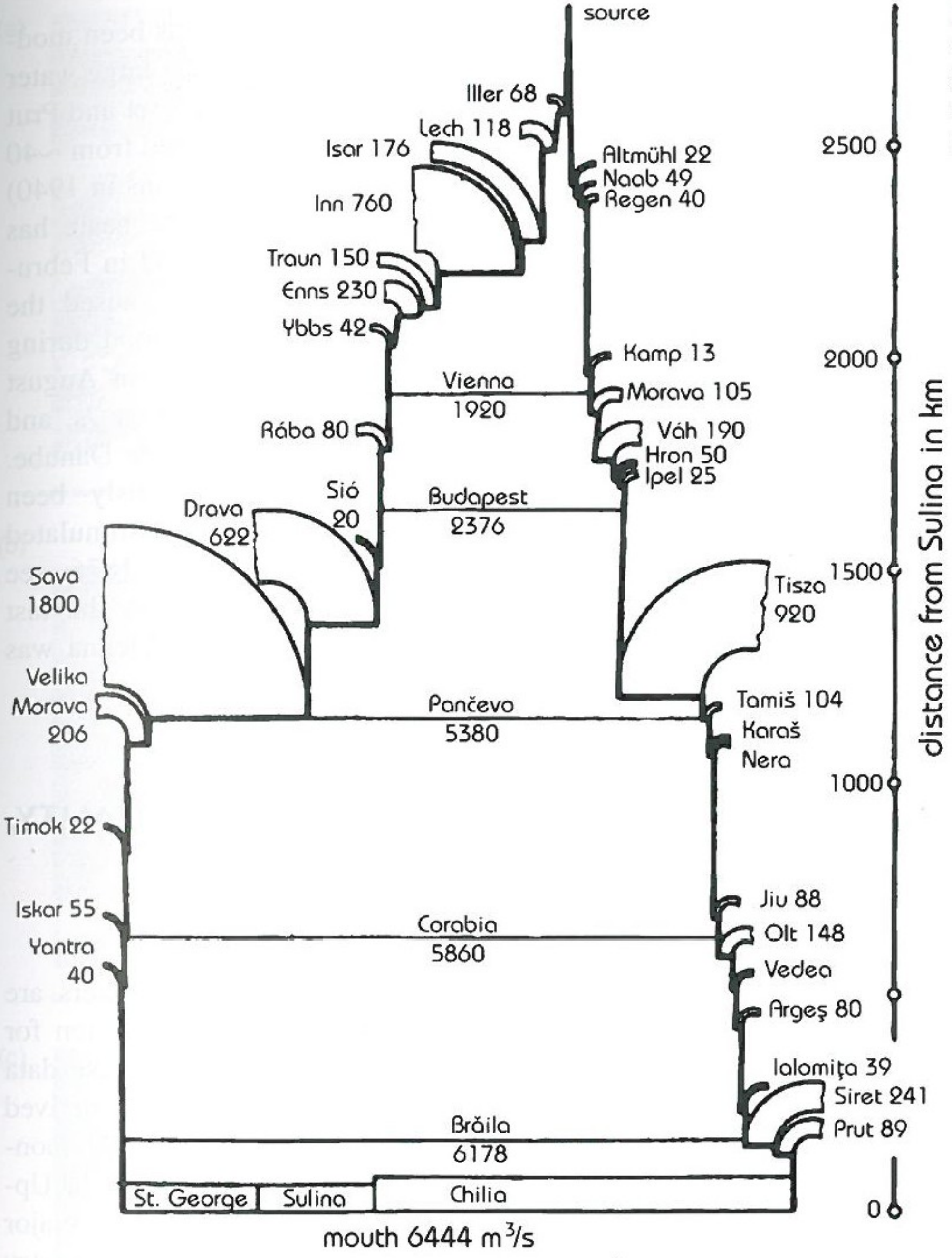

source
Iller 68
Lech 118
Isar 176
Inn 760
Altmühl 22
Naab 49
Regen 40
Traun 150
Enns 230
Ybbs 42
Kamp 13
Vienna
1920
Morava 105
Rába 80
Váh 190
Hron 50
Ipel 25
Sió
20
Budapest
2376
Drava
622
Sava
1800
Tisza
920
Velika
Morava
206
Pančevo
5380
Tamiš 104
Karaš
Nera
Timok 22
Jiu 88
Iskar 55
Corabia
5860
Olt 148
Yantra
40
Vedea
Argeş 80
Ialomiţa 39
Siret 241
Prut 89
Brăila
6178
St. George
Sulina
Chilia
mouth 6444 m³/s
2500
2000
1500
1000
0
distance from Sulina in km

TABLE 3.4 Flood plain loss in the Danube River Basin

River stretch	Morphological floodplain (km^2)	Recent floodplain (km^2)	Loss
Upper Danube	1762	95	95%
Middle/Central Danube	8161	2002	75%
Lower Danube	7862	2200	72%
Danube delta	5402	3799	30%
In total	23 187	8096	65%
cf. River Rhine	8000	1200	85%

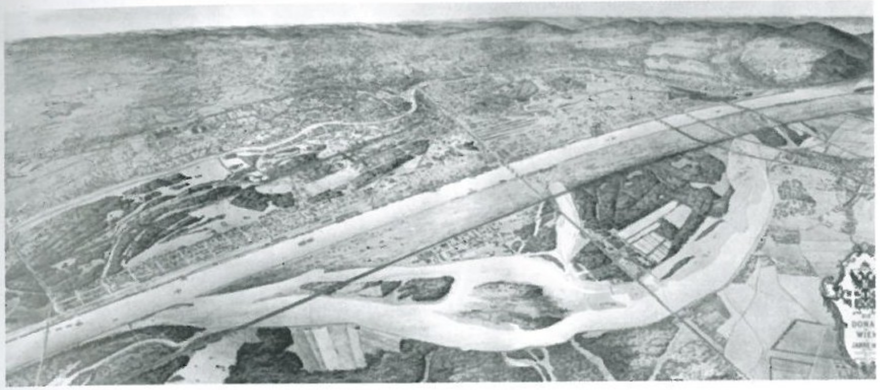
Data from Schneider (2002).

(a)

Die Donau bei Wien 1848

The Danube i

(b)



Die Donau bei Wien 1888

The Danube in

(c)

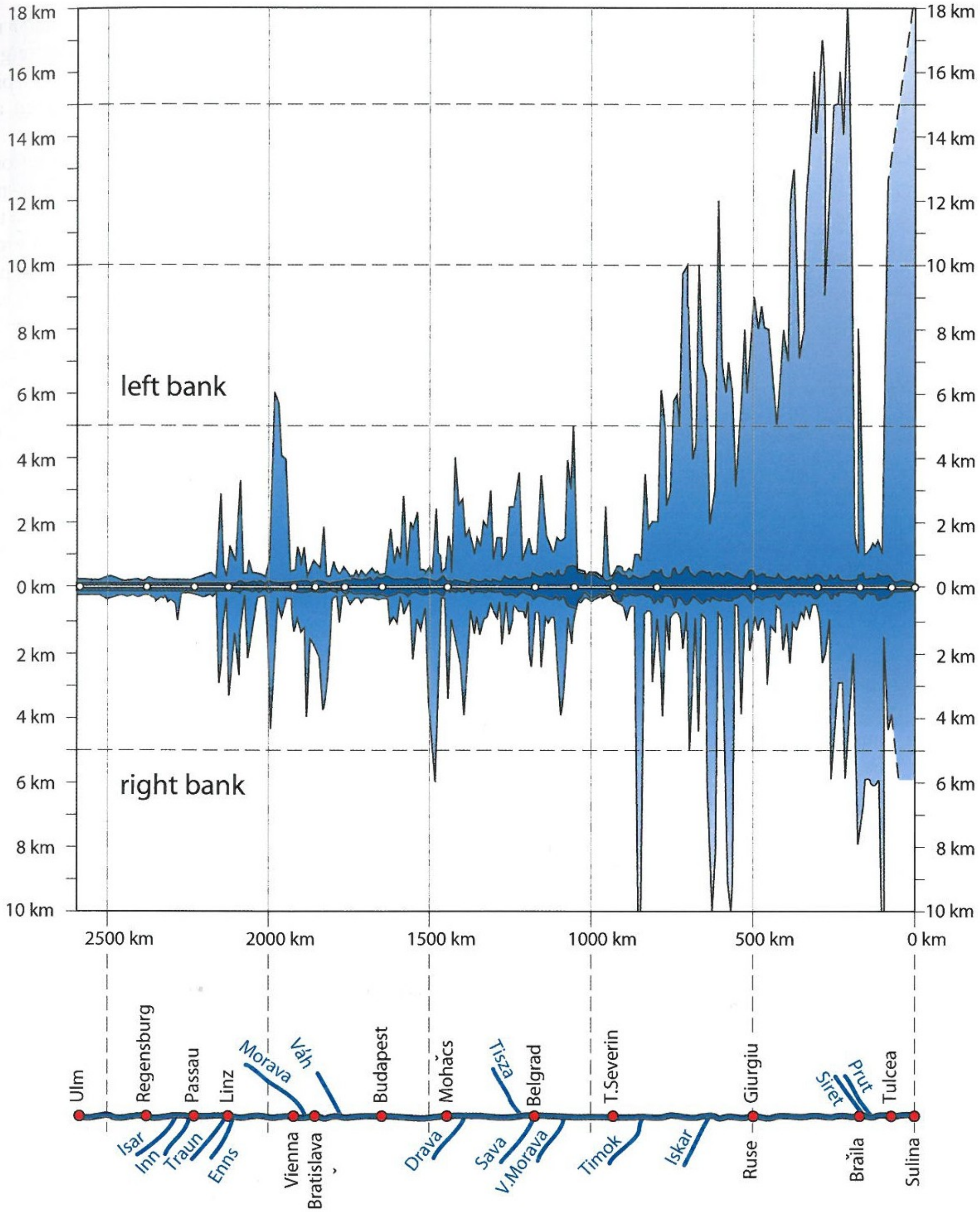


FIGURE 3.8 Extension of former inundation areas along the Danube River (area shaded in light blue)(from Ulm, Germany, downstream to the mouth). Dark blue band marks the average width of the main river channel based on Lászlóffy (1967) and modified after Tockner et al. (1998).

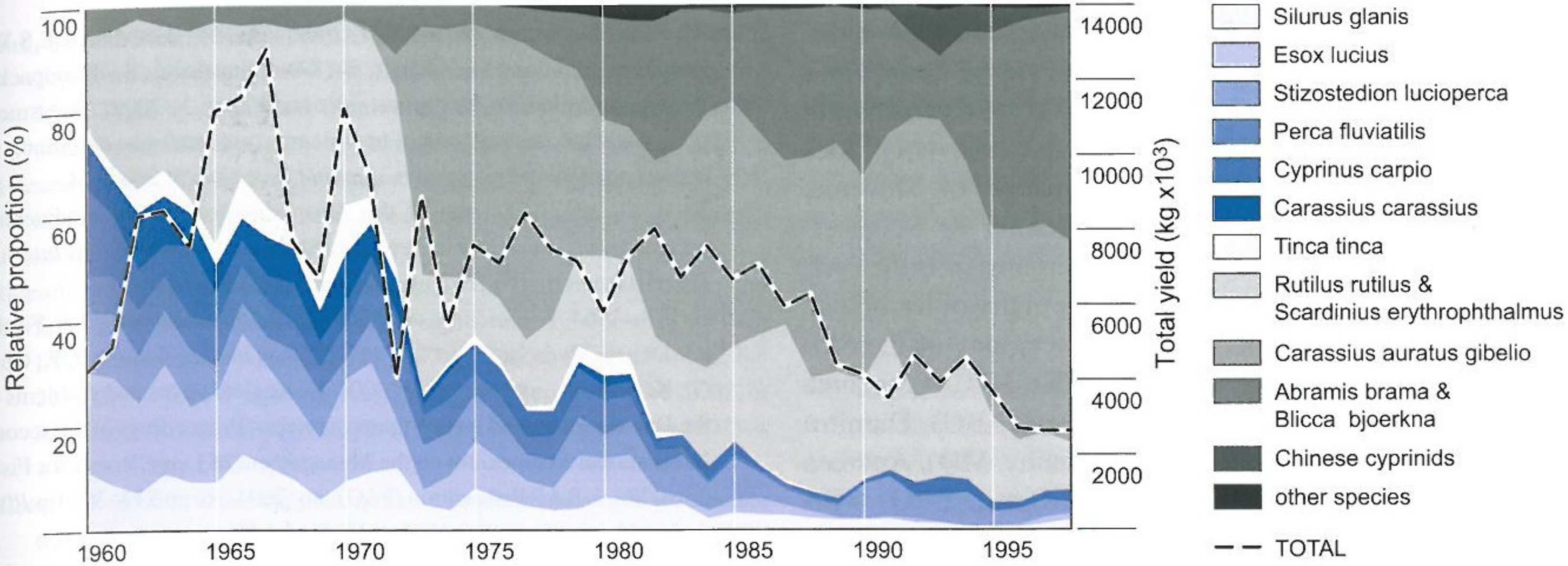


FIGURE 3.9 Total yield (dashed line; right axis) and relative proportion of species (left axis) of the commercial freshwater fishery in the lakes of the Danube delta (1960–1998; redrawn from Navodaru et al. 2002).

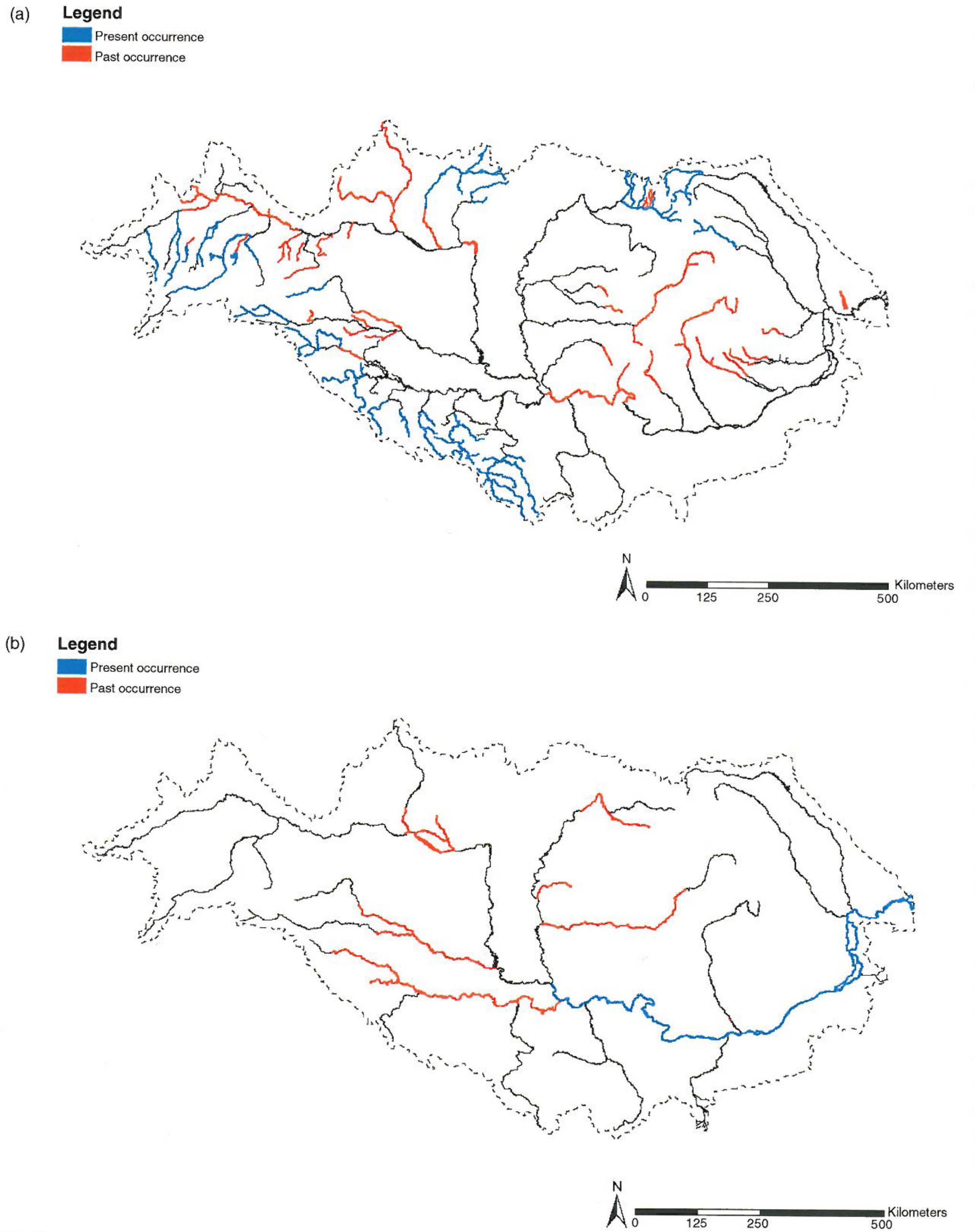
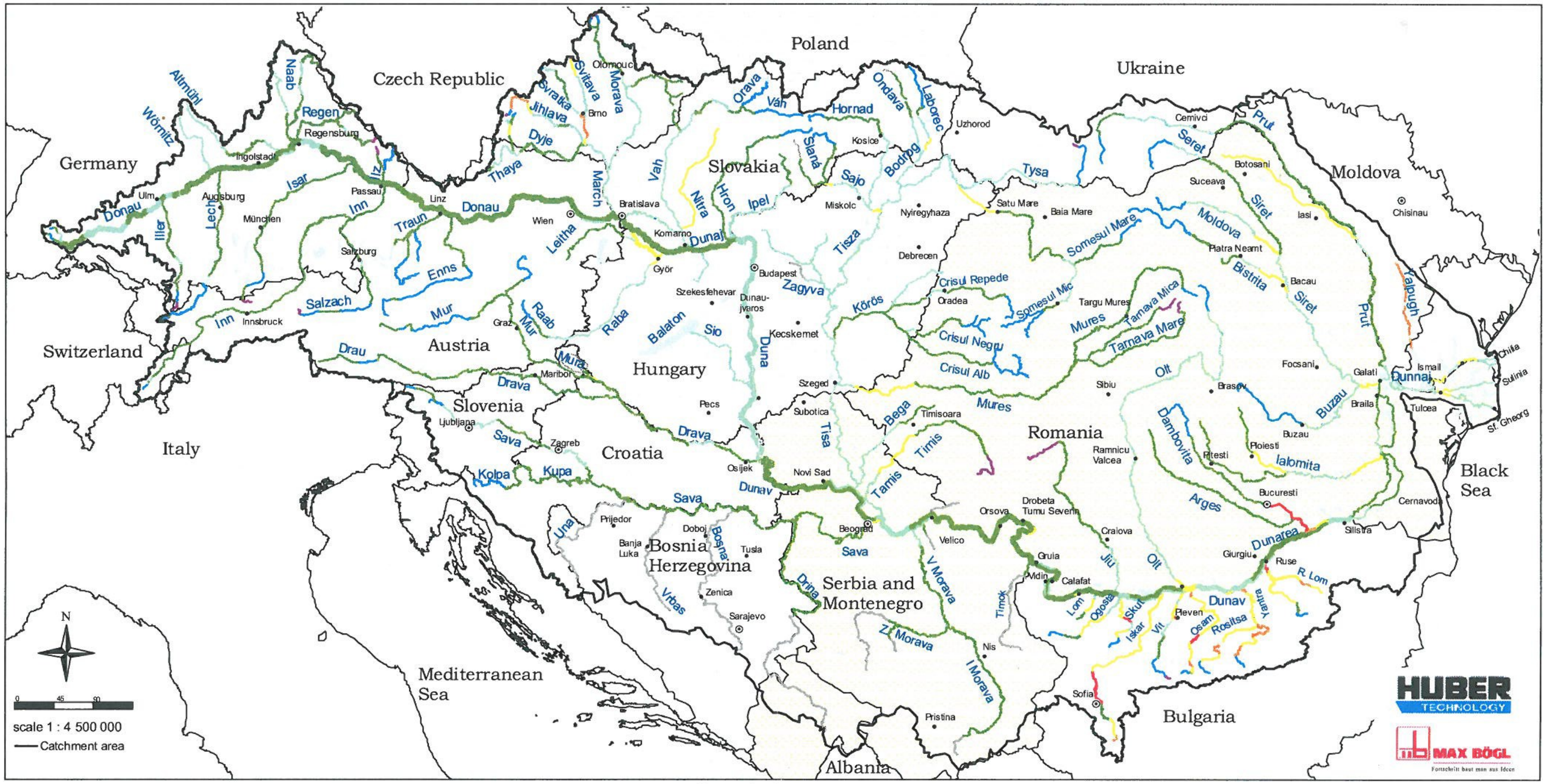


FIGURE 3.6 Past and present spatial distribution of huchen (*Hucho hucho*) (a) and sturgeon (Acipenseridae) (b) within the Danube River Basin, after Holčík et al. (1989) and Reinartz (2002). Maps produced by D. Tonolla.

Water quality of the Danube and its tributaries 2002



River quality classes

🟪 **I :Unpolluted to very slightly polluted (oligosaprobic)**

River reaches with clean water,with oxygen permanently near saturation level and low nutrient load;low bacteria concentration; moderately dense colorization mainly by algae, mosses, flatworms, and insect larvae; water cool in summer-suitable for spawning of salmonids.

🟦 **I - II :Slightly polluted (oligosaprobic to beta-mesosaprobic)**

River reaches with low inorganic nutrient inputs and without significant oxygen consumption ; densely colonized with mostly high species diversity ; water cool in summer- suitable for spawning of salmonids.

🟩 **II :Moderately polluted (beta-mesosaprobic)**

River reaches with moderate pollution and good oxygen supply ; very high species diversity and abundance of algae,snails, entomostracans, insect larvae ; aquatic plants may cover wide areas; high fish diversity.

🟩 **II-III : Critically polluted (beta-mesosaprobic to alpha-mesosaprobic)**

River reaches where loads of organic oxygen -depleting substances cause critical conditions;possible fishkills;decreasing number of macrophyte species; tendency to outbreaks of some plant and animal species.

🟨 **III : Heavily polluted (alpha-mesosaprobic)**

River reaches with heavy organic pollution; the usually low oxygen content is often insufficient for higher water organisms like fish;local sludge deposition; mass occurrences of sewage bacteria and ciliates,occasionally also sponges, leeches, and isopods; sparse aquatic vegetation.

🟧 **III -IV : Very heavily polluted (alpha-mesosaprobic to polysaprobic)**

River reaches with extremely restricted living conditions for higher life forms; the very high organic pollution often causes total oxygen depletion; turbidity due to suspended wastewater constituents ; widespread sapropel deposits; densely colonized by chironomid larvae and oligochaetes.

🟥 **IV : Excessively polluted (polysaprobic)**

River reaches with excessive pollution by organic,oxygen depleting waste-water; bacteria ,flagellates ,and ciliates dwell on widespread sapropel banks; often total absence of oxygen , so that survival of higher life-forms is locally and temporarily limited.

Publisher : International Association for Danube Research , Vienna , 2004.
Cartography : supported by Ulrich Schwarz, Vienna
Workshop : supported by Bavarian State Ministery of the Environment, Public Health and Consumer Protection ,Munich
Fa. Huber Technologies ,Berching
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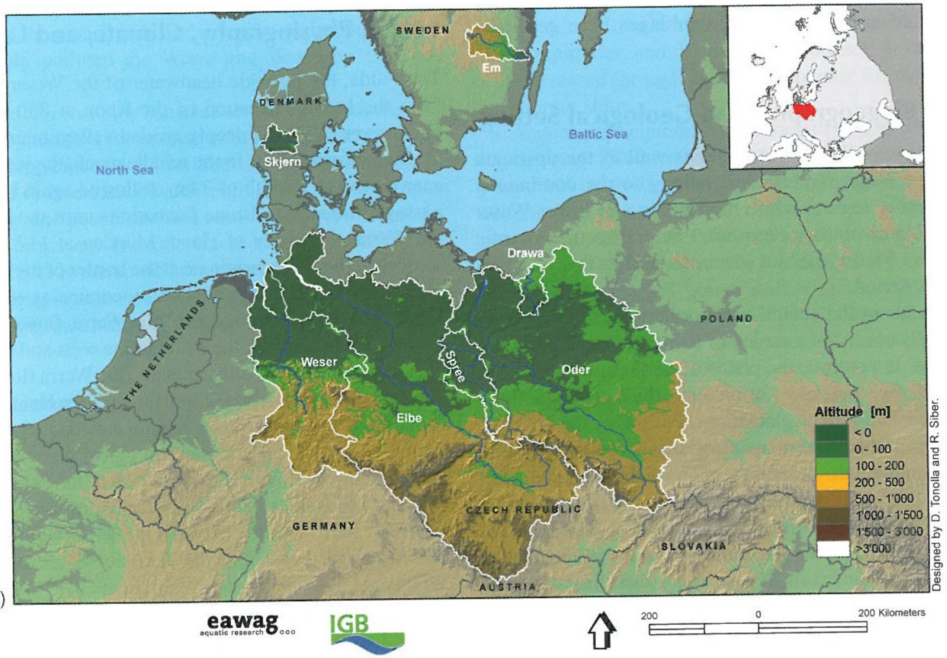
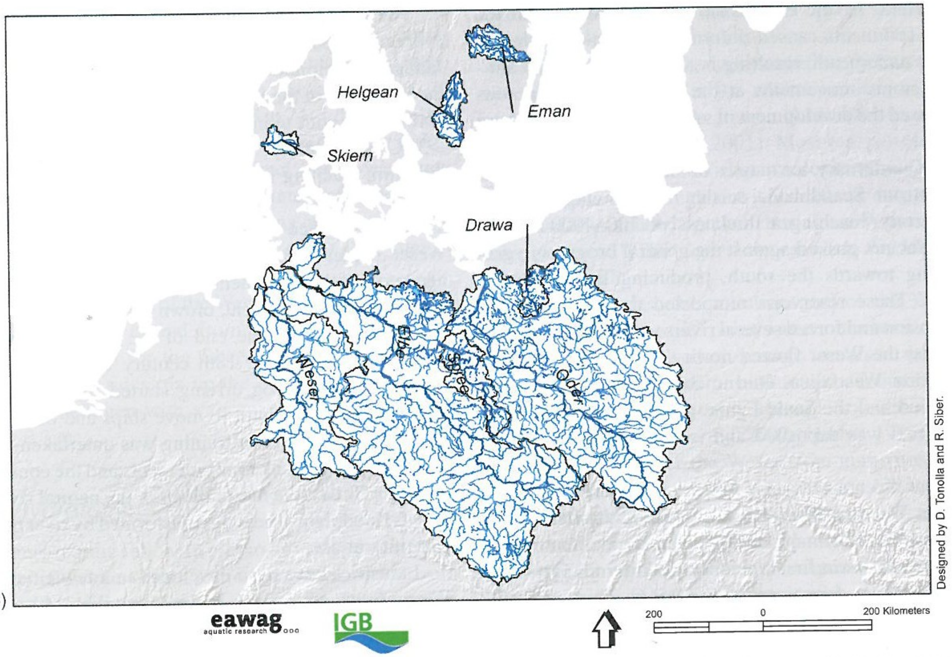
More explanations overleaf

Wasserwirtschaftsamt Regensburg


SWEDEN
Em
DENMARK
Skjern
North Sea
Baltic Sea
Drawa
POLAND
THE NETHERLANDS
Weser
Spree
Oder
Elbe
Altitude [m]
< 0
0 - 100
100 - 200
200 - 500
500 - 1'000
1'000 - 1'500
1'500 - 3'000
>3'000
GERMANY
CZECH REPUBLIC
SLOVAKIA
AUSTRIA
Designed by D. Tonolla and R. Siber.
200
0
200 Kilometers
eawag
aquatic research
IGB

(A)


Helgean
Eman
Skiern
Drawa
Elbe
Weser
Spree
Oder
Designed by D. Tonolla and R. Siber.
200
0
200 Kilometers
eawag
aquatic research
IGB

(B)


a


b

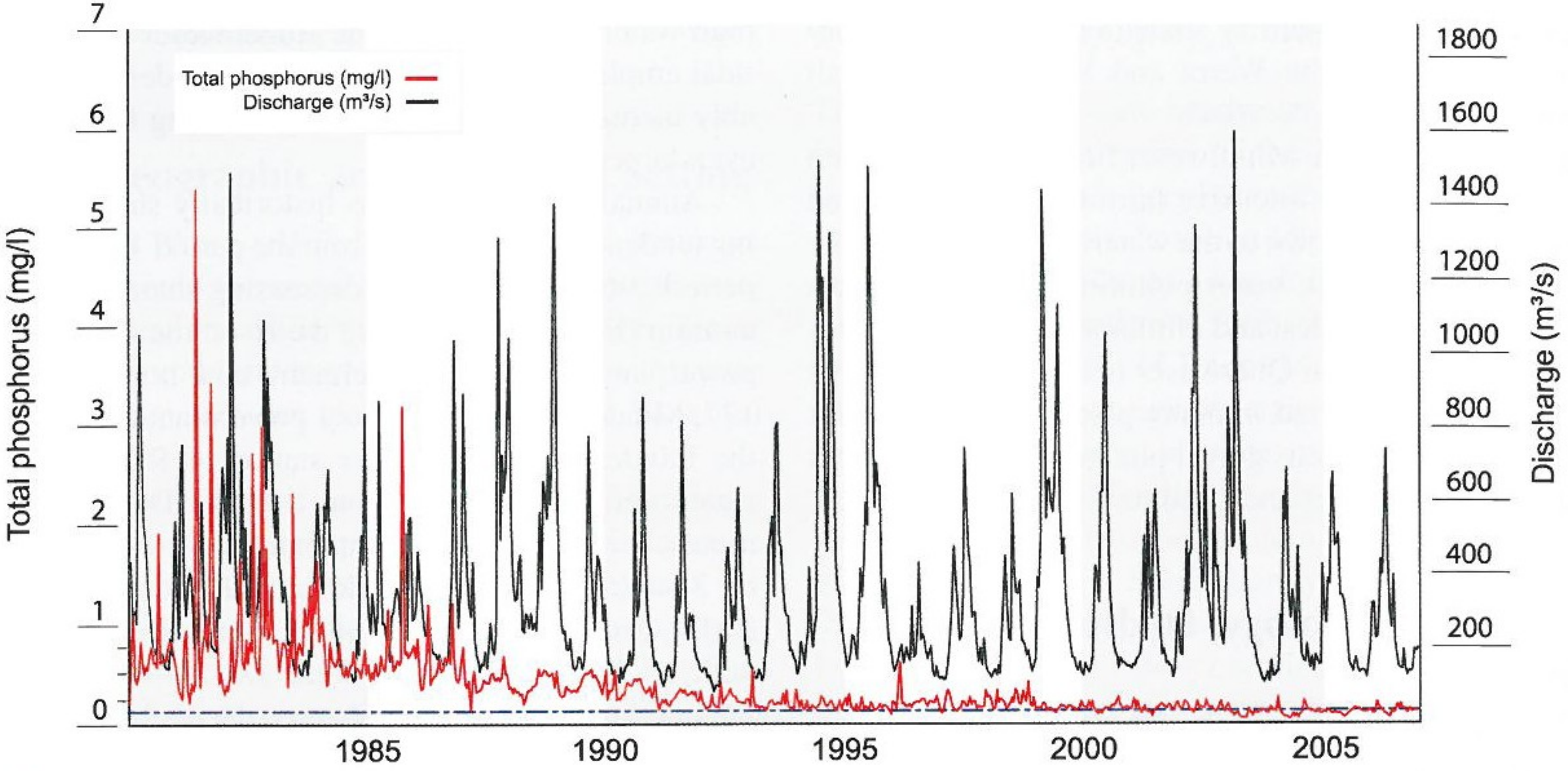
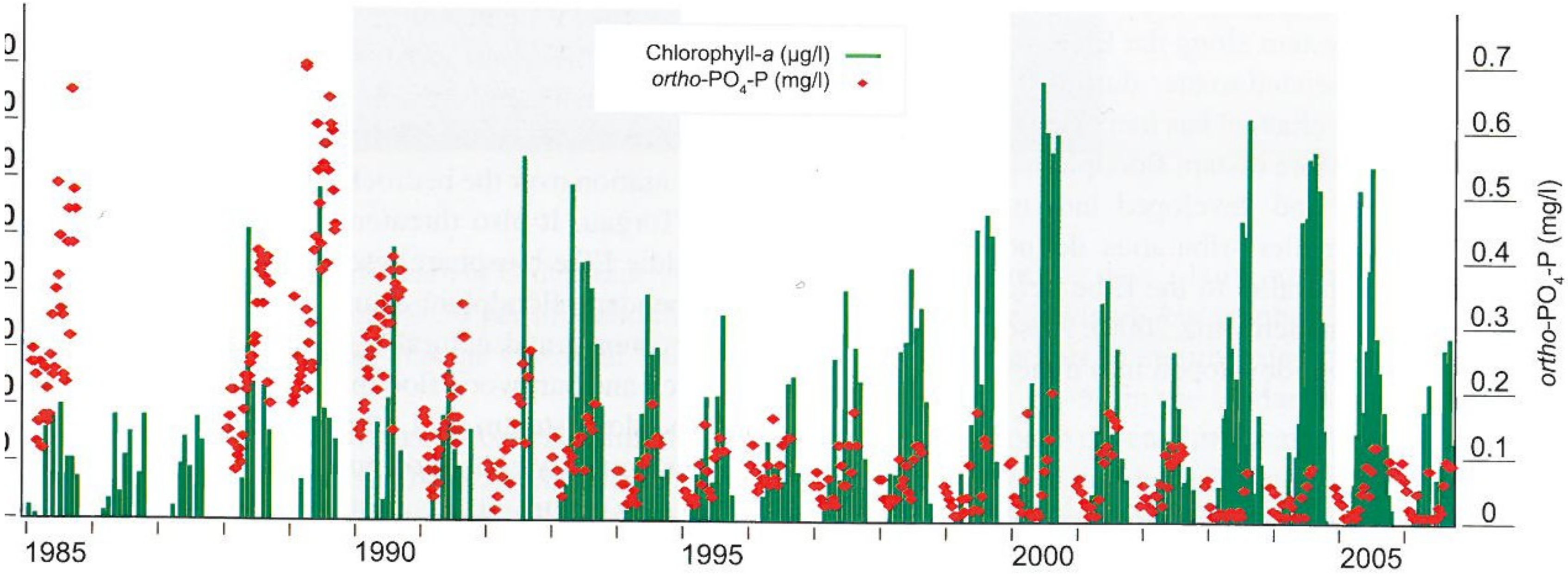
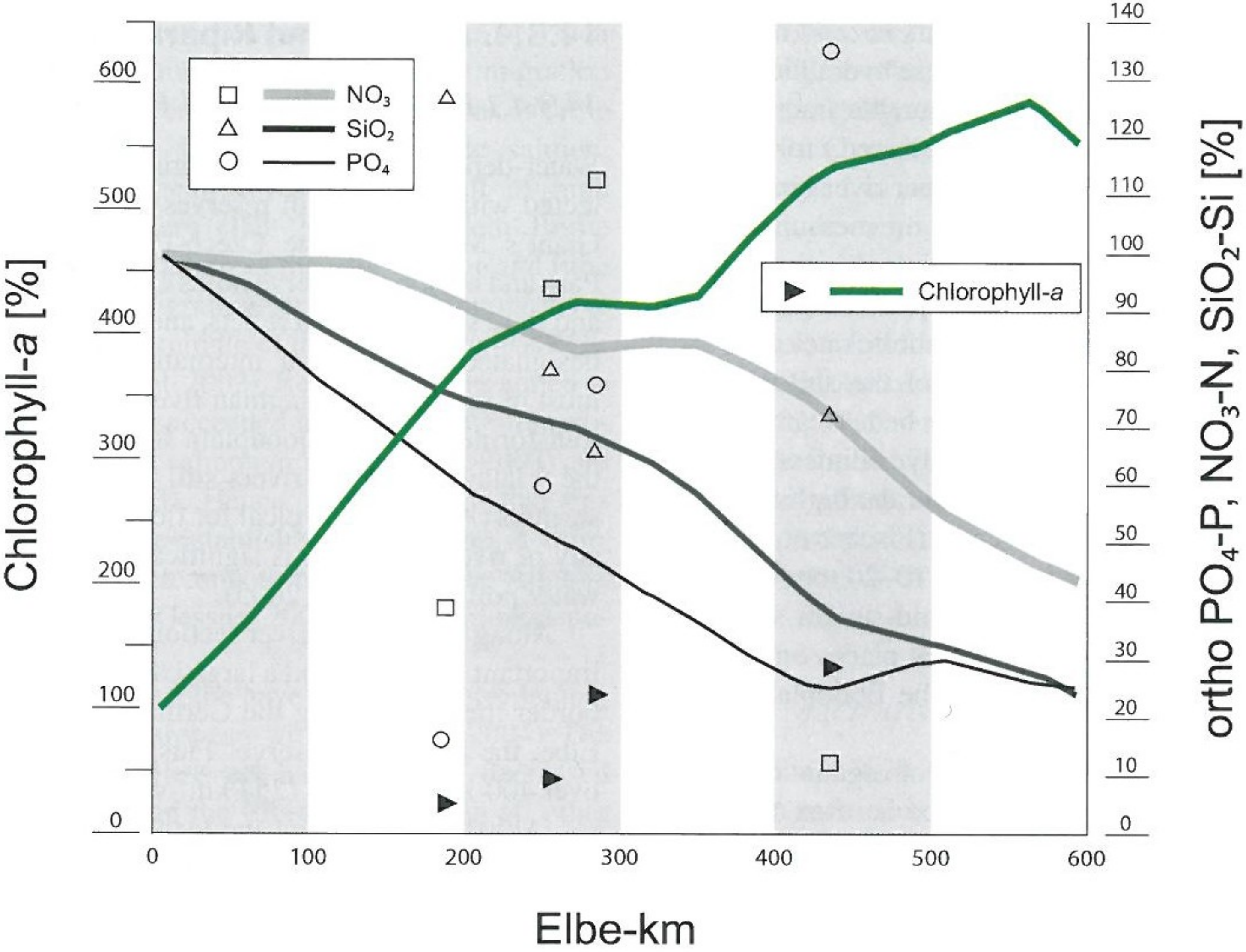


FIGURE 14.2 Long-term dynamics of phosphorous concentrations and discharge at the Bremen/Hemelingen measuring station (data: FGG Weser).



14.6 Long-term development of the concentrations of chlorophyll-*a* and ortho-phosphate at the measuring station Schnackenburg (Rkm 475, pstream of Hamburg; data by ARGE Elbe).



Chlorophyll-a [%]
0
100
200
300
400
500
600
□ NO3
△ SiO2
○ PO4
▶ Chlorophyll-a
ortho PO4-P, NO3-N, SiO2-Si [%]
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
0
100
200
300
400
500
600
Elbe-km

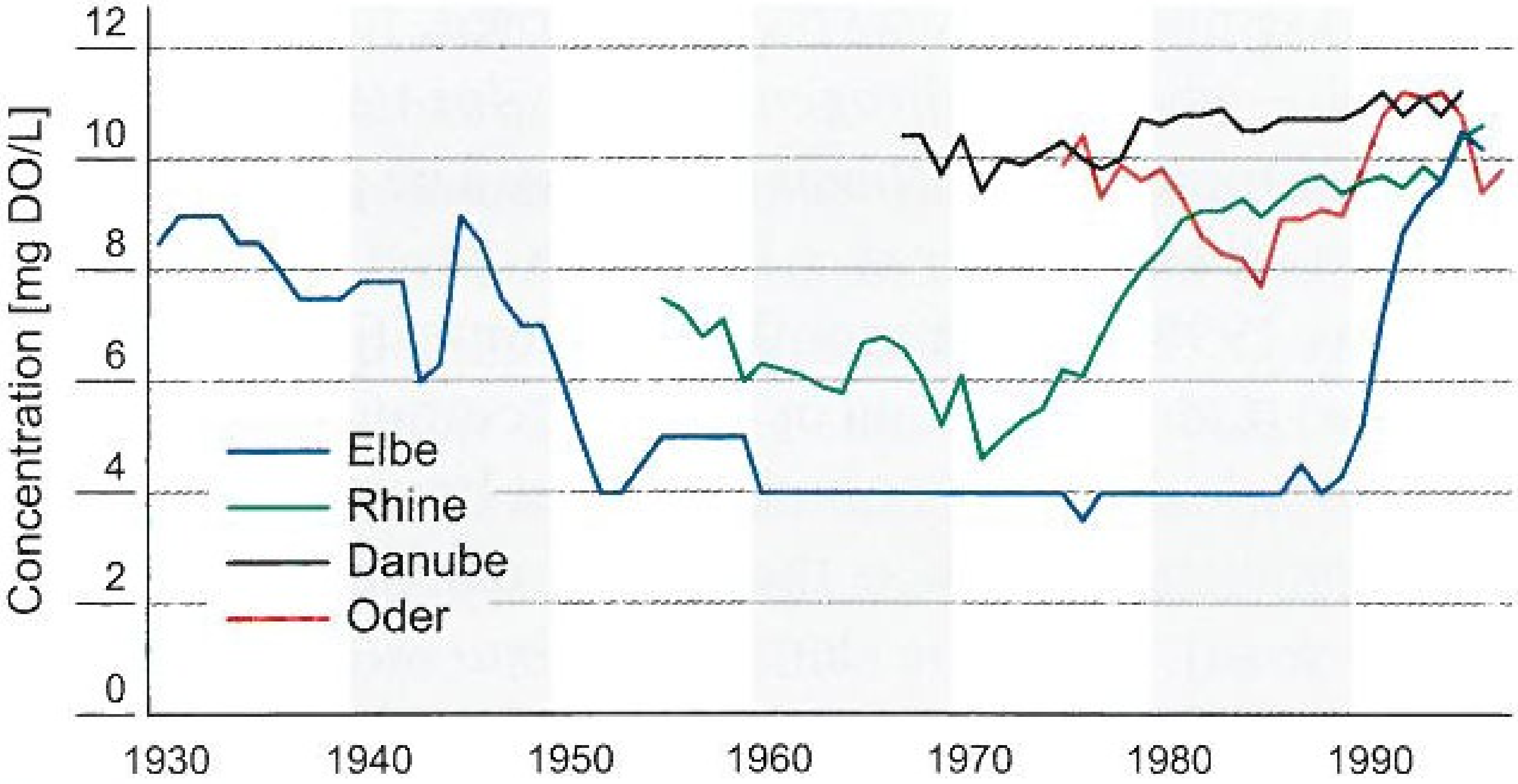


FIGURE 14.16 Historic course of dissolved oxygen concentrations in major rivers of central Europe (Graph: F. Schöll, BfG).

TABLE 14.2 Invasive benthic invertebrates in the Oder, with geographic origin

Species name	Original ecoregion
Cordylophora caspia	Pontocaspis
Dugsia tigrina	North America
Ferrissia wauteri	Southwest Europe
Lithoglypus naticoides	Pontocaspis
Physella acuta	Southwest Europe
Potamopyrgus antipodarum	New Zealand
Viviparus viviparus	East-Europe
Corbicula fulminea	Asia
Dreissena polymorpha	Pontocaspis
Branchiura sowerbyi	South Asia
Hemimysis anomala	Pontocaspsis
Limnomysis benedeni	Pontocaspis
Echinogammarus ishnus	Pontocaspis
Chelicorophium curvispinum	Pontocaspis
Dikerogammarus villosus	Pontocaspis
Dikerogammarus haemobaphes	Pontocaspis
Pontogammarus robustoides	Pontocaspsis
Gammarus tigrinus	North America
Obesogammarus crassus	Pontocaspis
Orconectes limosus	North America
Erichoeir sinensis	East Asia

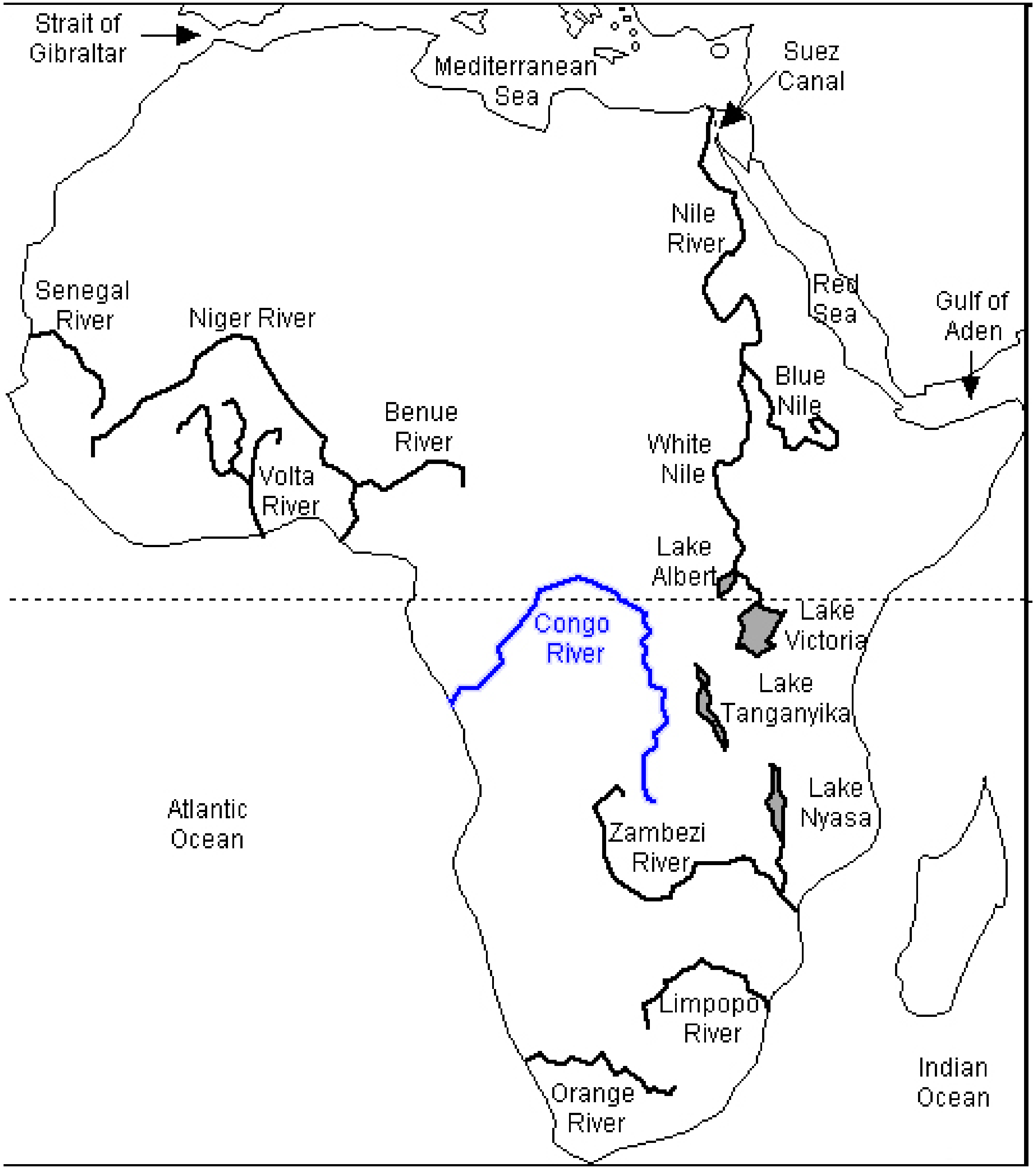
Invazní blešivci
- Corophium
- Dikerogammarus
- Echinogammarus

Dikerogammarus villosus


North Sea
East Sea
Ems
Hamburg
2000
Elbe
2000
Odra
Bremen
1998
Berlin
2000
1998
1998
2000
1995
Weser
Elbe
1995
Düsseldorf
2000
Dresden
1995
Saale
Rhine
1996
1995
Main
1997
1995
1995
1997
Neckar
Regensburg
1995
Stuttgart
Rhine
Danube
1992
1991
1997
München
1997
Basel
100 km

Invazní měkkýši

Invazní rakovci


Strait of Gibraltar
Mediterranean Sea
Suez Canal
Nile River
Red Sea
Gulf of Aden
Senegal River
Niger River
Benue River
Blue Nile
White Nile
Volta River
Lake Albert
Lake Victoria
Congo River
Lake Tanganyika
Lake Nyasa
Atlantic Ocean
Zambezi River
Limpopo River
Orange River
Indian Ocean

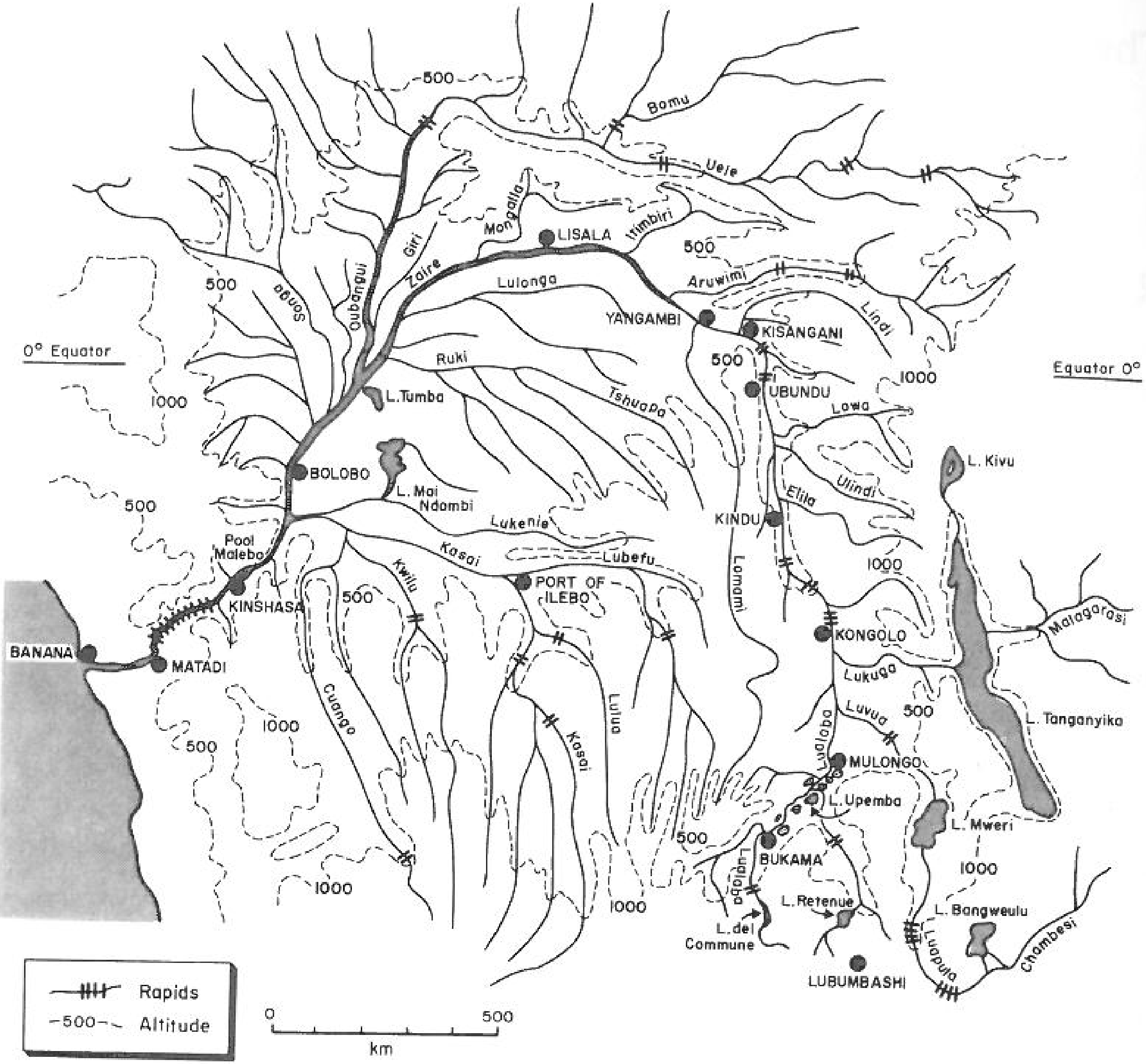


Figure 1. Some geographic features of the Zaïre Basin. Contours are metres AMSL.

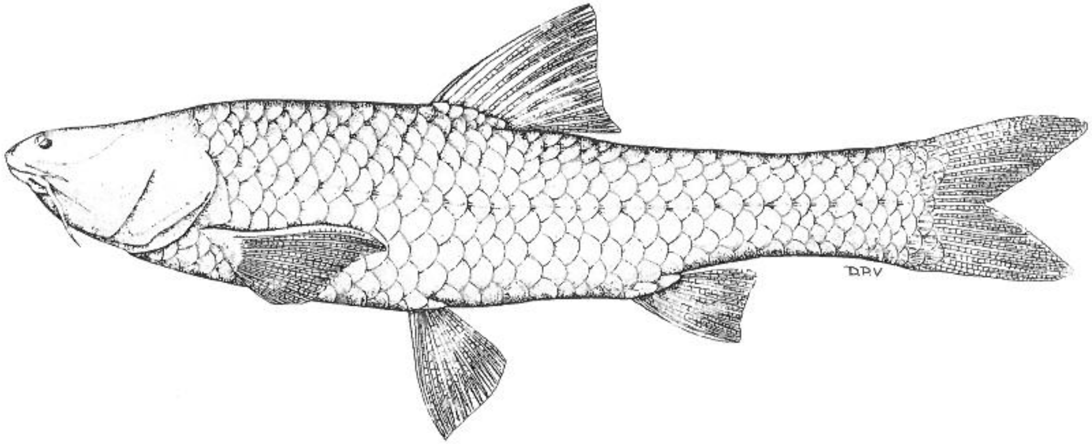


Figure 2. *Caecobarbus geertsi*, the blind cave barb from caves near Thysville.

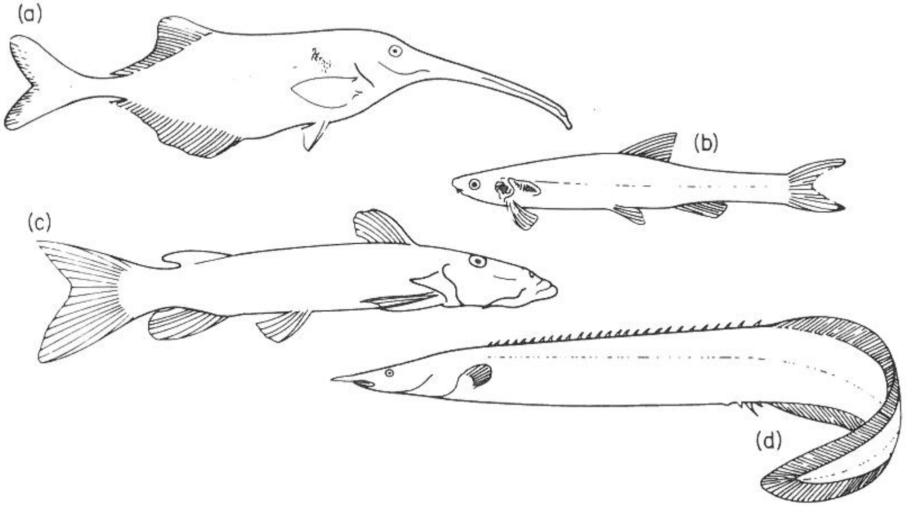


Figure 1. Fish of the Zaïre system. (a) *Campylomormyrus rhynchophorus*, (b) *Kneria auriculata*, (c) *Euchilichthys royauxi*, (d) *Mastacembelus* sp.

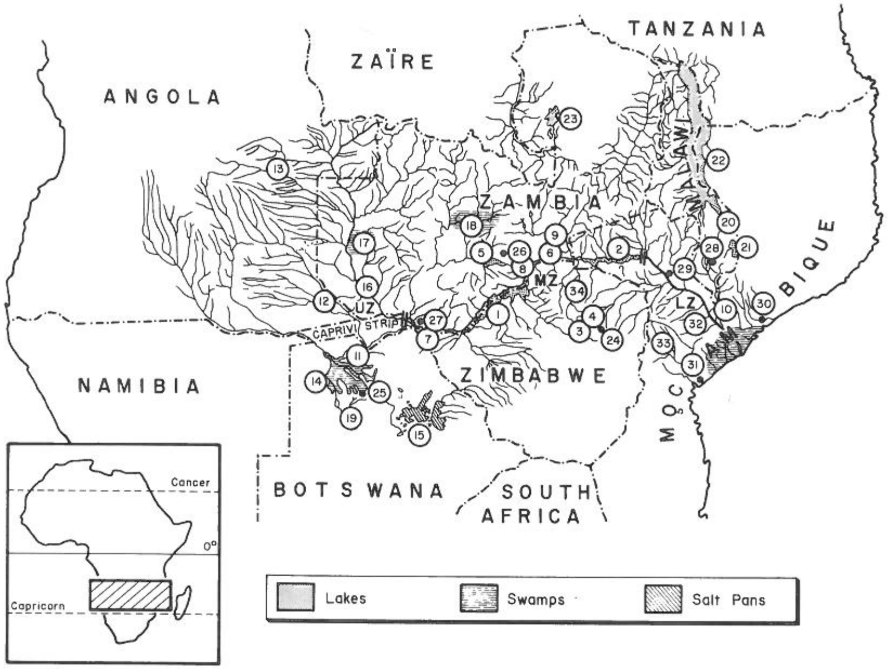


Figure 1. Geographic features of the Zambezi River System. Key: UZ, Upper Zambezi, eastern boundary at Victoria Falls (paired vertical lines); MZ, Middle Zambezi, eastern boundary at the Cahora Bassa Gorge (paired vertical lines); LZ, Lower Zambezi.

1. L. Kariba
2. L. Cahora Bassa
3. L. Darwendale
4. L. McIlwaine
5. L. Kafue
6. Proposed Mupata Gorge project
7. Proposed Batoka Gorge project below Victoria Falls
8. Kafue R.
9. Luangwa R.
10. Shiré R.
11. Chobe R.
12. Kwando (Cuando) R.
13. Lungwebungu R.
14. Okavango Swamps
15. Makgadikgadi Pans
16. Barotse Floodplain
17. Luena Flats
18. Lukanga Swamps
19. L. Ngami
20. L. Malombi
21. L. Chilwa
22. L. Malawi
23. L. Bangweulu
24. Harare (Salisbury)
25. Maun
26. Lusaka
27. Livingstone
28. Blantyre
29. Tete
30. Quelimane
31. Beira
32. Zangué R.
33. Pungoé R.
34. Hunyani R.

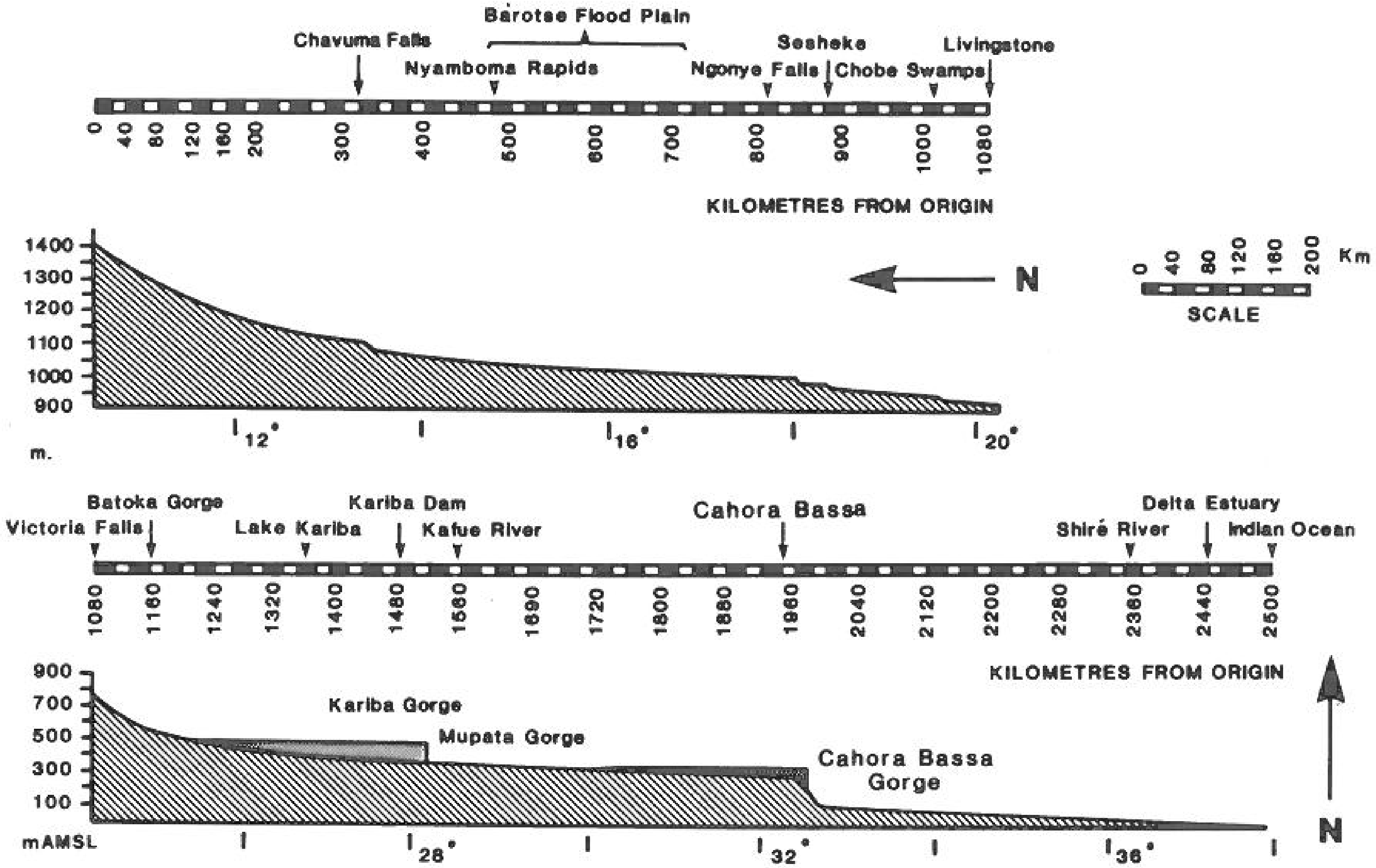


Figure 3. Profile of the Zambezi system (after Balon & Coche 1974).

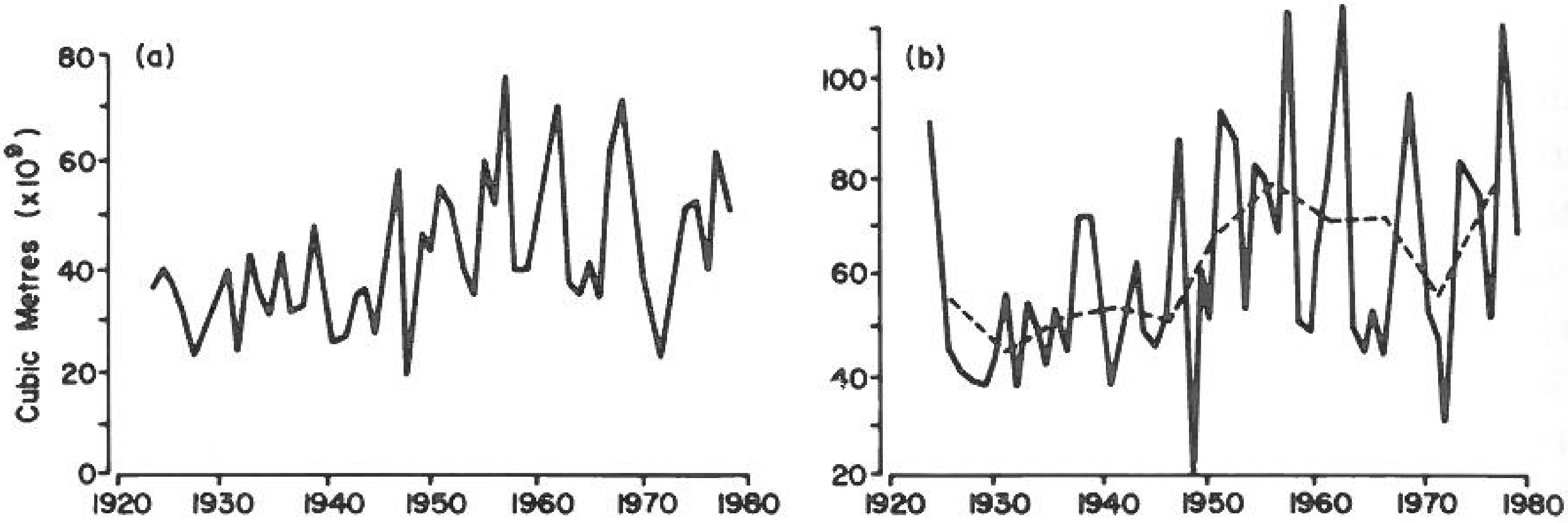
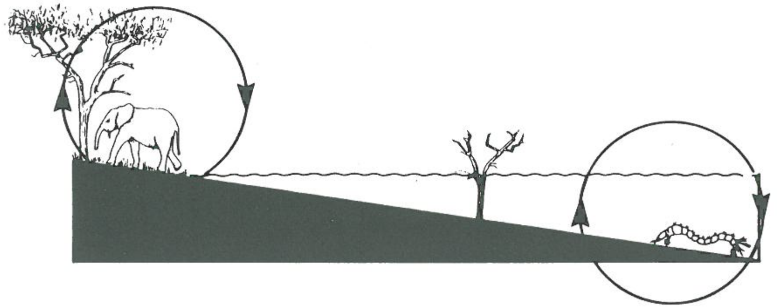
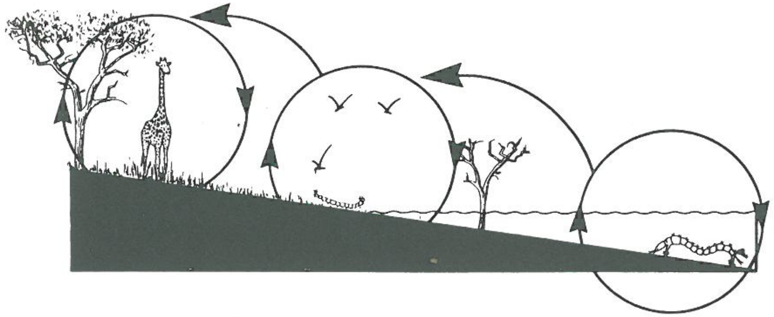
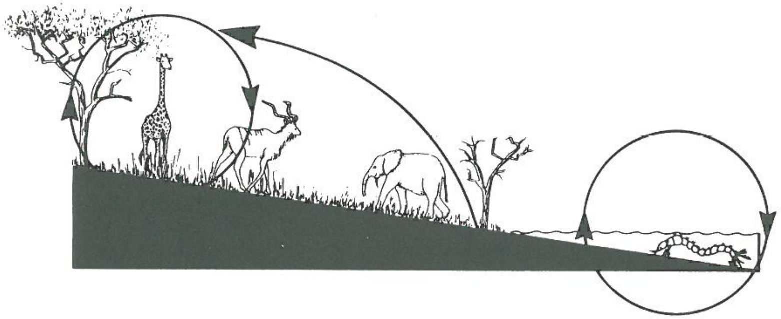
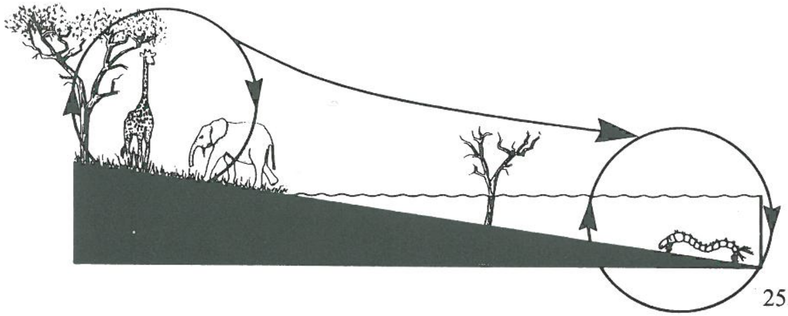


Figure 4. (a) Mean annual runoff as m^3 × 10^9 from the Upper Zambezi catchment (above Victoria Falls), over 1924–79. From Central African Power Corporation records (1978, 1981). (b) Mean annual runoff (m^3 × 10^9); "potential" (unbroken line) and mean "potential" (broken line) flow summed over 5-y periods between 1924–79, for the Upper Zambezi, the Kariba Catchment below Victoria Falls and the Kafue catchment (i.e. the potential supply to L. Cahora Bassa and the Lower Zambezi, excluding the Luangwa inflow). These figures exclude evaporation and rainfall effects of Lake Kariba and the Kafue Hydro-Electric schemes (after R. Du Toit 1982).









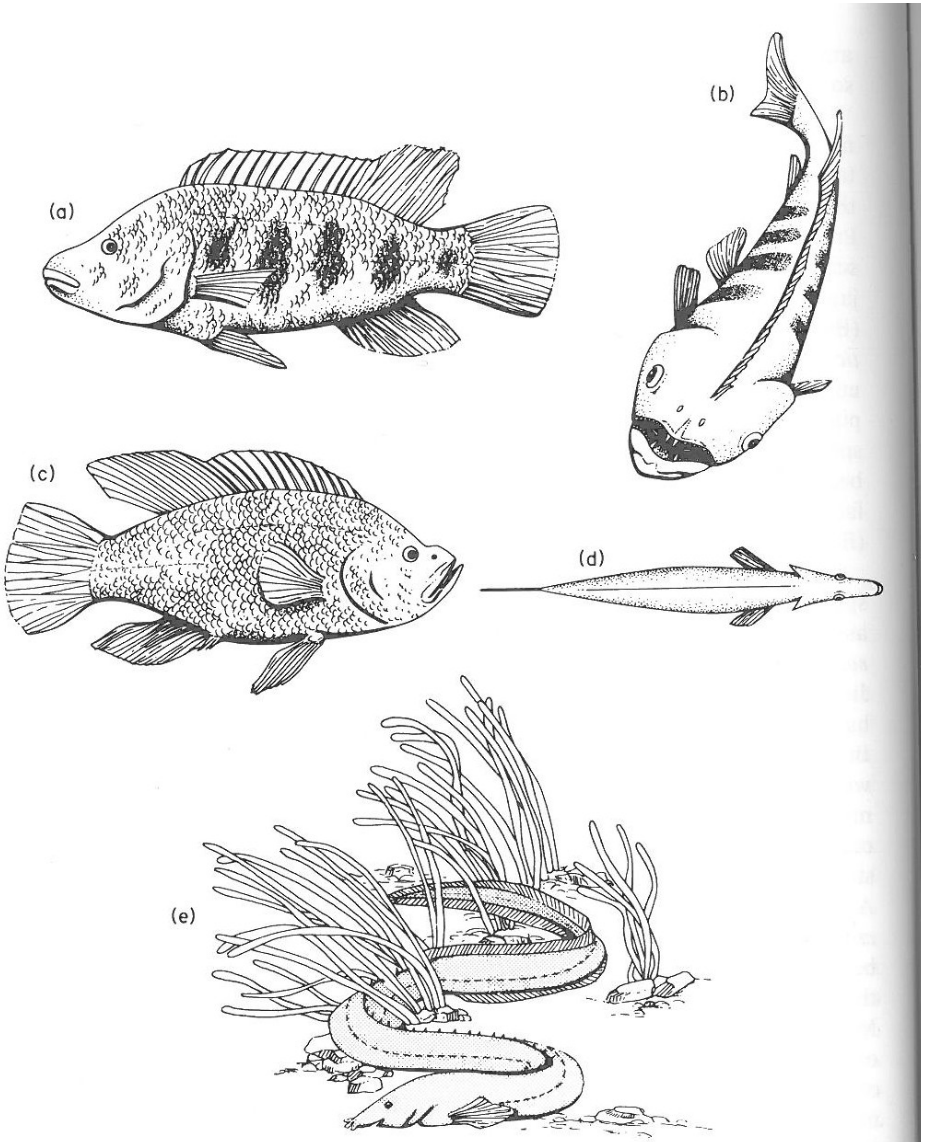


Figure 2. Adaptations of predators to Zambezi floodplain environments. (a)–(b) *Hemichromis elongatus* takes a toll of smaller fish, seizing them with the two pointed canines in each jaw. (c)–(d) The upturned jaw, narrow profile and protrusible mouth of *Serranochromis angusticeps*, another voracious floodplain predator, enables it to attack top minnows, small *Barbus* and other prey from below. (e) The eel-like shape of *Afromastacembelus frenatus* allows it to lurk in the most dense vegetation, capturing small crustaceans and insects. It may hide among rocks in deeper water.

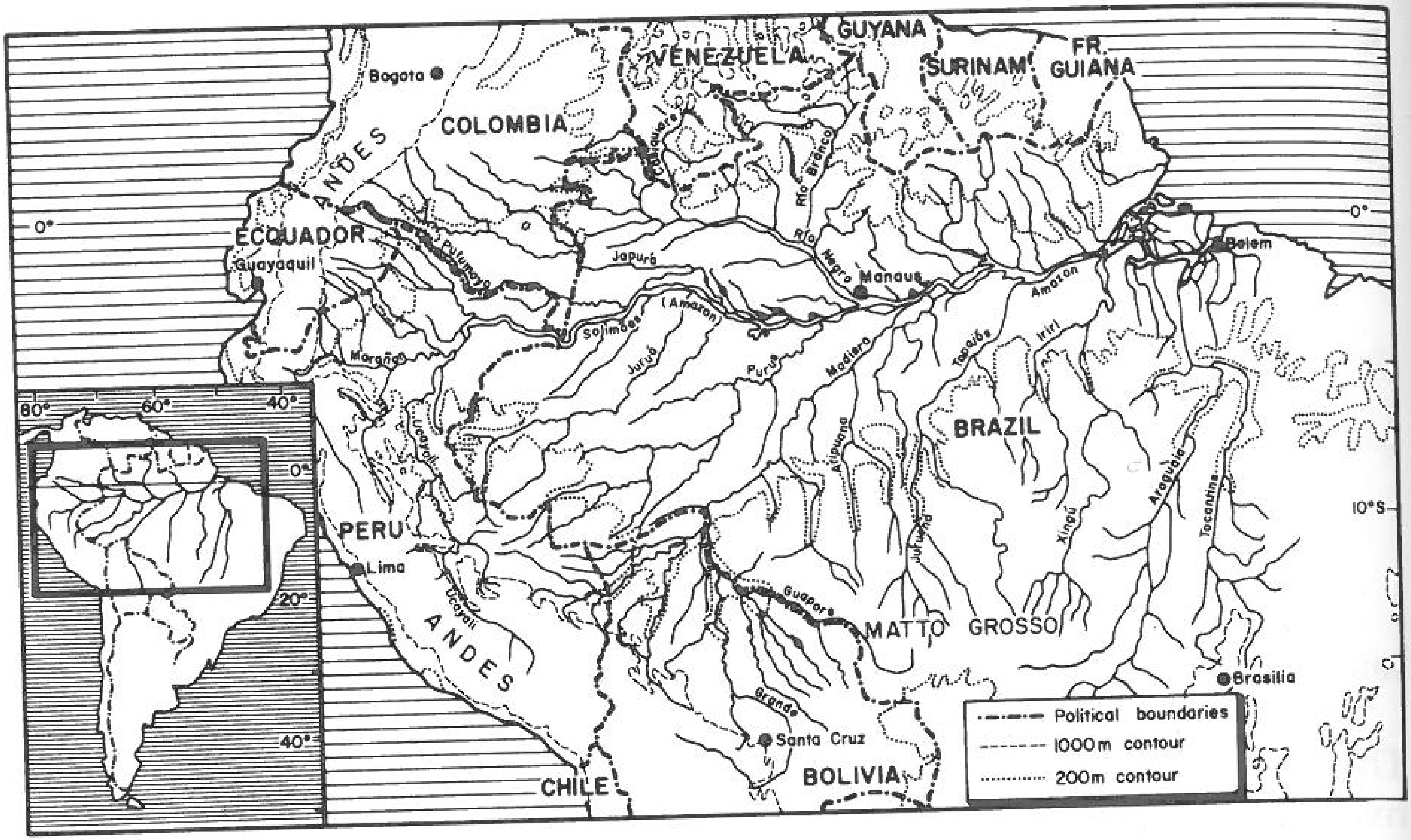
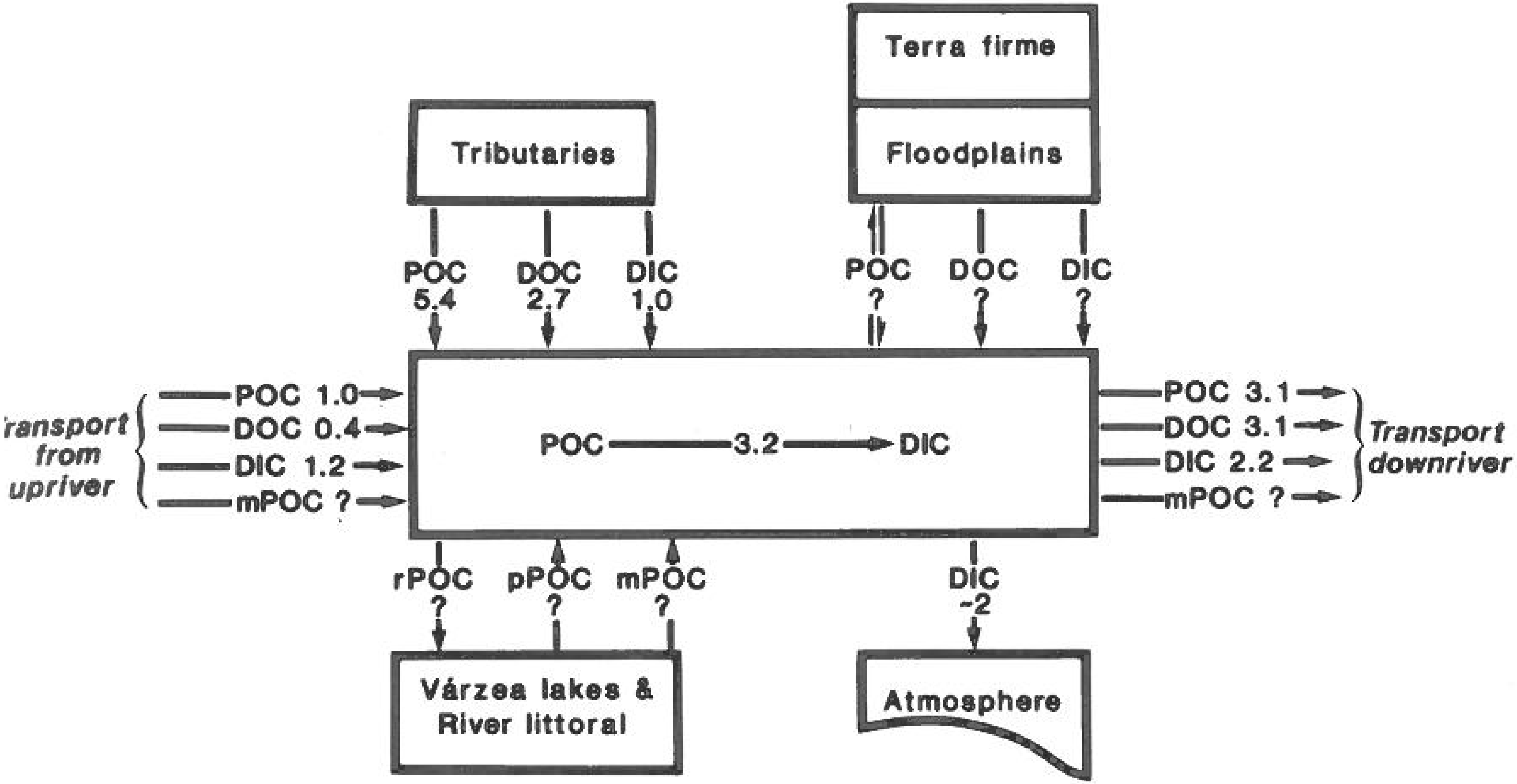


Figure 1. Major geographic features of the Amazon Basin.

Table 2. Selected climatic data for various parts of the Amazon catchment or nearby regions (after Fullard & Darby 1975)

	Temperature (°C)			Rainfall (mm)		
	Mean Annual Range	Daily Range "summer"	Daily Range "winter"	Mean Annual Range	Mean Monthly "wet"	Mean Monthly "dry"
La Paz (Bolivian Andes)	3.9	7–18 Oct	1–17 July	574	120 Jan	20 June
Quito (Ecuadoran Andes)	0.6	5–18/20	year round	1123	160 April	20 July
Manaus (Central Amazon)	1.7	24–32 Sept–Oct	24–30 Jan–June	1811	260 Mar	30 Aug
Cuiaba (Mato Grosso)	4.2	21–23 Sept	17–28 July	1395	220 Mar	10 July
Belém (Estuary)	0.8	23–32 Dec	21–29 Sept	2438	350 Feb–Mar	60 Nov



gure 5. A carbon budget for the Amazon River (see text for explanation). Modified after Richey 982).

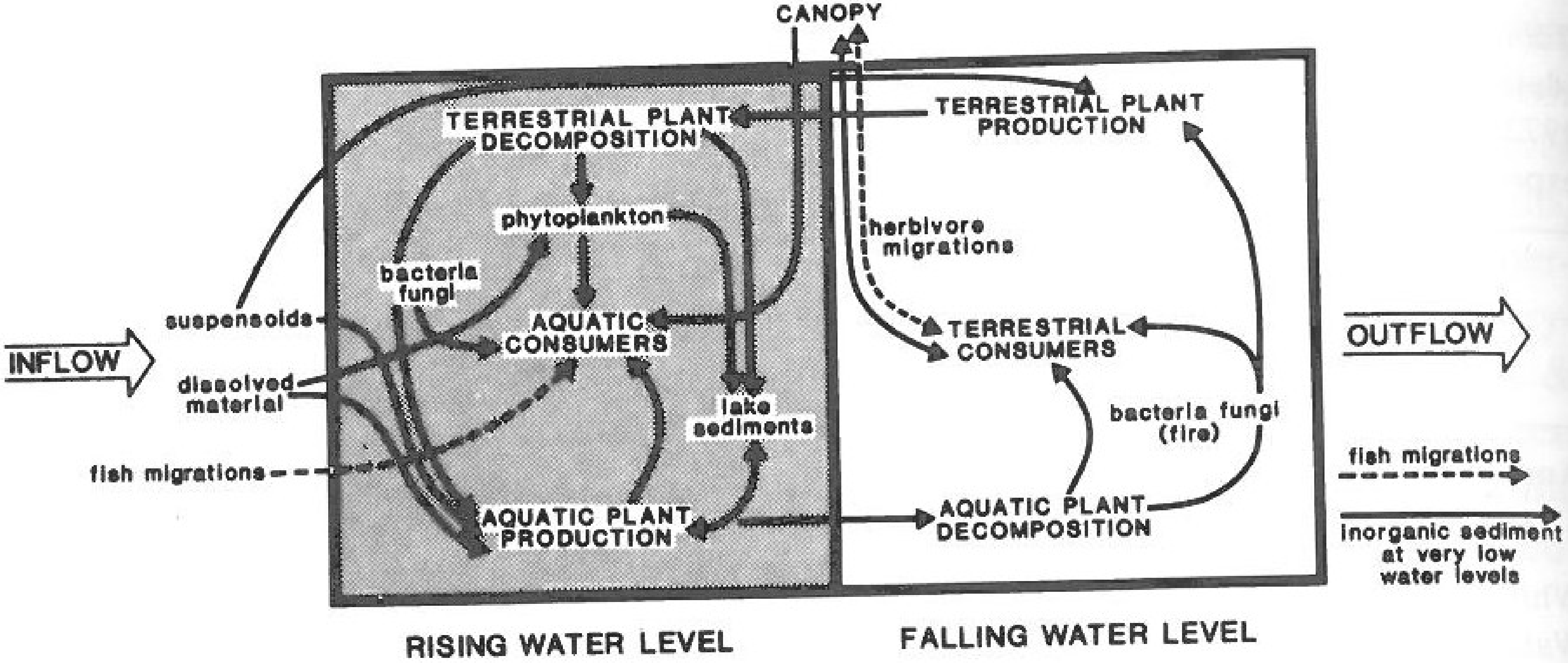


Figure 6. A nutrient budget for the Amazon (after Junk 1980).

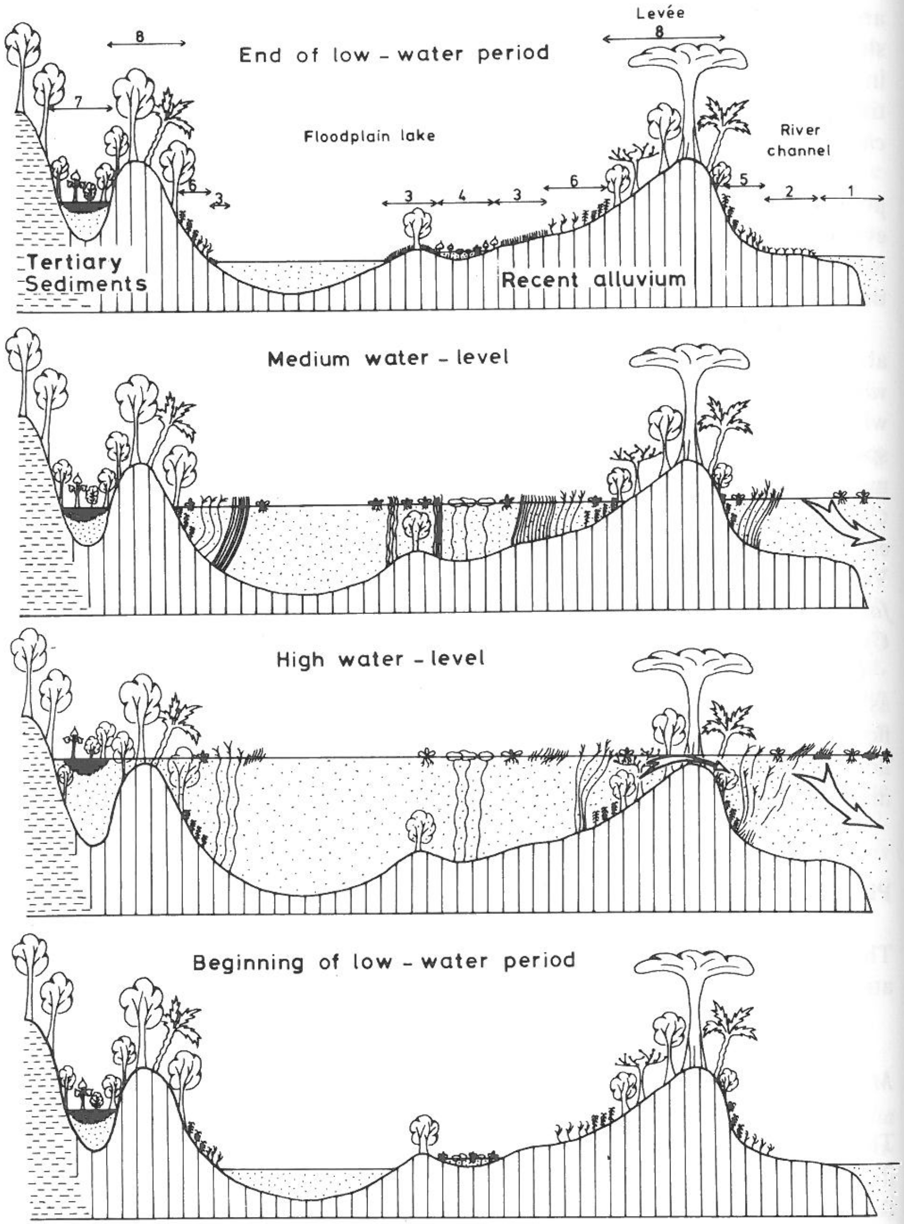


Figure 2. Aquatic plant habitats and communities in the middle Amazon floodplain. (1: river channel; 2: low-lying channel bar; 3: low-lying flat; 4: swale; 5: river shore; 6: lake shore; 7: habitat with minor water-level variation; 8: levée).

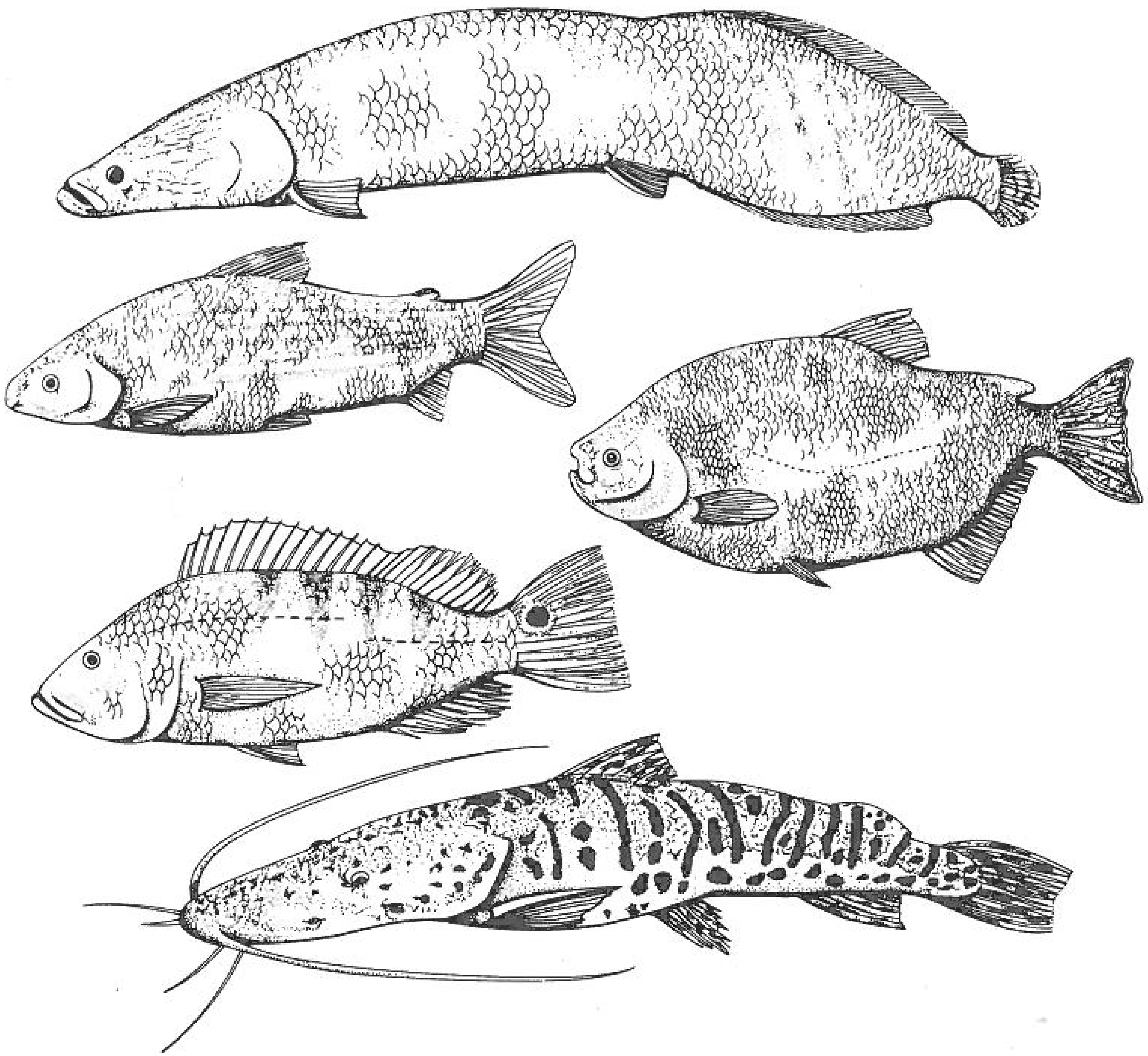


Figure 1. Representative fish from the Amazon system (after Lowe-McConnell 1975). From top: *Arapaima* (length to 300 cm SL, Osteoglossidae), *Prochilodus* (to 50 cm SL, Prochilodontidae), *Colossoma* (to 90 cm SL, Characidae), *Cichla* (to 75 cm SL, Cichlidae) and *Pseudoplatystoma* (to 40 cm SL, Pimelodidae).

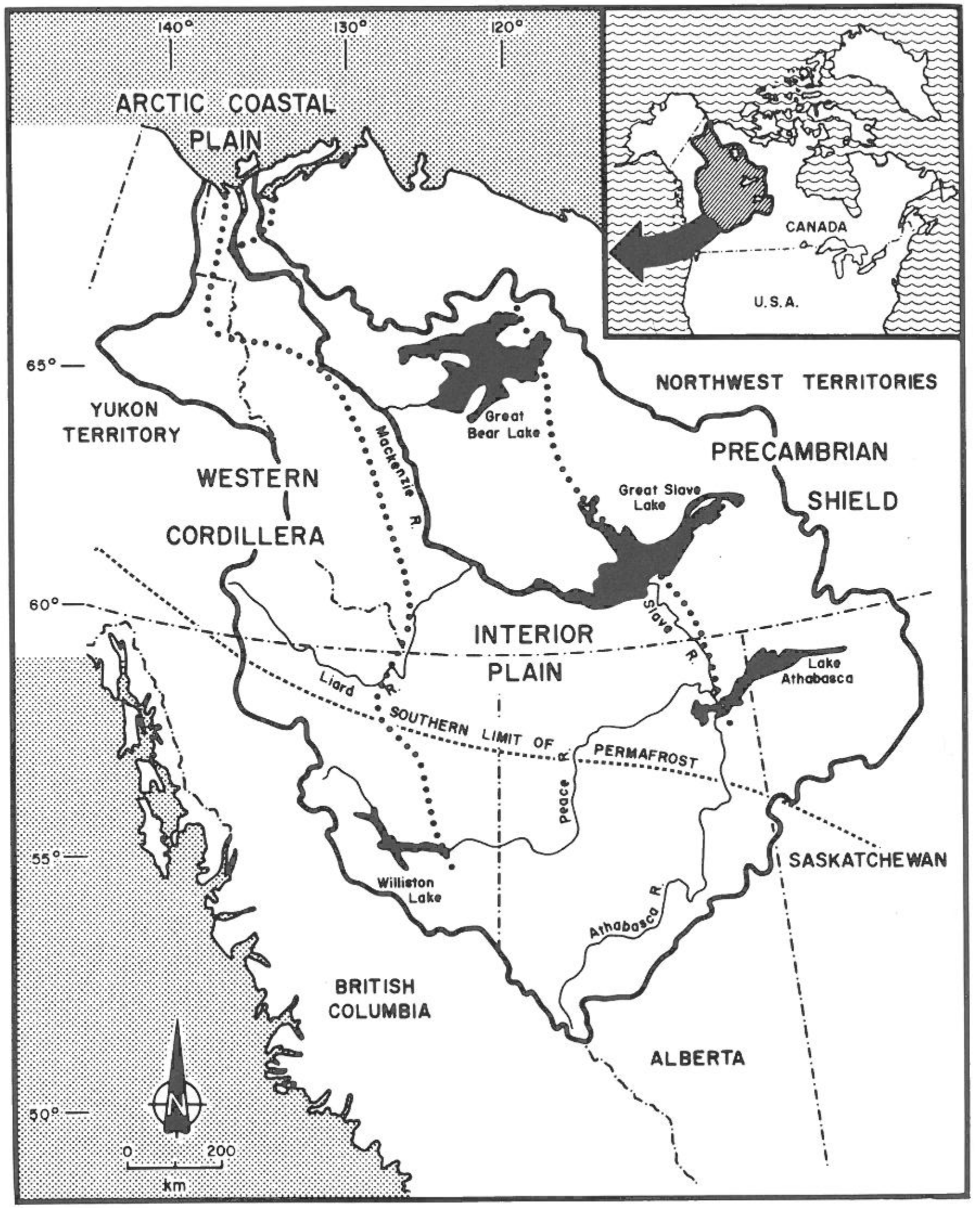


Figure 1. Physiographic regions of the Mackenzie Basin. The inset map shows the extent of the basin (cross-hatching) within Canada. Modified after MRBC (1981), with permission of the Mackenzie River Basin Committee.

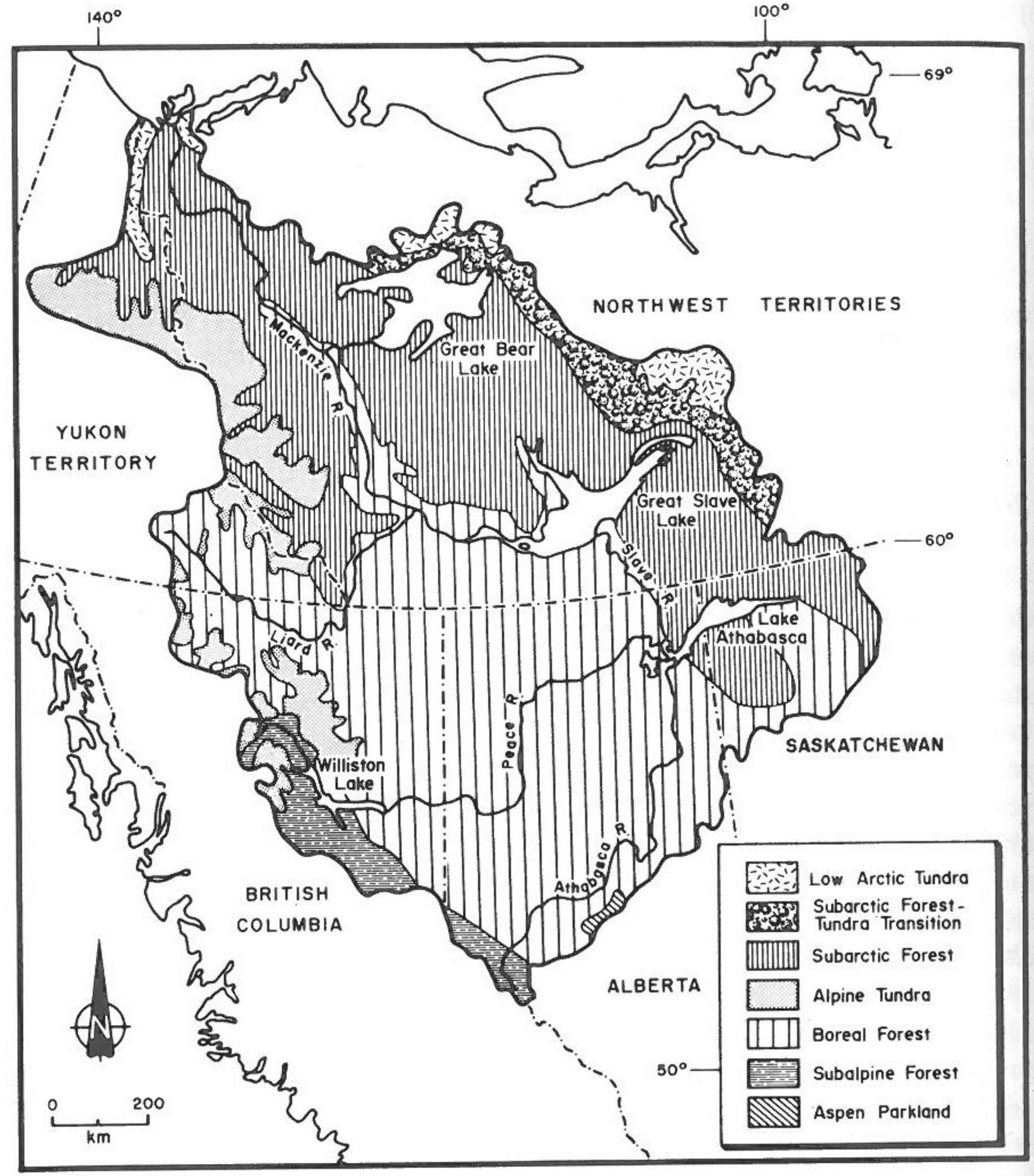


Figure 1. Vegetation regions of the Mackenzie Basin. Modified after MRBC (1981), with permission of the Mackenzie River Basin Committee.


Mackenzie Delta

Table 1. Mean percent composition of invertebrates from baskets of stones suspended in the Athabasca (A–B), Mackenzie (C) and Liard (D) rivers, from debris on anchor lines (E) and airlift samples from bedrock substrata (F) in the Athabasca River (ND = no data). Sources – A: McCart *et al.* (1977); B: Flannagan *et al.* (1979); C–D: Brunskill *et al.* (1973), E–F: Barton (1980b)

Taxon	A	B	C	D	E	F
Oligochaeta	2.0	2.7	0.3	0.3	1.0	6.2
Ephemeroptera	15.0	9.0	5.1	14.2	16.2	13.8
Plecoptera	54.4	35.2	24.8	27.1	46.2	17.7
Trichoptera	6.0	34.7	11.0	8.3	15.8	6.3
Simuliidae	1.0	40.9	46.5	1.0	12.8	0.2
Chironomidae	18.8	12.5	18.0	3.4	6.9	35.4
Empididae	1.6	ND	0	0	0	13.0
Other Insecta	0.9	ND	0	0.2	0.7	1.4

Table 2. Mean standing stock and percent contribution of benthic invertebrate taxa in fresh waters of the Mackenzie Delta during summer (August–September; $N = 21$) and winter 1971 (December; $N = 4$). From Brunskill *et al.* (1973)

Taxon	Summer	Winter
Nematoda	0.3	0.6
Oligochaeta	22.3	0.9
Gastropoda	18.3	0.5
Bivalvia	6.6	0.8
Amphipoda	4.9	4.8
Chironomidae	27.3	76.2
Ceratopogonidae	9.8	13.0
Other Insecta	10.5	3.1
Mean number m^{-2}	166.1	417.1

Table 3. Mean total standing stocks (individuals m^{-2}) and percent contribution of major taxa in stream riffles at different latitudes in the Mackenzie Basin. Based on Surber samples between July and early October (ND = no data). Sources – A–C: Brunskill *et al.* (1973) (fast streams only); D: Barton & Wallace (1980); E: Clifford (1972c)

Taxon	Study and latitude (°N)				
	A 67°	B 64–65°	C 61–62°	D 57°	E 53°
Oligochaeta	9.6	57.5	8.2	7.0	5.2
Amphipoda	11.8	0.3	0.1	ND	ND
Ephemeroptera	3.5	8.9	18.0	33.6	17.8
Plecoptera	10.5	12.7	5.2	3.8	7.6
Trichoptera	0.8	3.1	5.2	13.6	8.6
Chironomidae	52.4	12.4	47.4	37.6	42.4
Mean individuals m^{-2}	850	192	4046	12 781	4772