Ekologie tropických toků

Jan Helešic

PLATE 5 (a) A stream surrounded by *Espletia* shrubs on the El Angel páramo at 3800 m asl in northern Ecuador. (b) A stream enclosed by *Polylepis* woodlands at 3600 m asl in Central Ecuador covered by dense *Polylepis* woodlands. (c) Low flow in a wide stream channel on the Bolivian Altiplano (3800 m asl). (d) A stream at 3000 m asl in a Dry Inter-Andean valley close to La Paz, Bolivia (Photos by D. Jacobsen) (See Fig. 2 in Chapter 8 on page 223).

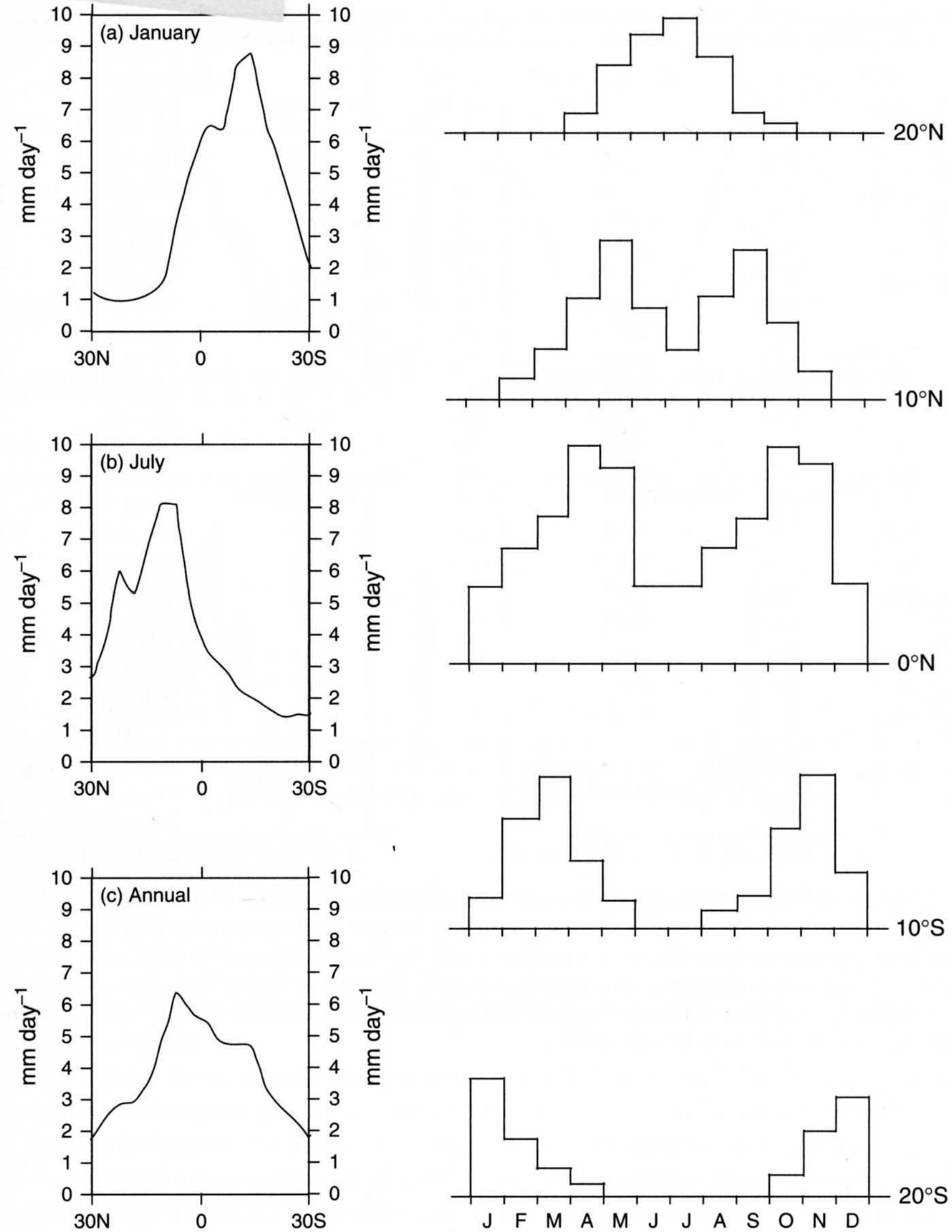


FIGURE 8 Latitudinal distribution of rainfall in the tropics (left panels) and expected seasonal patterns (right panels). There are numerous deviations from these patterns at specific locations, as explained in the text. Redrawn and slightly modified from McGregor and Nieuwolt (1998).

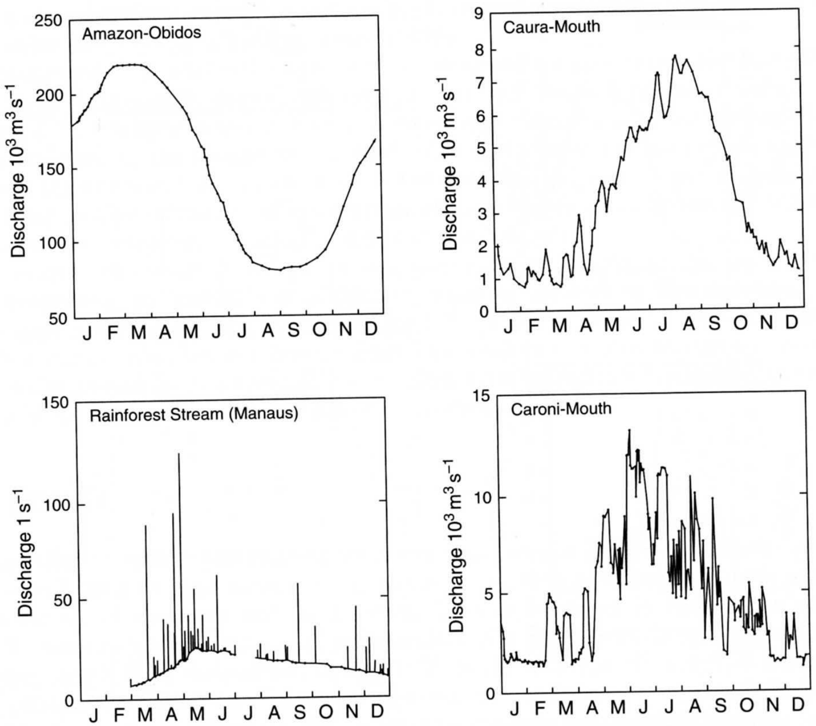


FIGURE 9 Tropical hydrographs illustrating seasonal and short-term variations in discharge. The Amazon shows the smoothing effects of area-based and latitudinal averaging because of its great size. The Caura, a tributary of the Orinoco, shows an intermediate degree of smoothing, and the Caroni, adjacent to the Caura, shows the effects of hydroelectric regulation superimposed on a regime essentially identical to that of the Caura. Extreme short-term variation is illustrated by an Amazonian rainforest stream. Modified from Lewis *et al.* (1995), with permission from Elsevier; rainforest stream data from Lesack (1988).

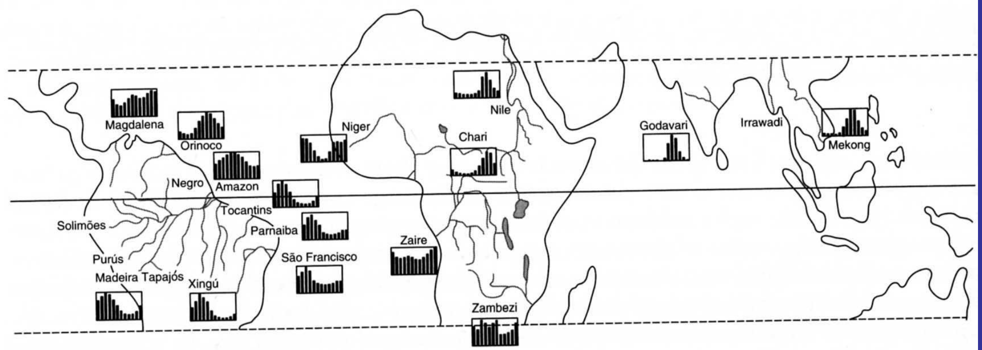


FIGURE 10 Multi-year average hydrographs for large rivers at tropical latitudes showing latitudinal tendencies in seasonal discharge. Redrawn from Vorosmarty *et al.* (1998).

TABLE III Characteristics of 20 of the Largest Tropical Rivers (Amazon Tributaries are Indented)

Location	*Latitudinal span*	*Orientation*	*Area,* 10^3 km^2	*Discharge (Q),* m^3 s^{-1}	*Q/Area,* mm y^{-1}	*TSS,* mg L^{-1}	*TDS,* mg L^{-1}
Magdalena	2 N–11 N	N–S	270	7000	830	780	120
Orinoco	2 N–10 N	E–W	950	38000	1300	80	25
Amazon	15 S–2 N	E–W	6100	220000	1200	220	41
Solimões	12 S–0	E–W	1200	43000	1200	380	82
Purús	12 S–6 N	N–S	370	11000	1000	74	–
Negro	4 S–3 N	E–W	620	30000	1600	7	6.5
Madeira	20 S–4 S	N–S	1300	30000	740	540	60
Tapajós	13 S–3 S	N–S	500	14000	910	–	18
Xingú	15 S–2 S	N–S	510	17000	1200	–	28
Tocantins	16 S–2 S	N–S	820	18000	680	–	–
São Francisco	20 S–8 S	N–S	640	2800	140	60	–
Parnaiba	10 S–3 S	N–S	320	2300	220	–	–
Nile[2,3]	0–31 N	N–S	2960	950	10	0	208
Niger[2,3]	5–15 N	E–W	1210	6090	159	208	53
Zaire[2,3]	10 S–10 N	E–W	3820	39600	327	34	38
Zambezi[2,3]	20 S–10 S	E–W	1200	7070	186	148	70
Chari[3]	5 N–15 N	E–W	600	1320	69	–	64
Godavari[2]	17 N–20 N	E–W	310	2660	271	1143	–
Mekong[1,2,3]	10 N–33 N	N–S	790	14900	595	340	105
Irrawaddy[1,2]	15 N–29 N	N–S	430	13600	995	619	–

Source for South America is Lewis *et al.* (1995); source for discharge and area outside South America is Vorosmarty *et al.* (1998) except as noted. Hyphens show missing data. See Fig. 10 for hydrographs. TSS = total suspended solids, TDS = total dissolved solids.

[1] Watershed narrow above tropic of Cancer.

[2] Sediment from Milliman and Meade (1983).

[3] Meybeck (1976).

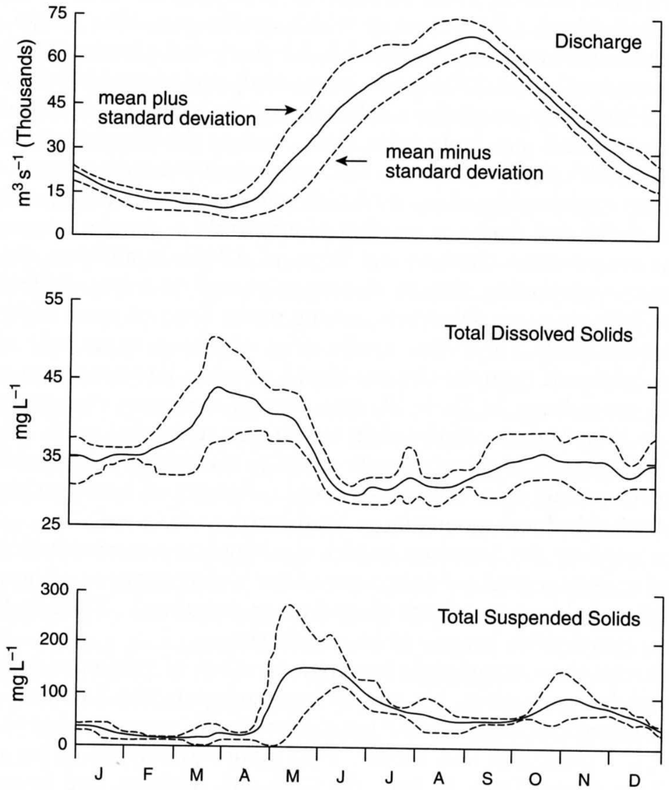


FIGURE 12 Illustration of seasonal changes in concentrations of dissolved and suspended solids in a large tropical river (the Orinoco). Standard deviations indicate interannual variation for a given time of the year. Redrawn from Lewis and Saunders (1989), with permission from Springer-Verlag.

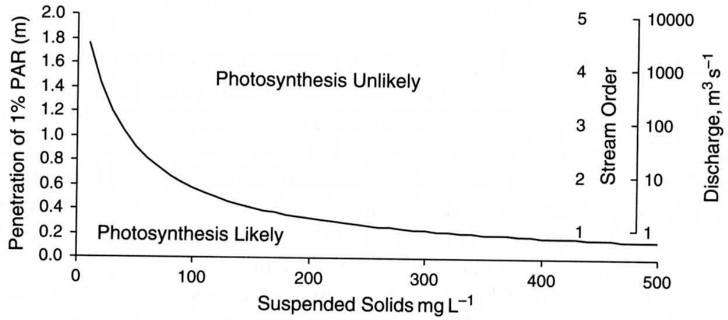


FIGURE 13 Relationship between suspended solids and depth of penetration for 1% of photosynthetically available radiation (PAR assumed here to be the threshold for positive net photosynthesis). Approximate mean depth for streams of various order indicate the approximate range of suspended solids consistent with net photosynthesis for streams of a given order. The detached axis to the right shows river size (expressed as discharge) corresponding to light penetration on the Y-axis on the left.

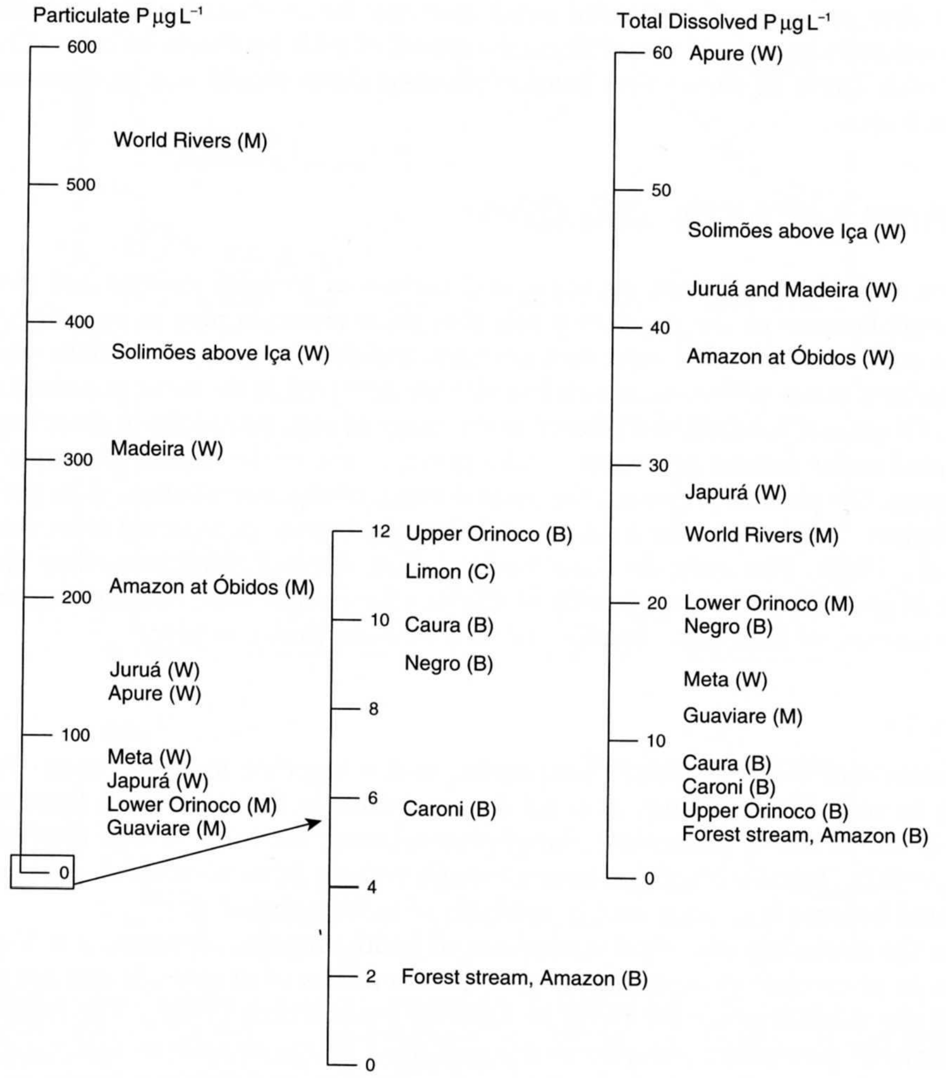


FIGURE 14 Concentrations of particulate phosphorus and total dissolved phosphorus in undisturbed or minimally disturbed rivers of South America (central and northern South America). Apure, Meta, Guaviare, Caura, and Caroni are the main tributaries of the Orinoco main stem. Juruá, Negro, and Japurá are tributaries of the Amazon/Solimões. Limon is a second order montane drainage near the Caribbean coast of Venezuela. Letters indicate general classification (W = white water, B = black water, C = clear water, M = mixed). All data are from Lewis *et al.* (1995). Data on world rivers are from Meybeck (1979).

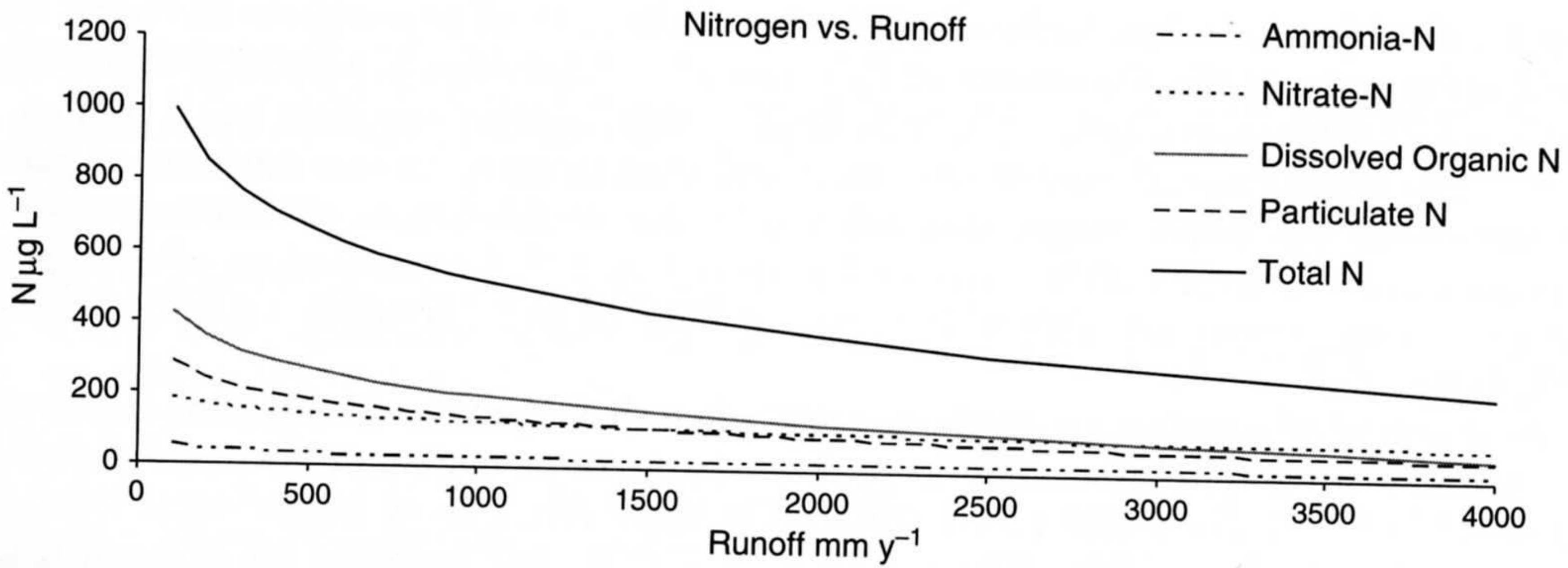


FIGURE 15 Concentrations of total nitrogen and nitrogen fractions (discharge-weighted) over a range of annual runoff as determined by Lewis *et al.* (1999).

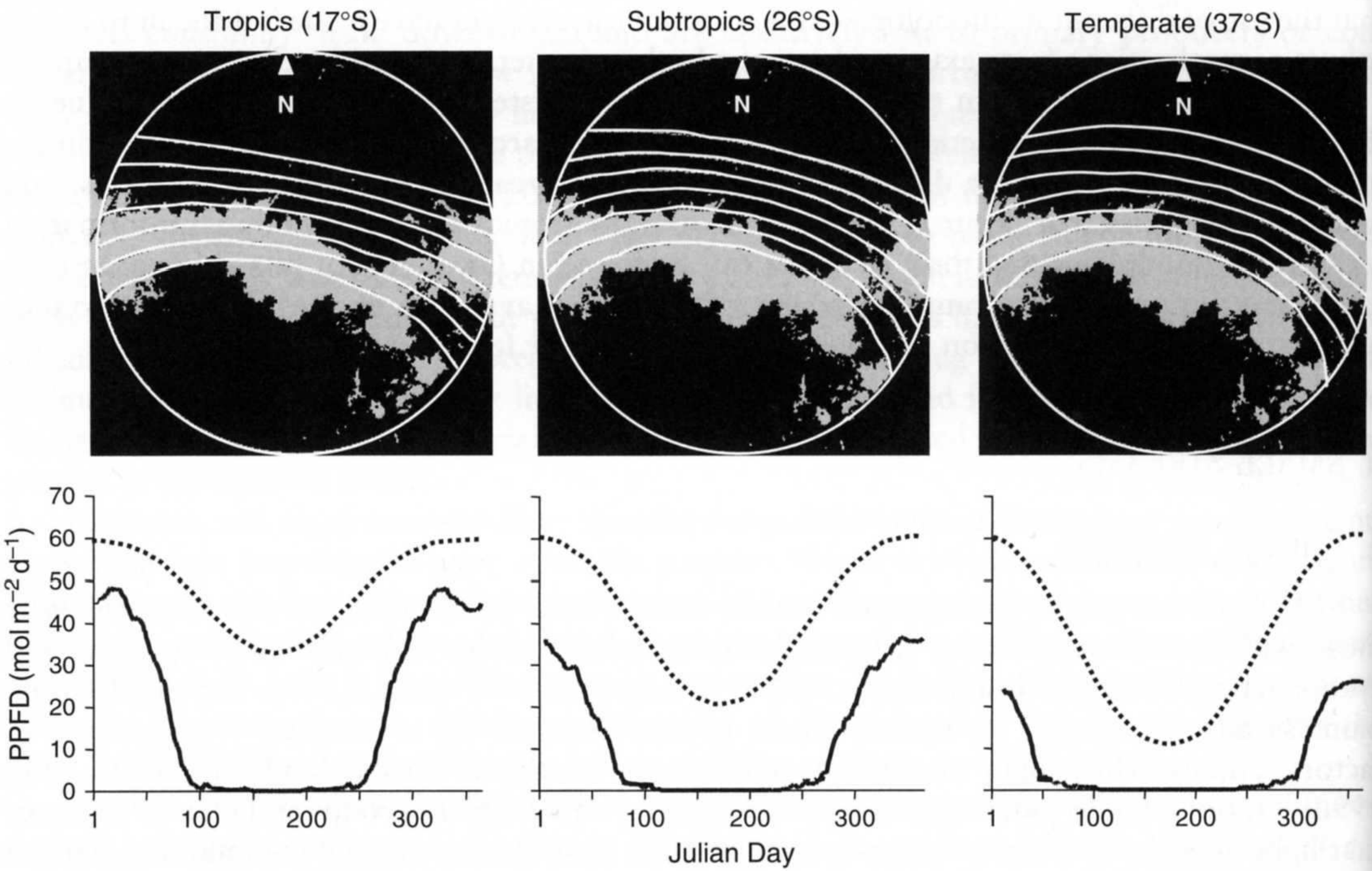


FIGURE 1 Hemispherical images of the riparian canopy above a small rainforest stream in eastern Australia (13 m wide) showing the effect of latitude (tropics, subtropics, and temperate zone). The white curves indicate the trajectory of the sun during each month of the year (Bunn *et al.*, 1999b). The associated graphs show estimated photosynthetically active photon flux density above canopy (dotted line) and below canopy (solid line) throughout the year.

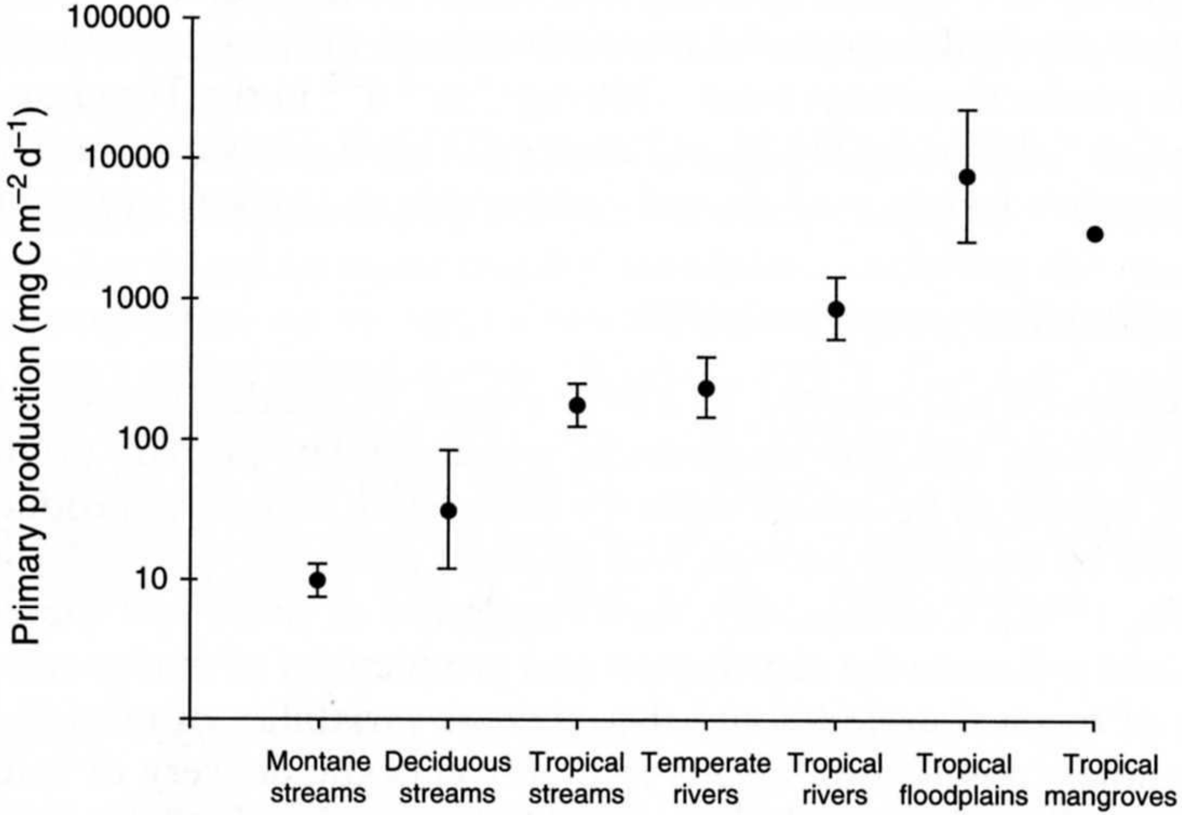


FIGURE 3 Rates of primary production (in mg C m^{-2} d^{-1}) for a range of temperate streams, tropical streams, tropical rivers, tropical floodplains and mangrove systems. Sites only included where methodologies for measuring GPP were comparable. Data are from Table I and, for temperate systems largely from Webster and Meyer (1997) and Bunn and Davies (unpublished Australian data). Note, the temperate river data includes some nutrient-enriched sites. For the Amazon and Orinoco floodplains, data represent overall means accounting for the relative areas of each habitat (Lewis *et al.*, 2001; Melack and Forsberg, 2001).

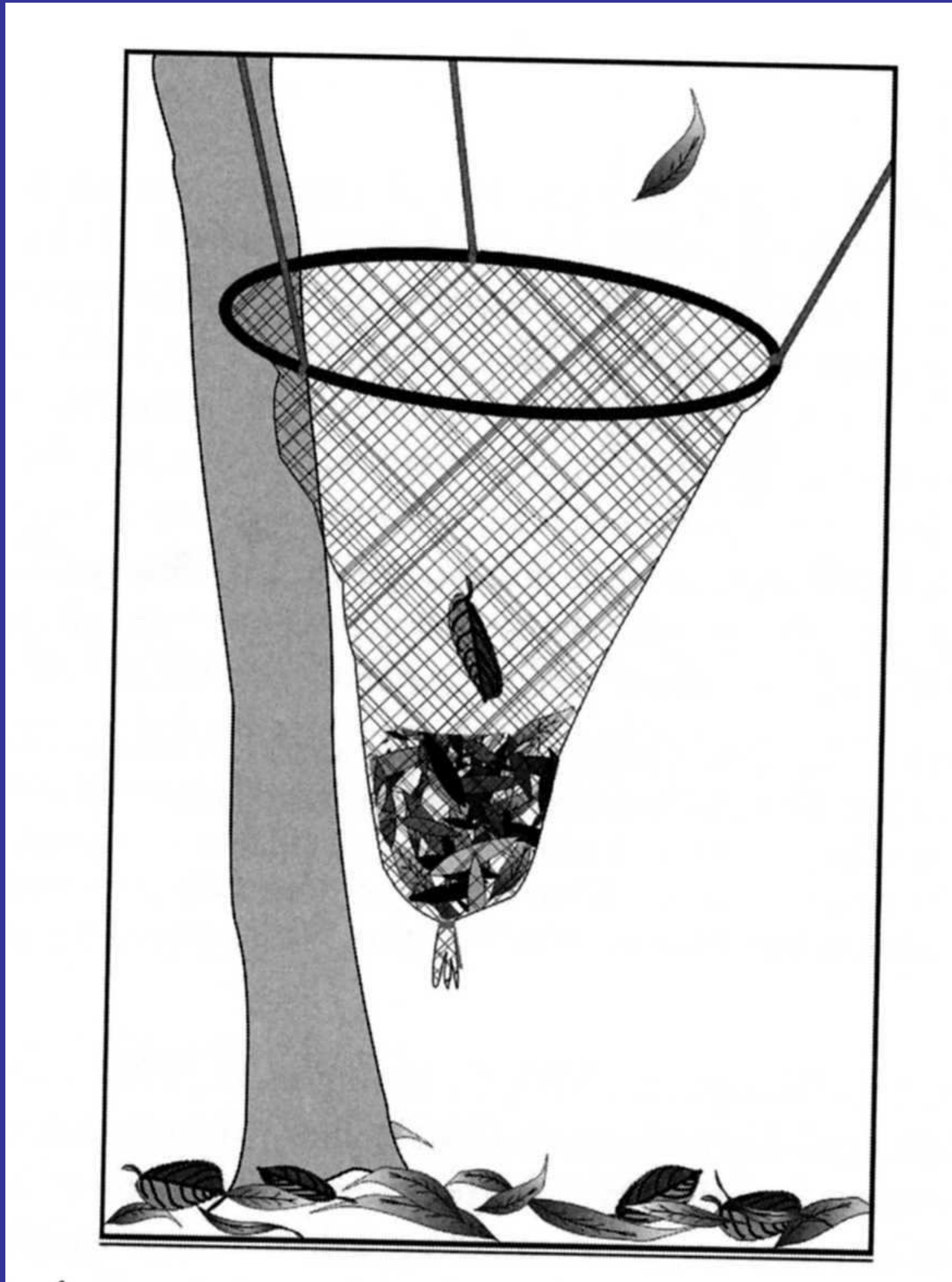


TABLE I Annual Input of Different Litter Types and their Carbon to Nitrogen Ratios at Open- and Closed-Canopy Sites along the Nyoro River, Kenya [Data from Magana (2000)]

Litter type	*Site*	$kg\,m^{-2}\,yr^{-1}$	*C : N*
Wood and bark	Open canopy	0.036	
	Closed canopy	0.271	51.9
Fruits	Open canopy	0.061	
	Closed canopy	0.045	39.9
FPOM	Open canopy	0.014	
	Closed canopy	0.143	19.4
Unidentified fragments	Open canopy	0.196	
	Closed canopy	0.415	58.1

TABLE II Summary of Data on Litter Fall ($kg\,m^{-2}\,yr^{-1}$) at a Range of Tropical Sites

Forest type	*Location*	*Total litter*	*Leaf litter*	*%N*	*%p*	*Source*
Montane (2550 m asl)	Amazonia	0.70	0.46	1.2	0.09	Veneklaas (1991)†
Montane (3370 m asl)	Amazonia	0.43	0.28	0.7	0.04	Veneklaas (1991)†
Upland	Amazonia	0.80		1.3	0.04	Dantas and Phillipson (1989)†
Terra firme	Amazonia	0.74	0.56	1.4	0.03	Klinge and Rodrigues (1968)†
Terra firme	Amazonia	0.79	0.64	–	–	Franken (1979)†
Terra firme	Amazonia	0.83	0.54	1.8*	0.02*	Luizao (1989)†
Terra firme	Amazonia	1.02	0.76	1.6*	0.03*	Cuevas and Medina (1986)†
Riparian	Amazonia	0.64	0.43	1.2	0.02	Franken (1979)†
Terra firme	Amazonia	0.74	0.47	1.4*	0.03*	Luizao (1989)†
Campina	Amazonia	–	–	1.0	0.05	Klinge (1985)†
Tall caatinga	Amazonia	0.56	0.40	0.7	0.05	Cuevas and Medina (1986)†
Bana	Amazonia	0.24	0.21	0.6	0.02	Cuevas and Medina (1986)†
Igapó	Amazonia	0.68	0.53	–	–	Adis *et al.* (1979)†
Igapó	Amazonia	0.67	–	1.4	–	Irmler (1982)†
Average	Amazonia	0.68	0.48	1.2	0.04	McClain and Richey (1996)†
Gallery forest	Cerrado, Central Brazil	0.82				Wantzen and Wagner (2006)
Evergreen savanna	Pantanal, Central Brazil	0.75 – 1.02				Haase (1999)
Semi-deciduous savanna	Pantanal, Central Brazil	0.48 – 0.75				Haase (1999)
Tropical rainforest	Pasoh, Malaysia	1.06	0.63 – 0.75			Ogawa (1978)
Shorea plantation	India		0.59			Puri (1953)‡
Tectona plantation	India		0.53			Seth *et al.* (1963)‡
Deciduous forest	Sagar, India		0.26 – 0.93			Upadhyaya (1955)‡
Deciduous forest	Varansi, India		0.10 – 0.62			Singh (1968)‡
Deciduous forest	Udaipur, India		0.4			Garg and Vyas (1975)‡
Average	10°S–10°N	0.68				Bray and Gorham (1964)

*Calculated as percent of leaf litter.
†Cited from McClain and Richey (1996).
‡Cited from Garg and Vyas (1975).

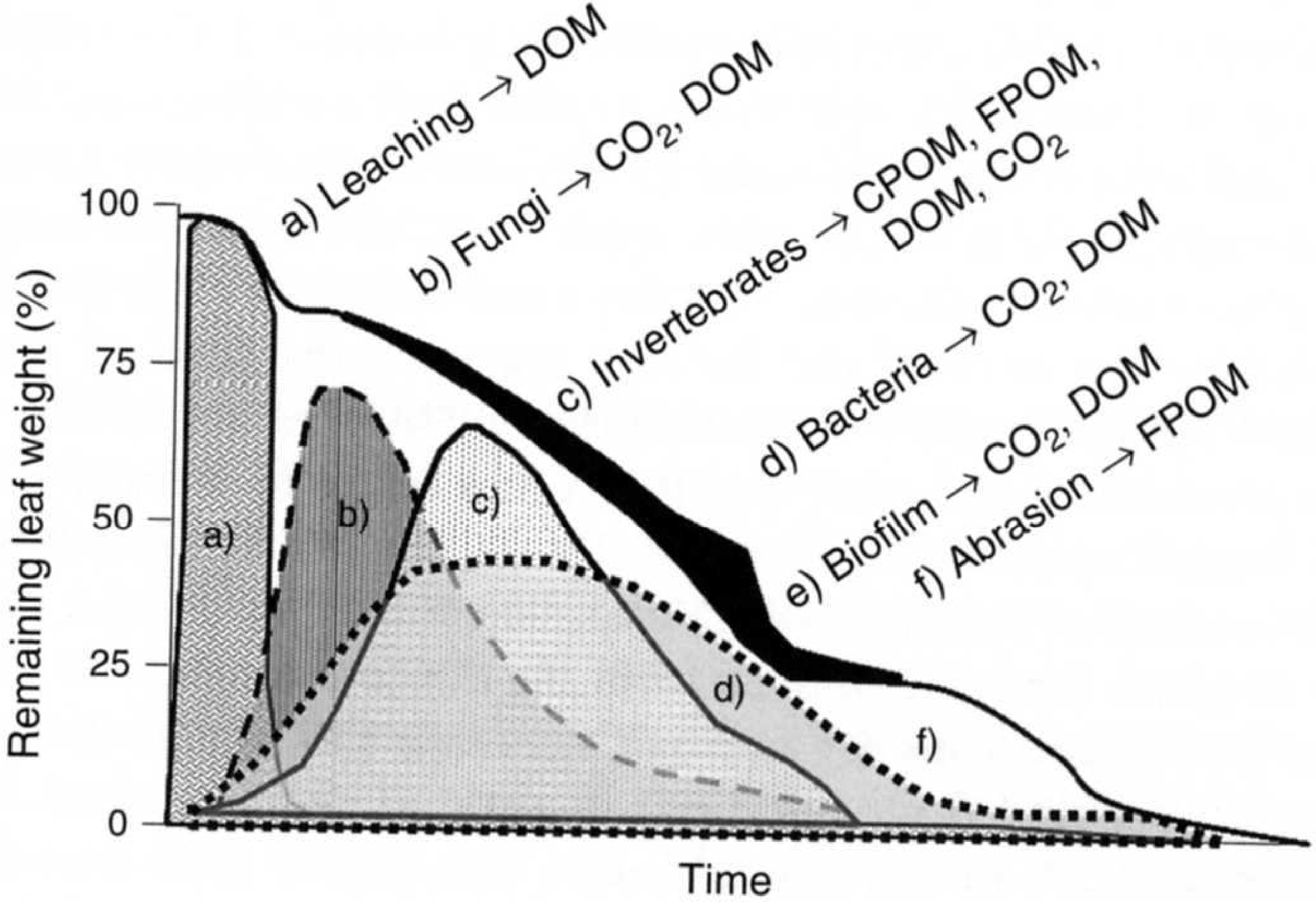

a) Leaching → DOM
b) Fungi → CO_2, DOM
c) Invertebrates → CPOM, FPOM, DOM, CO_2
d) Bacteria → CO_2, DOM
e) Biofilm → CO_2, DOM
f) Abrasion → FPOM
Remaining leaf weight (%)
100
75
50
25
0
a)
b)
c)
d)
f)
Time

TABLE I Mean Percent of Total Individuals Attributed to Specific Non-insect Taxa Classes and Insect Orders in the Stream Macrobenthos of Six Tropical Regions

	Total individuals (%)						
	SU	*HK*	*PN*	*EP*	*EA*	*BO*	*Mean*
Non-insects							
Planariidae	<0.1	0.5	–	3.2	1.3	0.2	0.9
Oligocheata	–	–	–	–	0.2	1.0	0.2
Hydracarina	–	–	–	–	<0.1	0.3	<0.1
Decapoda	–	0.4	<0.1	–	–	–	<0.1
Bivalvia	–	<0.1	–	0.1	–	–	<0.1
Gastropoda	–	3.4	–	0.8	<0.1	0.7	0.8
Insects							
Plecoptera	<0.1	3.1	–	0.3	0.8	1.7	1.0
Ephemeroptera	47.3	28.2	50.9	29.9	21.2	25.4	33.8
Odonata	0.4	0.8	1.3	8.3	1.6	1.4	2.3
Megaloptera	–	0.1	–	0.7	0.3	0.7	0.3
Hemiptera	–	1.4	0.8	6.4	1.3	1.6	1.9
Coleoptera	6.7	15.5	10.1	25.8	13.3	22.1	16.6
Lepidoptera	0.2	0.2	1.4	0.9	2.2	0.3	0.9
Trichoptera	23.7	13.1	14.3	9.9	8.4	28.0	16.2
Diptera	21.6	34.3	21.1	13.6	47.9	16.6	25.2

Only taxa comprising >0.1% in at least one region are included.

SU, Sulawesi (number of sites = 5; Dudgeon, 2006 and unpublished observations); HK, Hong Kong ($n = 36$; D. Dudgeon, unpublished observations); PN, Papua New Guinea ($n = 6$; Dudgeon, 1994); EP, Ecuador Pacific ($n = 12$; Schultz, 1997); EA, Ecuador Amazon ($n = 12$; Bojsen and Jacobsen, 2003); BO, Bolivia ($n = 12$; Moya, 2006).

TABLE III Dominant Taxa in the Stream Macrobenthos of Six Tropical Regions Listed in Order of Decreasing Density

Sulawesi	*Hong Kong*	*Papua New Guinea*	*Ecuador, Pacific*	*Ecuador, Amazon*	*Bolivia, Chapare*
Chironomidae (D)	Chironomidae (D)	Baetidae (E)	Elmidae (C)	Chironomidae (D)	Elmidae (C)
Baetidae (E)	Leptophlebiidae (E)	Chironomidae (D)	Baetidae (E)	Elmidae (C)	Hydropsychidae (T)
Hydropsychidae (T)	Scirtidae (C)	Leptophlebiidae (E)	Chironomidae (D)	Tricorythidae (E)	Tricorythidae (E)
Caenidae (E)	Baetidae (E)	Elmidae (C)	Tricorythidae (E)	Leptophlebiidae (E)	Chironomidae (D)
Tricorythidae (E)	Heptageniidae (E)	Hydropsychidae (T)	Leptophlebiidae (E)	Baetidae (E)	Baetidae (E)
Philopotamidae (T)	Elmidae (C)	Caenidae (E)	Naucoridae (H)	Hydropsychidae (T)	Odontoceridae (T)
Leptophlebiidae (E)	Hydropsychidae (T)	Philopotamidae (T)	Hydropsychidae (T)	Simuliidae (D)	Leptophlebiidae (E)
Elmidae (C)	Caenidae (E)	Glossosomatidae (T)	Libellulidae (O)	Pyralidae (L)	Xiphocentronidae (T)
Psephenidae (C)	Philopotamidae (T)	Pyralidae (L)	Gomphidae (O)	Euthyplocidae (E)	Helicopsychidae (T)
Simuliidae (D)	Simuliidae (D)	Libellulidae (O)	Hydroptilidae (T)	Limoniidae (D)	Perlidae (P)
Prosopistomatidae (E)	Gastropoda	Psephenidae (C)	Psephenidae (C)	Naucoridae (H)	
Pyralidae (L)	Ephemerellidae (E)	Ptilodactylidae (C)	Planariidae	Coenagrionidae (O)	
	Perlidae (P)	Tipulidae (D)	Odontoceridae (T)	Ceratopogonidae (D)	
	Hydrophilidae (C)	Philopotamidae (T)	Ptilodactylidae (C)		
	Psephenidae (C)	Coenagrionidae (O)			
	Helotrephidae (H)				
	Pseudoneureclipsidae (T)				
	Nemouridae (P)				

Only taxa comprising >1% in at least one region are included.
D, Diptera; E, Ephemeroptera; T, Trichoptera; C, Coleoptera; P, Plecoptera; H, Heteroptera, L, Lepidoptera.
For sources, see Table I.

TABLE V Number of families (F), species (S) and the species: family (S : F) ratio for aquatic insect orders on three continents

	Tropical South America			*Europe*			*North America*		
	F	*S*	*S : F*	*F*	*S*	*S : F*	*F*	*S*	*S : F*
Ephemeroptera	10	184	18.4	17	217	12.8	21	599	28.5
Plecoptera	2	230	50.0	7	387	55.3	9	577	64.1
Odonata	19	1491	78.5	10	127	12.7	10	422	42.2
Heteroptera	14	715	51.1	12	129	10.8	18	421	23.4
Megaloptera	4	42	11.5	4	16	4.0	4	70	17.5
Coleoptera	18	1913	106.3	23	967	42.0	18	1214	67.4
Trichoptera	14	>2500*	107.1	22	895	40.7	23	1385	60.2
Total	81	6975	73.4	95	2738	28.8	103	4688	45.5

Data for tropical South America from Hurlbert *et al.* (1981), Flint *et al.* (1999) and Cressa and Stark (2003); for Europe from Illies (1978); and for North America from Merritt and Cummins (1996). Megaloptera as used here includes Neuroptera. Diptera have been excluded because data for the order are very incomplete. * R. Holzenthal, University of Minnesota (personal communication). Modified from Jacobsen *et al.* (1997).

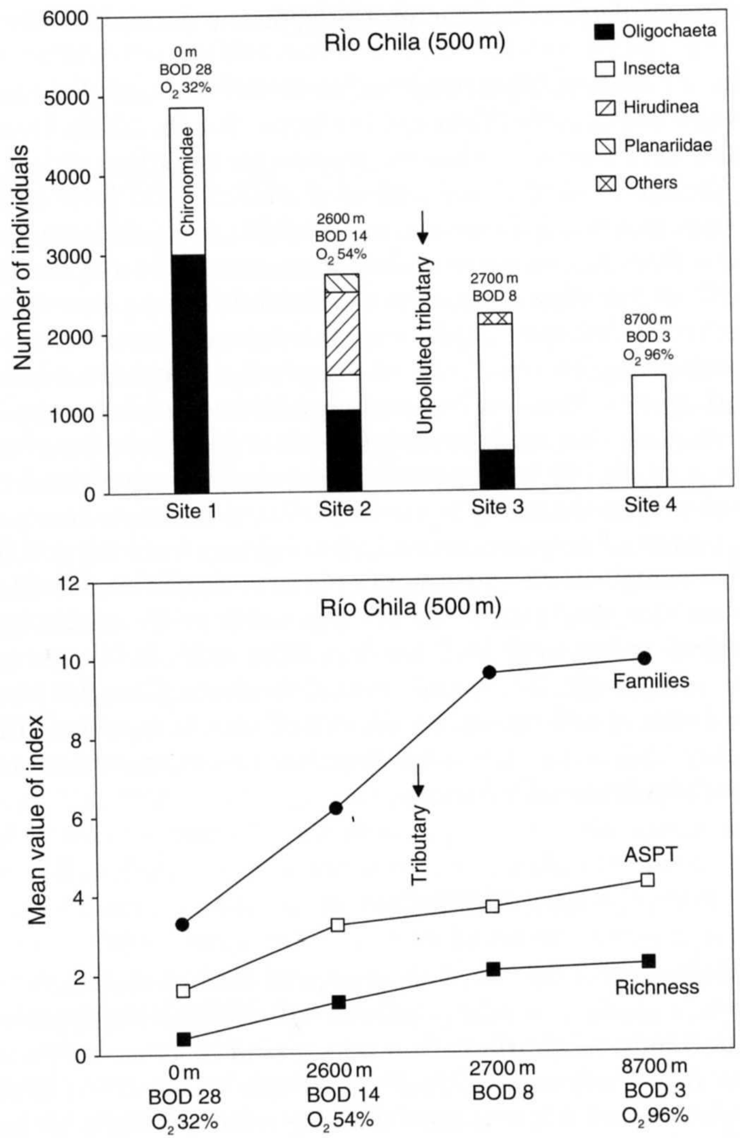


FIGURE 4 Composition (above) and mean values of three different biological indices (below) for benthic macroinvertebrate assemblages collected by semi-quantitative 'kick samples' at four sites at increasing distances from a point source of sewage in a coastal lowland stream (Río Chila) in Ecuador. Distances (m) from the source, mean biological oxygen demand (BOD mg L^{-1}), and minimum oxygen saturation (%) are given also. ASPT = Average Score Per Taxon biological index (Armitage *et al.*, 1983); Richness = Margaleff's richness index (D). Data are from Bang and Thomsen (1997).

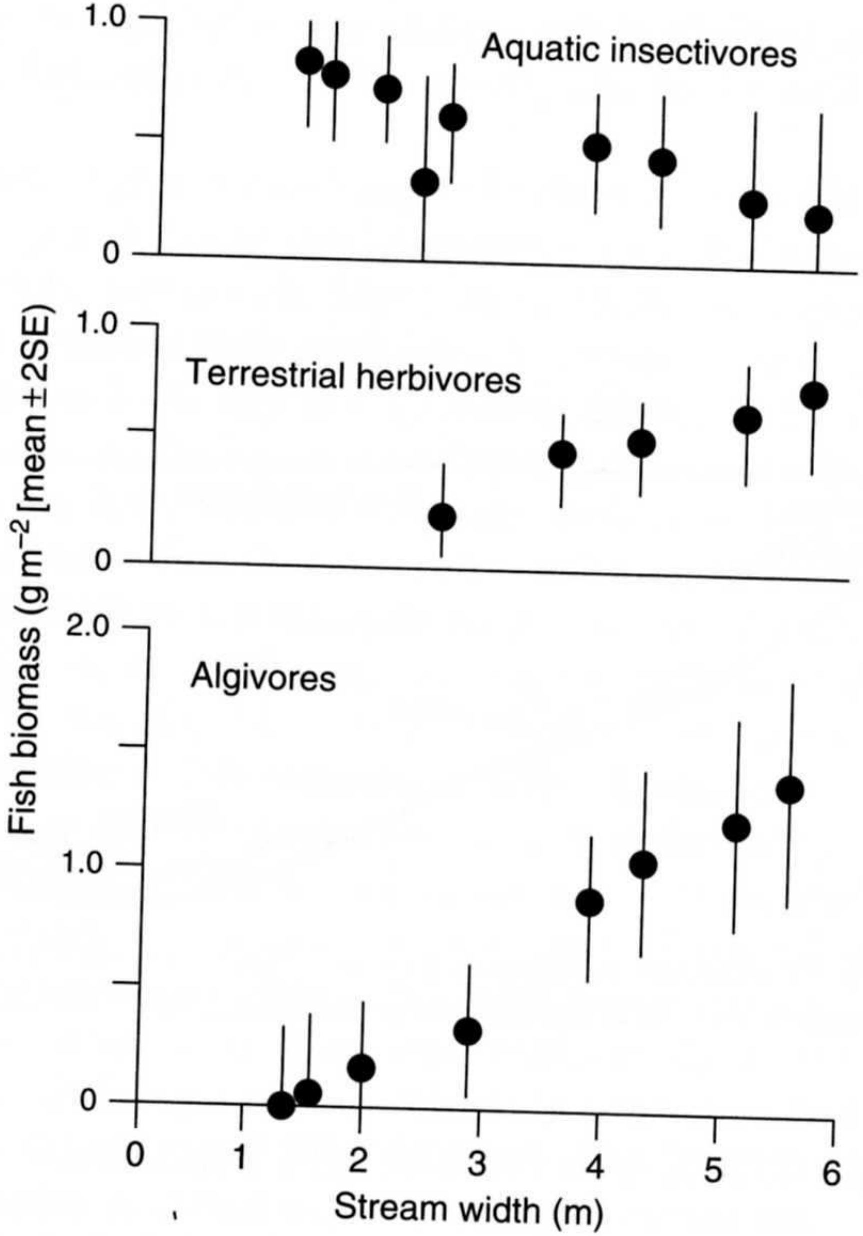


FIGURE 4 Relationship between stream width and fish biomass (density per unit area) for three feeding guilds in lowland streams of Panaman (from Angermeier and Karr, 1983).

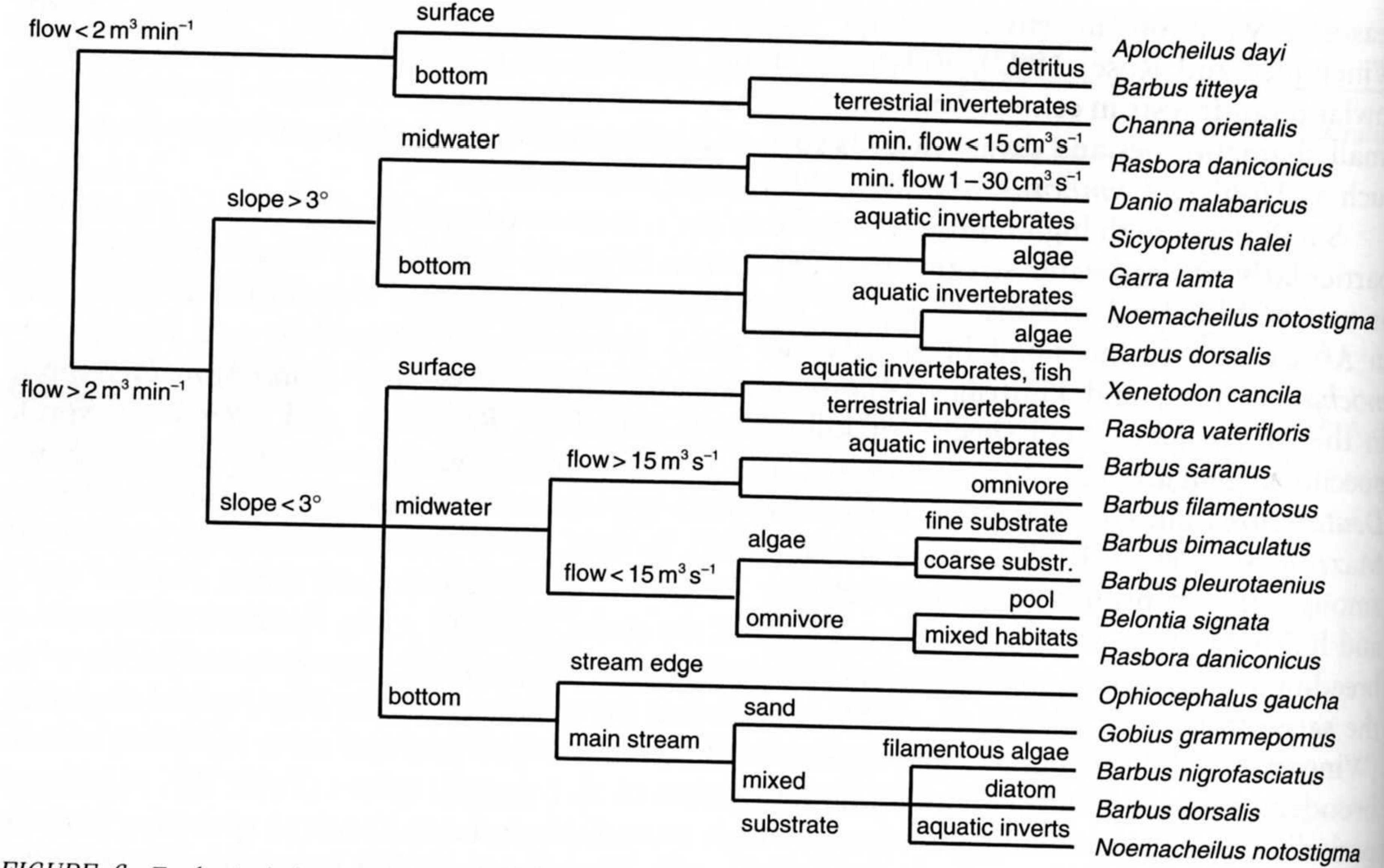
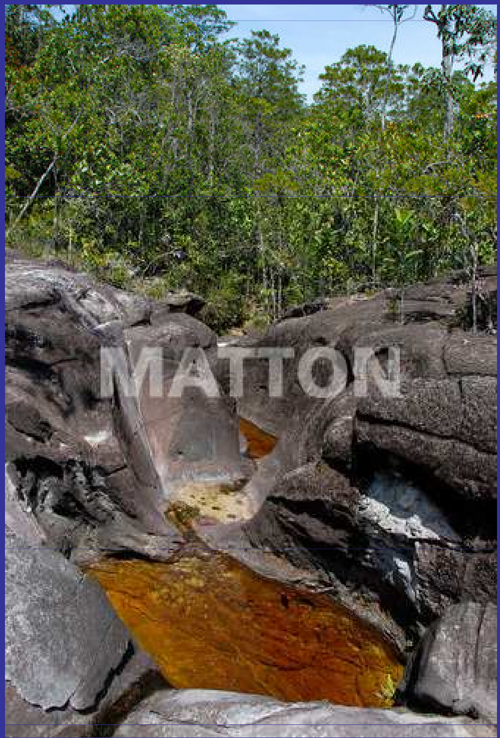
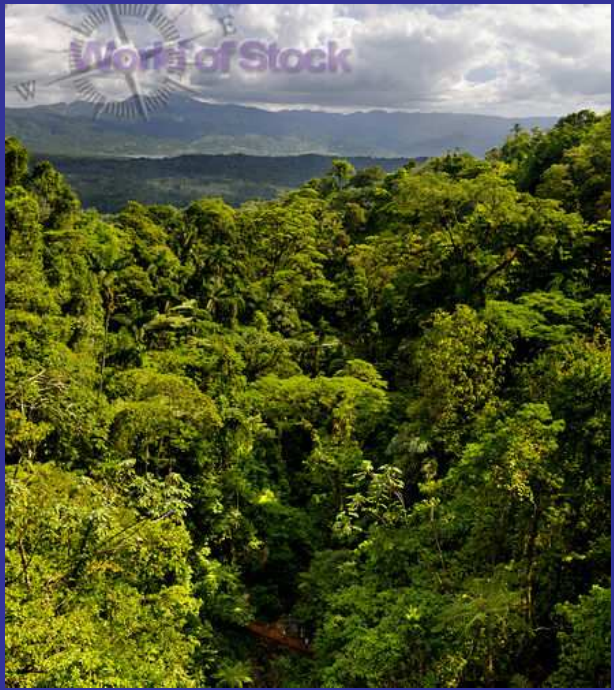


FIGURE 6 Ecological 'key' illustrating the high degree of microhabitat and food resource partitioning reducing ecological overlap among fishes in a Sri Lankan stream (from Moyle and Senanayake (1984)).


MATTON


World of Stock


World of Stock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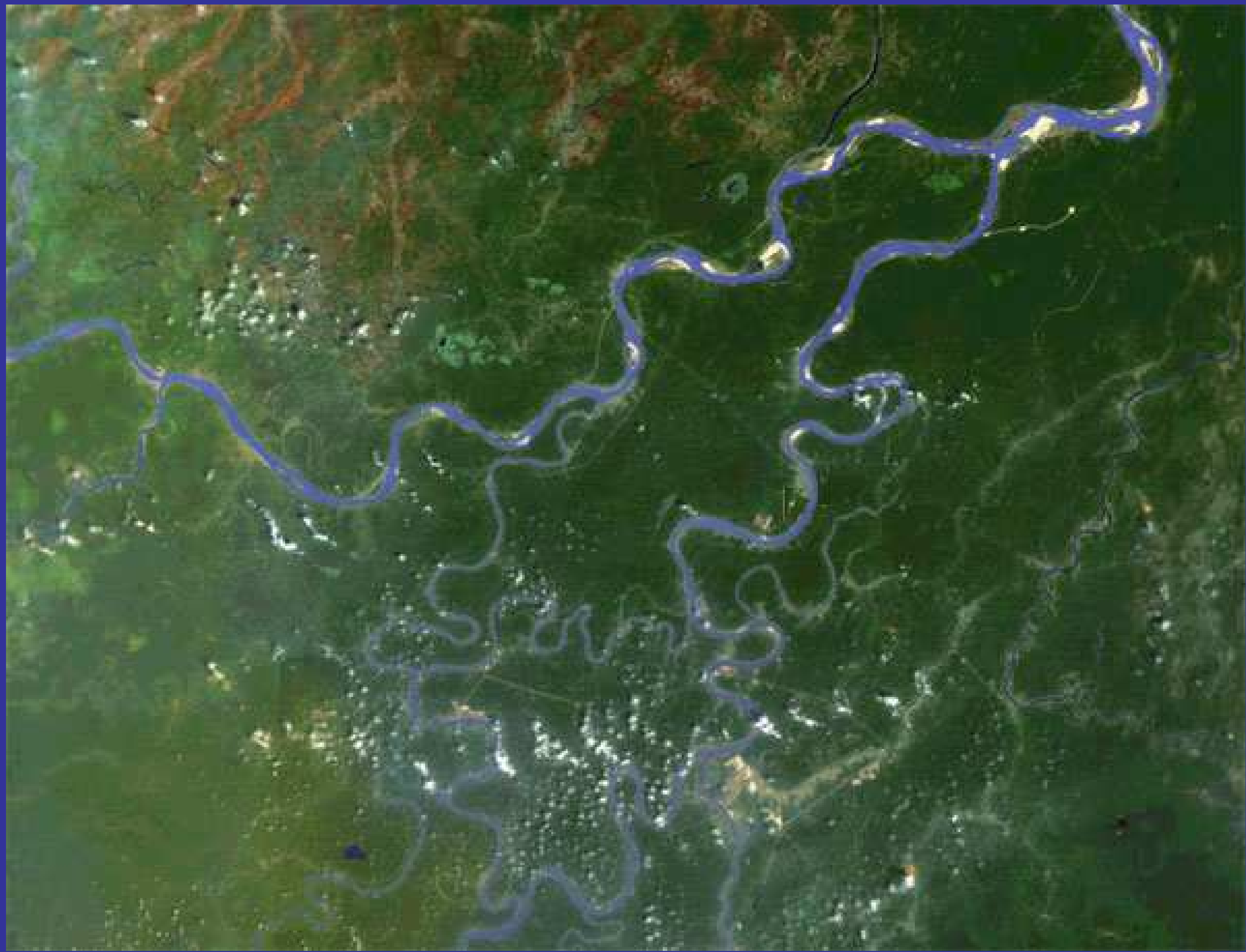

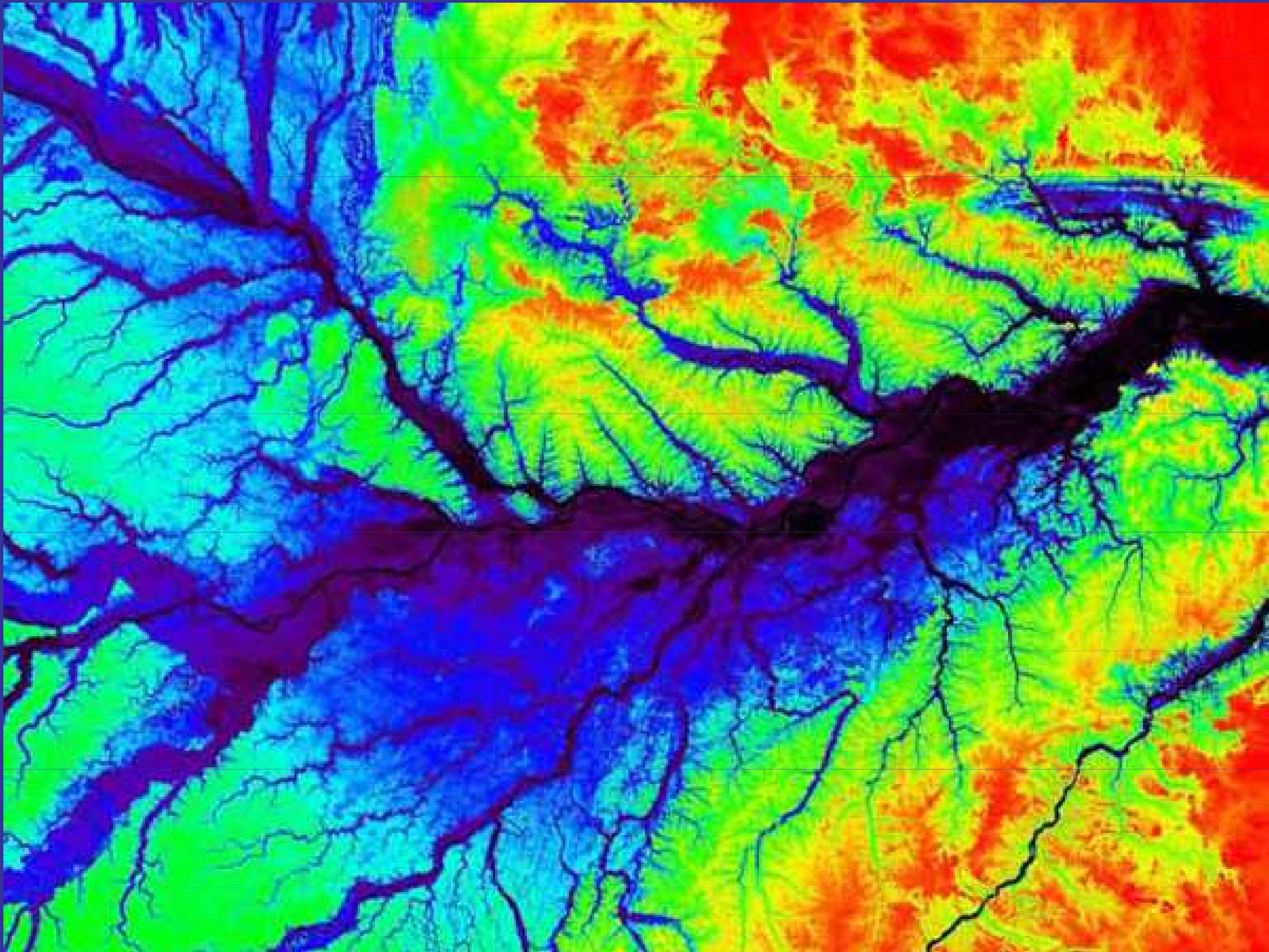


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Brazzaville
Congo River
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