Tropical lakes and rivers

Large river phenomenon: extinct and forgotten in Europe

Rio Negro

Variable water flow volumes – large gravel terraces

Thermal regime of lakes

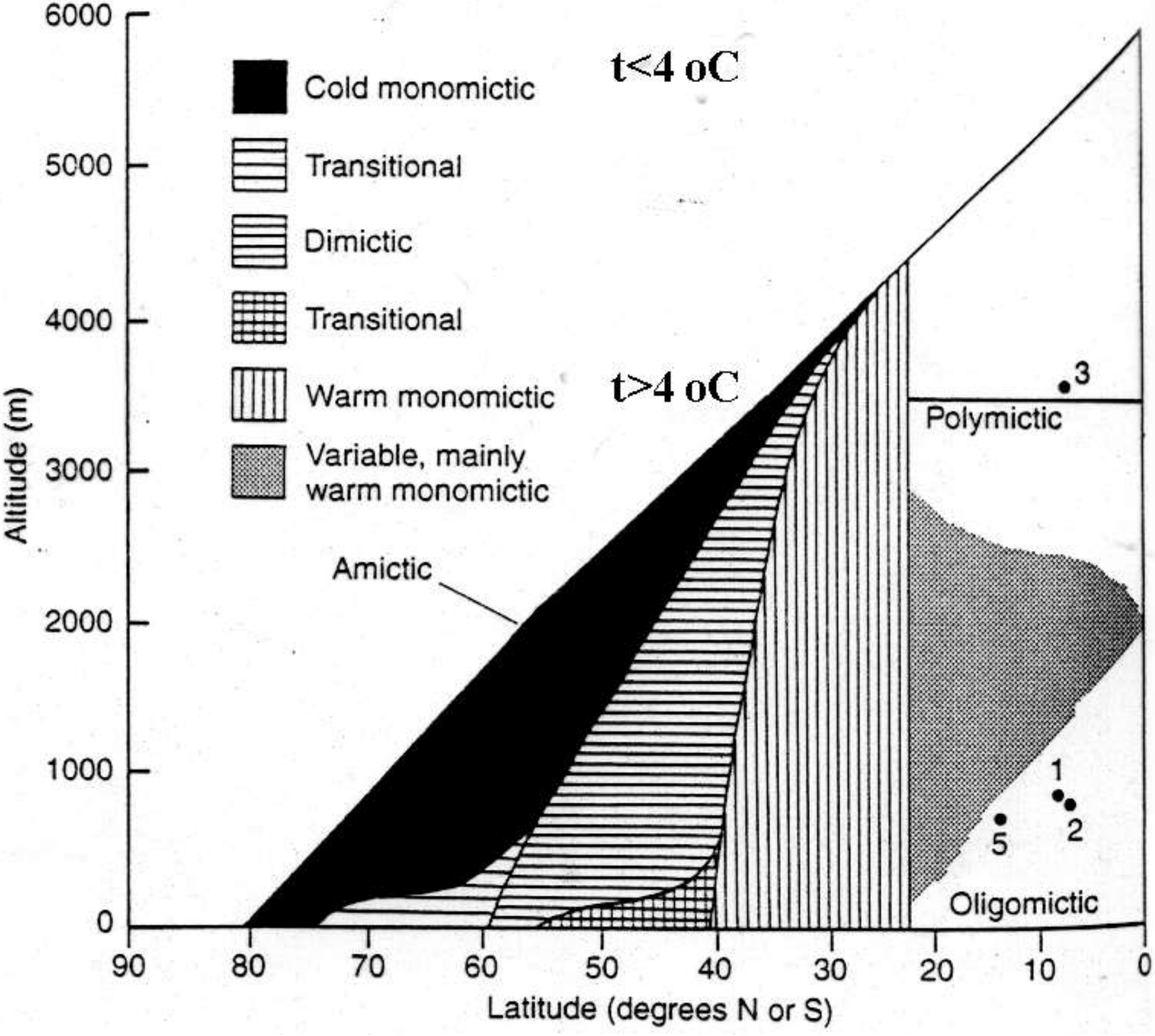


Figure 5.16 Relationship of the thermal regime of deep lakes to latitude and altitude. Transitional regions between warm and cold monomictic types and dimictic lakes are shown. Note the significant variation in the thermal regime of tropical lakes with mainly variants of warm monomixis at mid-altitudes. Geographical position of lakes mentioned in the text are indicated: (1) Lake Kutubu, Papua New Guinea; (2) Lake Lanao; Philippines; (3) Lakes on Mount Wilhelm, Papua New Guinea; (4) Lake Kariba, Zimbabwe and Zambia; (5) Lake Malawi, Malawi (adapted from Hutchinson and Löffler 1956).

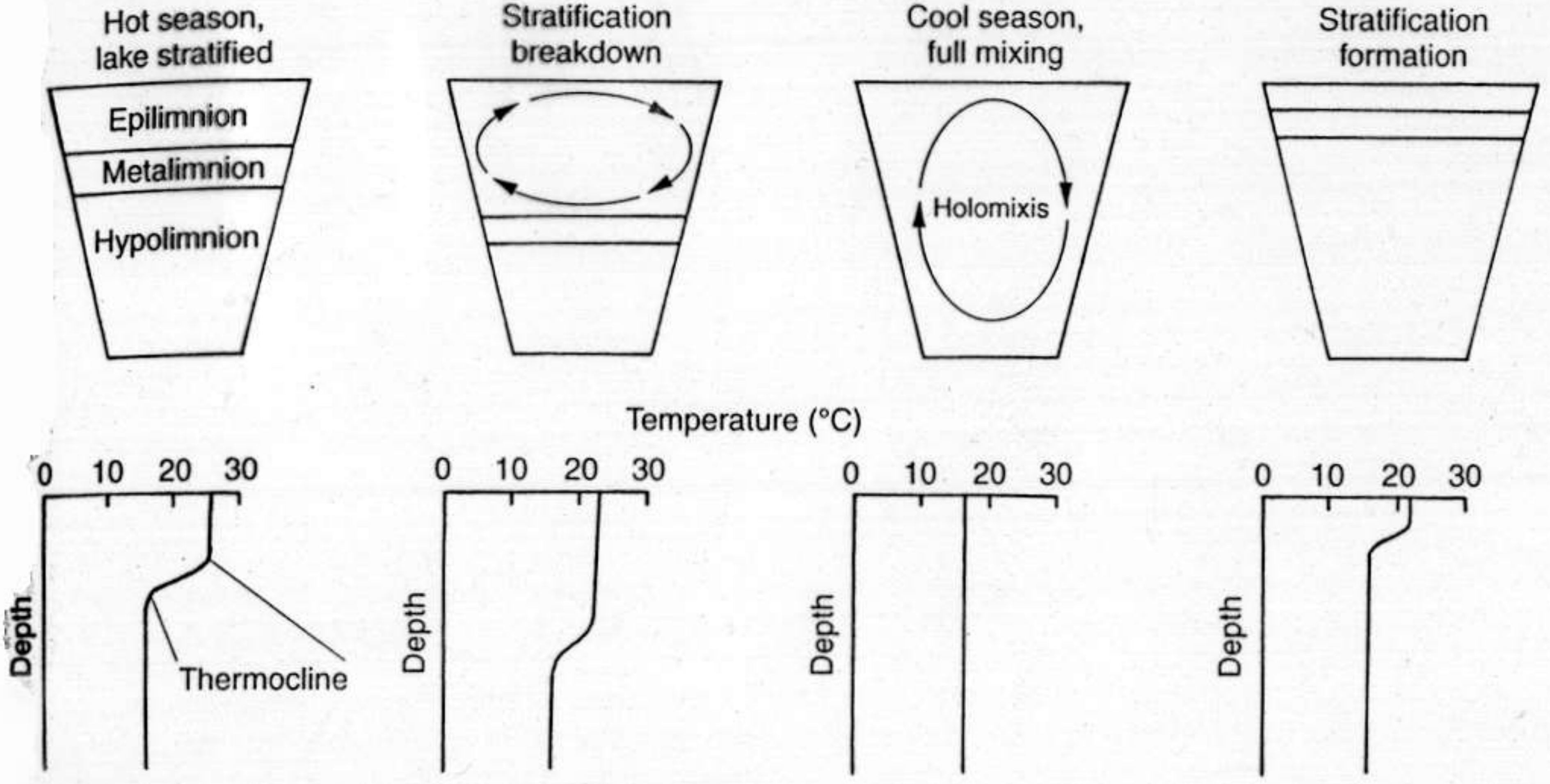
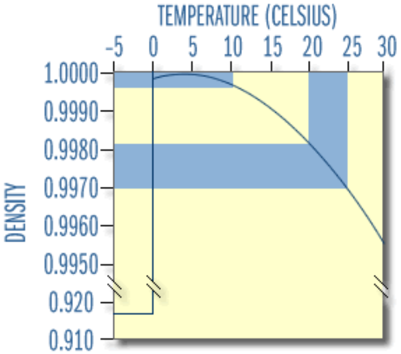


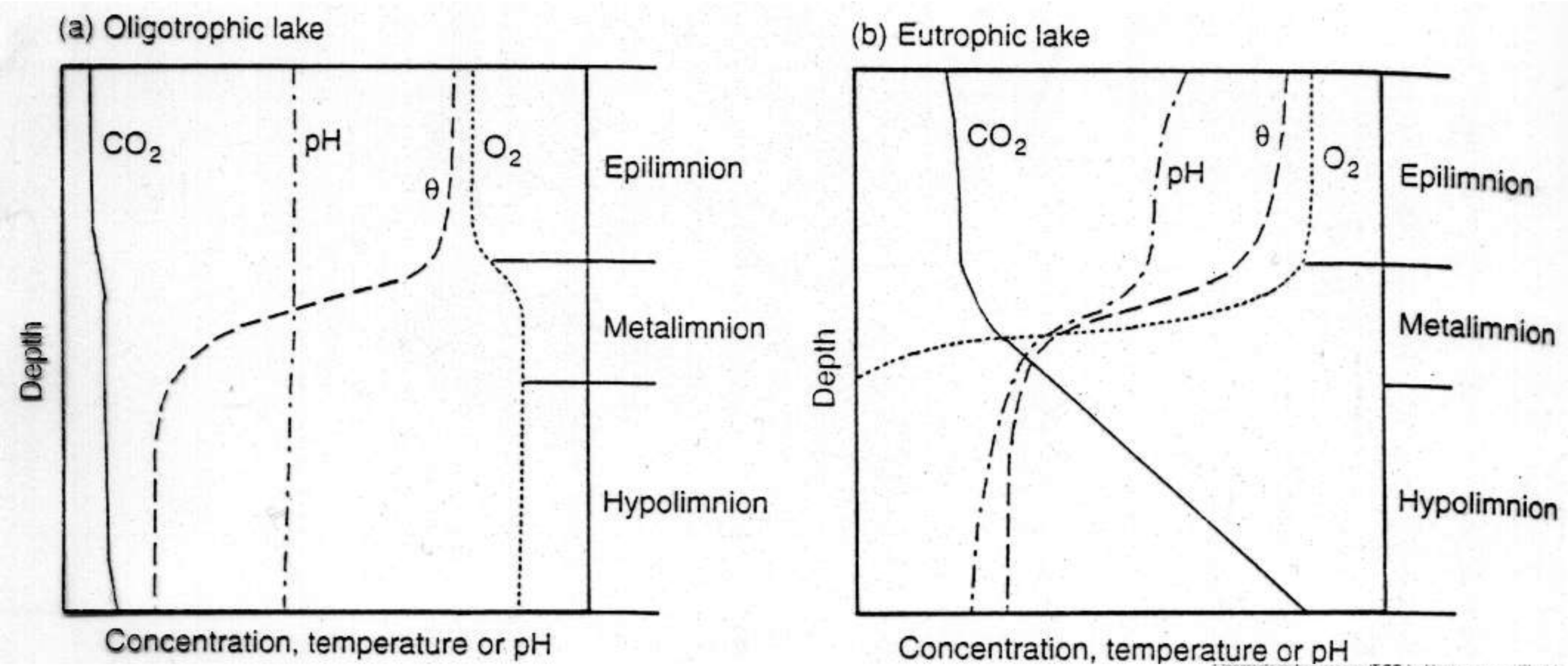
Figure 5.2 Layers of a stratified lake, showing the epilimnion, metalimnion (or thermocline) and hypolimnion and the breakdown of stratification at overturn leading to holomixis. Seasonal temperature-depth profiles are shown.



DENSITY/TEMPERATURE RELATIONSHIP FOR DISTILLED WATER. SHADED AREAS SHOW RELATIVE DIFFERENCE IN DENSITY FOR 5°C TEMPERATURE CHANGES.

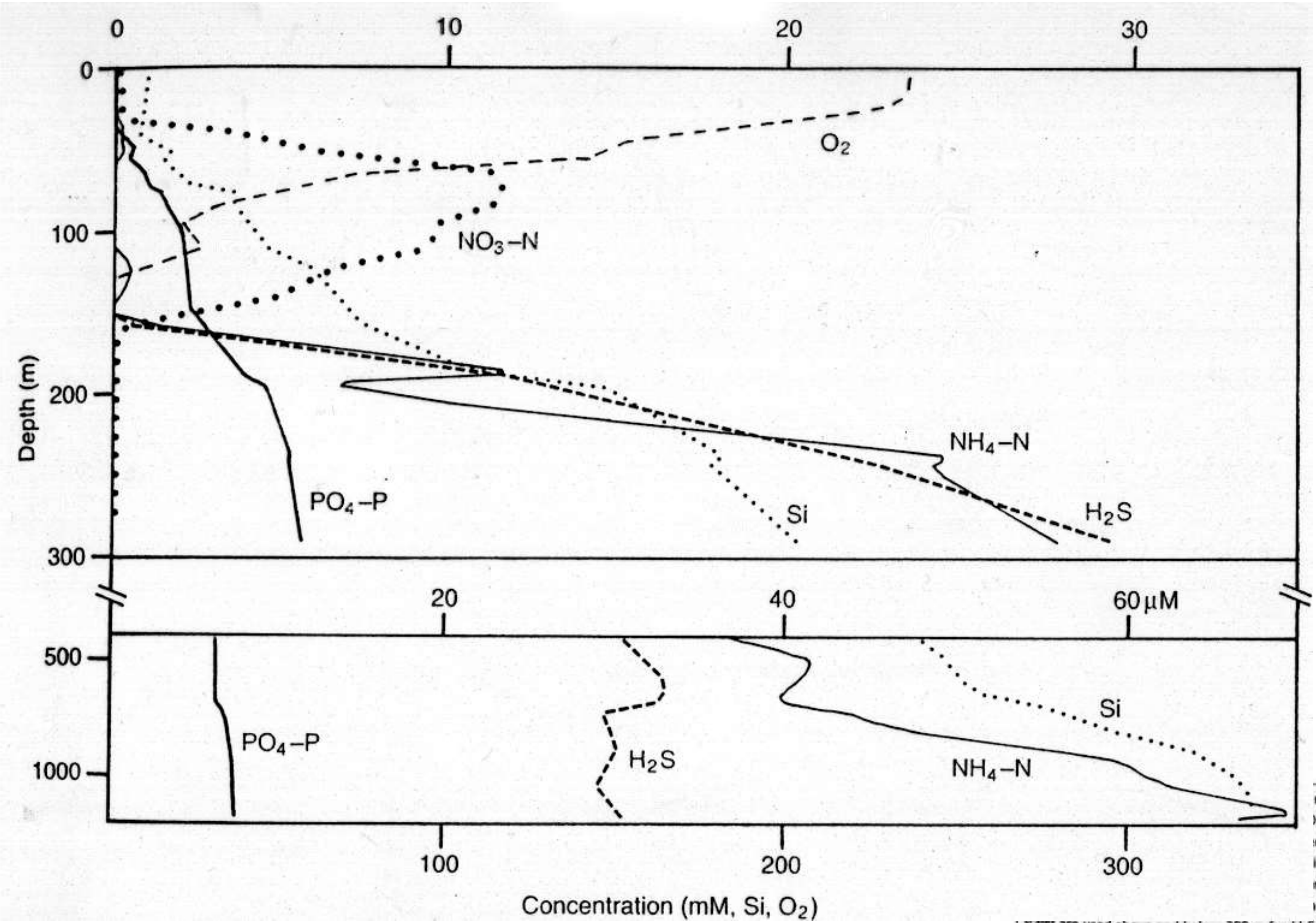
Temperature – density relationship for water

Stratification in oligothropic and eutrophic lakes



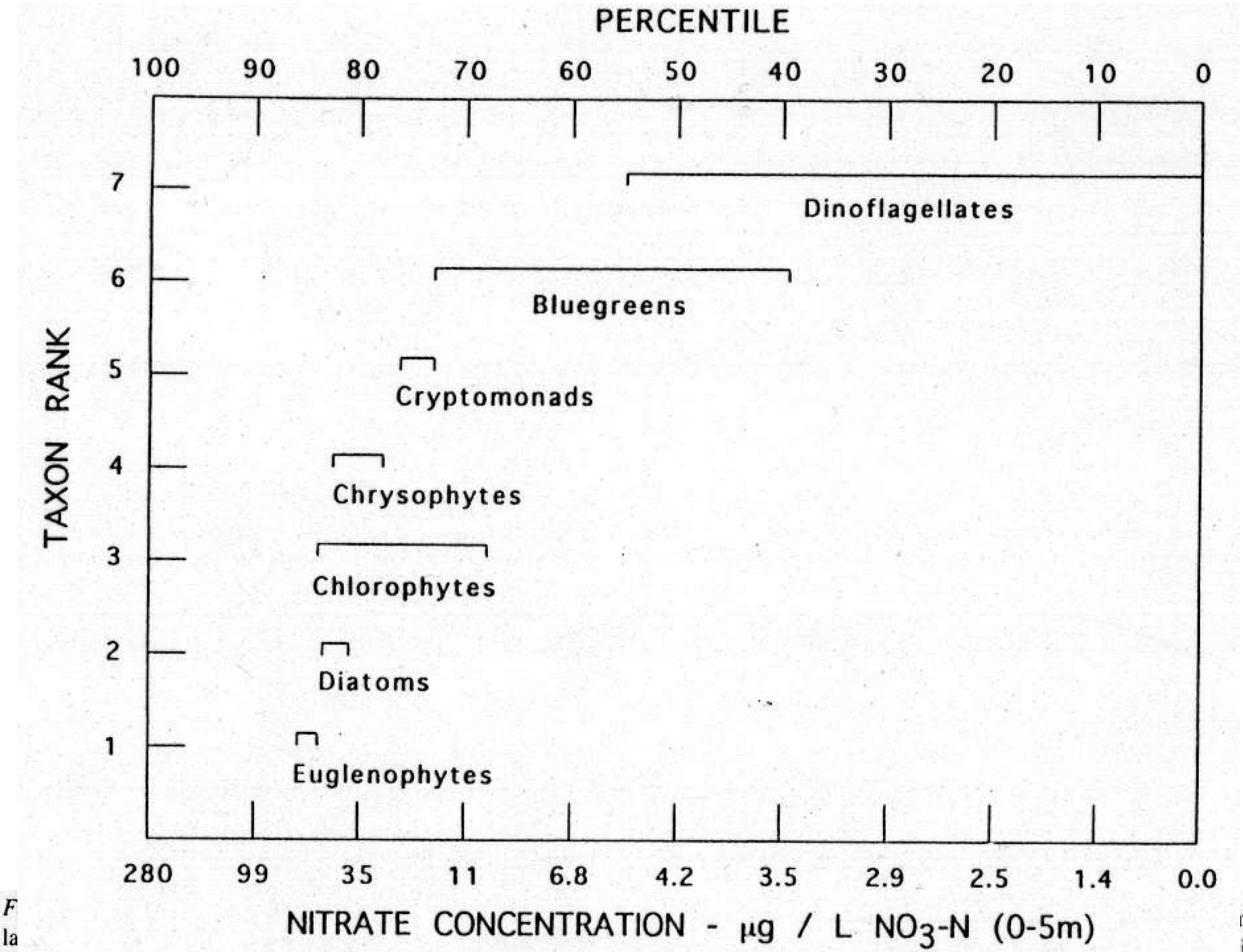
inorganic carbon content (ΣCO_2), pH, temperature (θ) and dissolved oxygen (O_2) in stratified lakes: (a) oligotrophic (nutrient-poor); (b) eutrophic (nutrient-rich, see sect 5.15). In the eutrophic lake, CO_2 is removed from the limnion by dense populations of phytoplankton which developed in response to the nutrient-rich conditions. Decomposition of the large amounts of organic matter duced in the epilimnion of the eutrophic lake occurs in hypolimnion resulting in enhanced concentrations of CC and depletion of O_2. In the oligotrophic lake, the O_2 concentration in the epilimnion decreases as the temperature of this layer increases, since the solubility of gases is inversely related to temperature. Oxygen producti by phytoplankton is inadequate in the nutrient-poor waters to compensate for this loss. Approximate positions of the epilimnion, metalimnion and hypolimnion are indicated (Figure from Limnology by R.G.Wetzel, © 1975 by Saunders

Lake Tanganyika: depletion of nutrients in the euphotic zone



nitrate
$_4$–P), hydro-
n (O_2) and
in the north
nt vertical
orizontal
scales are used above and below 300 m for H_2S, PO_4–P and
NH_4–N. Notice the depletion of the nutrients in the
euphotic zone and their accumulation in the unmixed layer
below 150 m depth and the switch from NO_3–N to NH_4–N
as the water becomes anoxic (after Hecky *et al.* 1991 with

Seasonal succession of phytoplankton with decreasing nitrate levels



F … nixed
la … ixing
event.

Lake Chad: an example of ‘inverted’ biomass pyramid

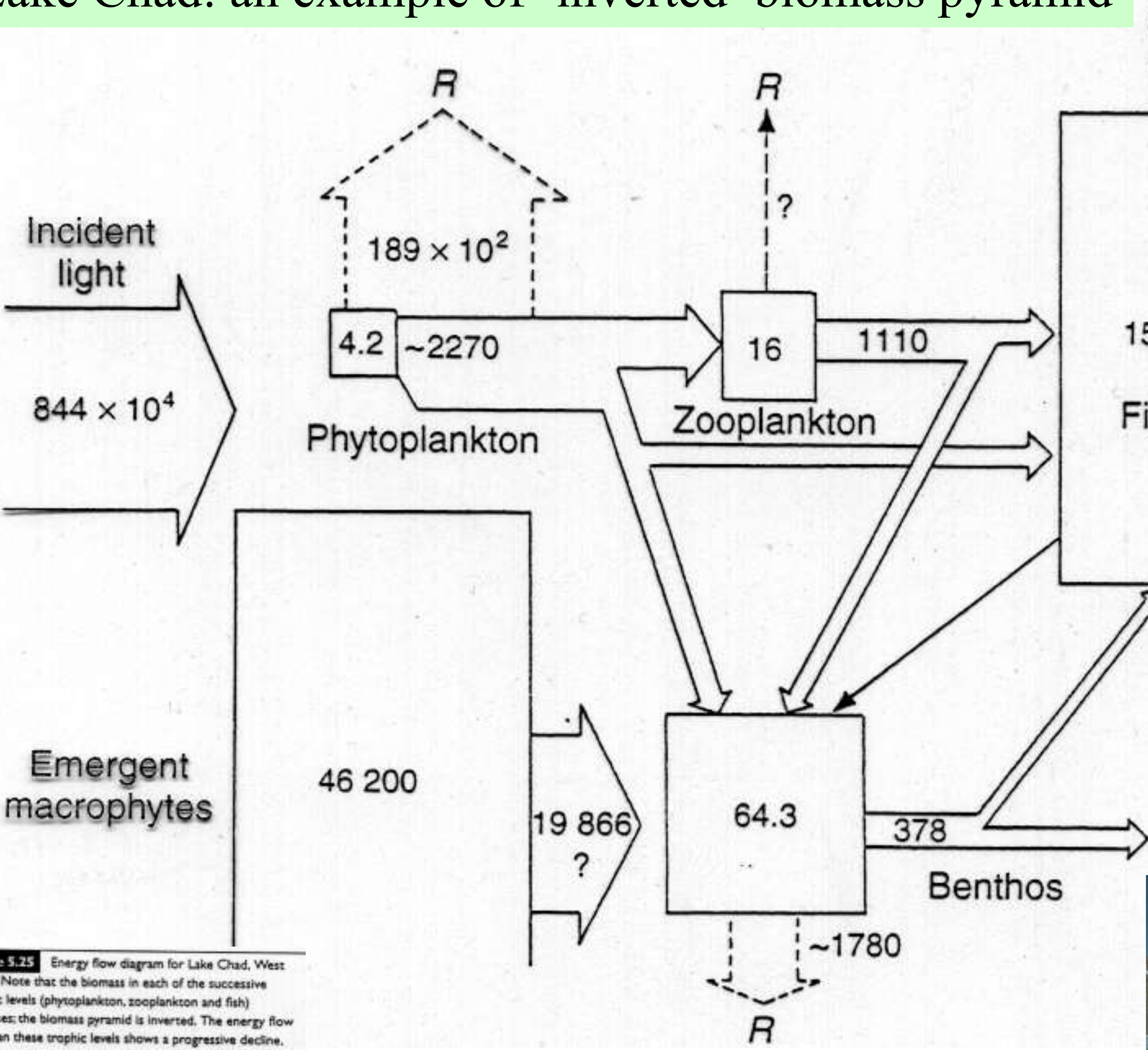
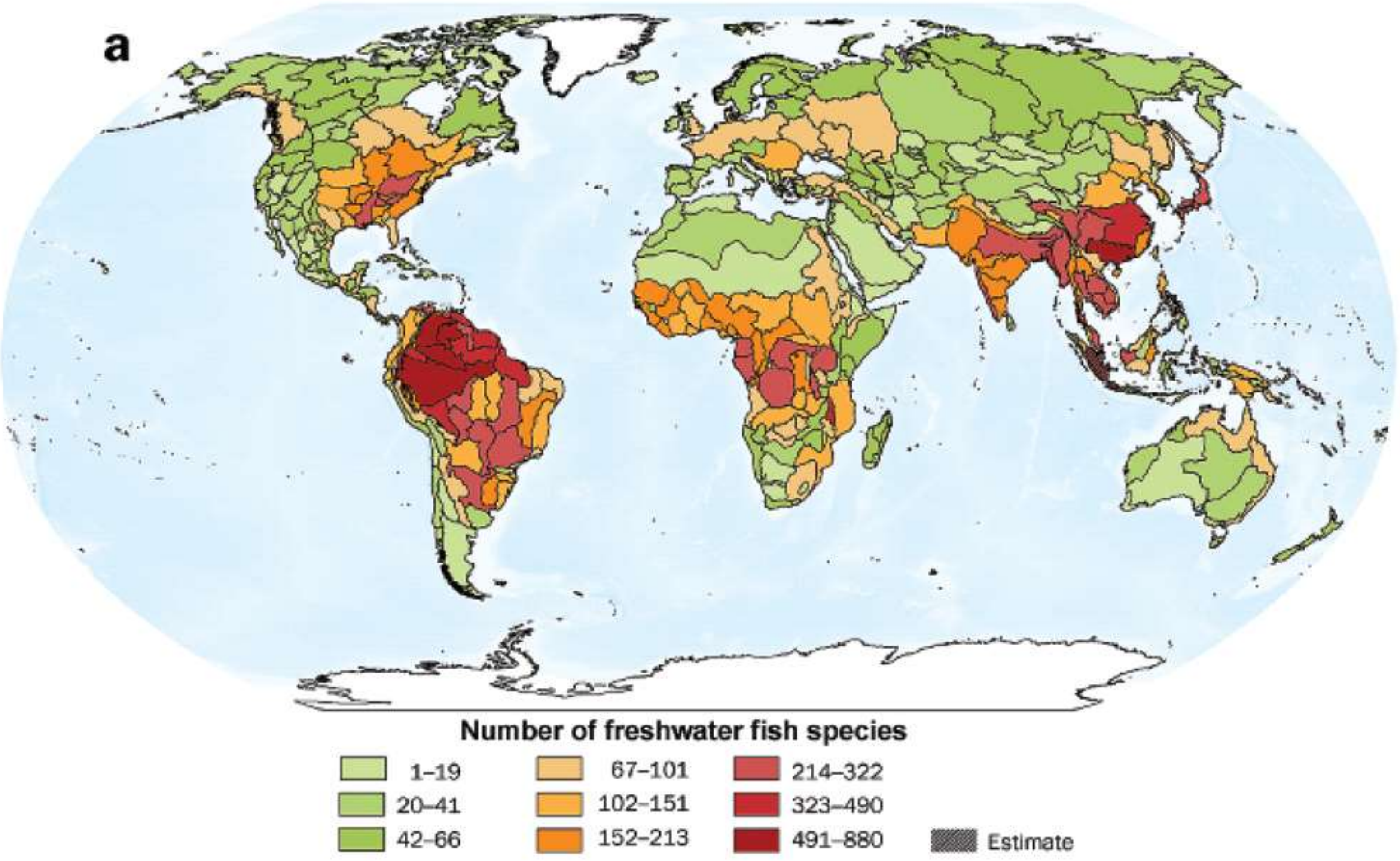


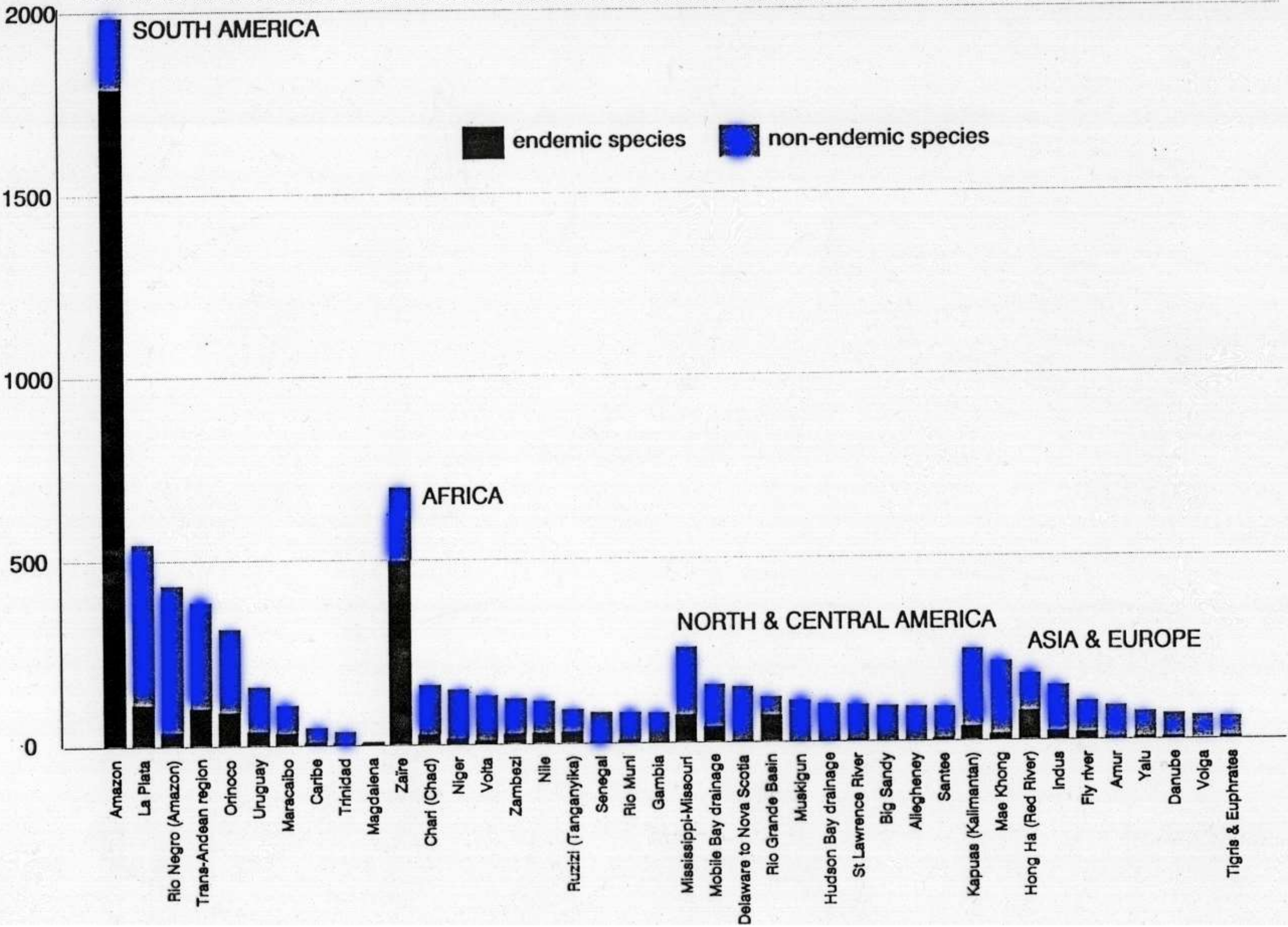
Figure 5.25 Energy flow diagram for Lake Chad, West Africa. Note that the biomass in each of the successive trophic levels (phytoplankton, zooplankton and fish) increases; the biomass pyramid is inverted. The energy flow between these trophic levels shows a progressive decline, with energy lost at each transfer and therefore the energy pyramid is not inverted. Biomass is in kJ m^{-2}, rates of production and respiration (*R*) are in kJ m^{-2} $year^{-1}$ (adapted from Carmouze et al. 1983 with kind permission from Kluwer

Number of freshwater fish species per ecoregion

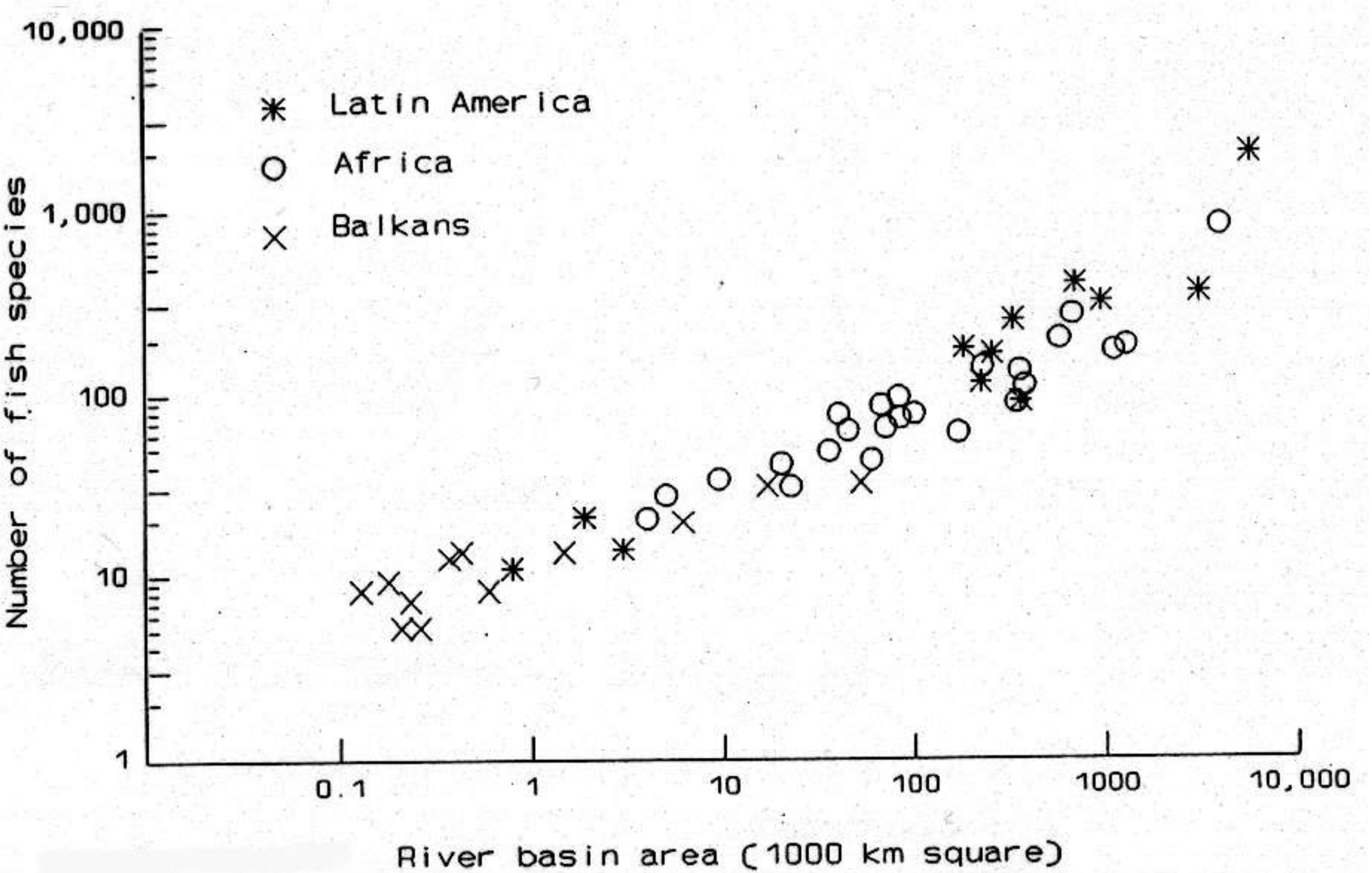


Abell et al., 2008, BioScience 58:403

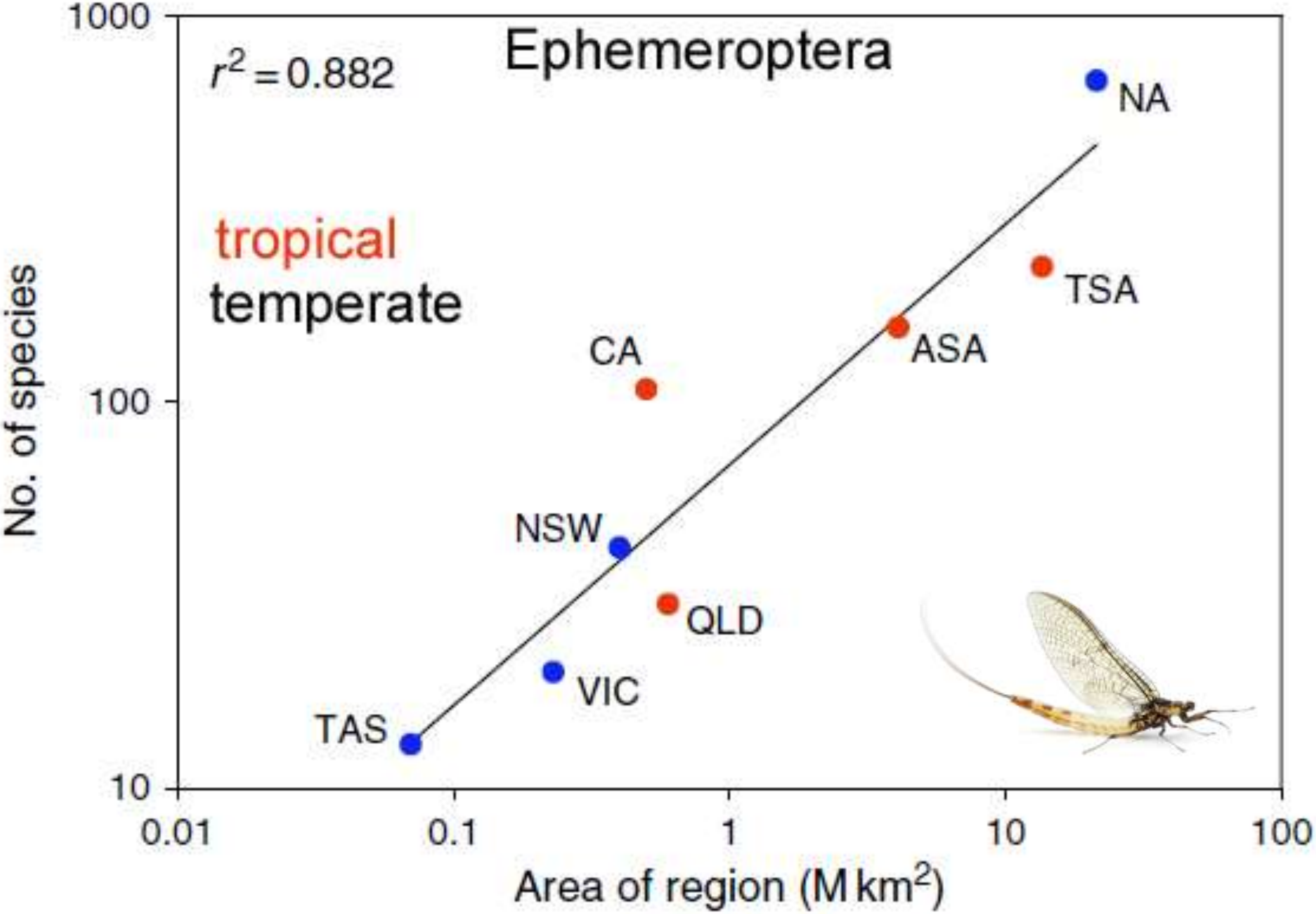
FRESHWATER RIVER FISHES: SPECIES RICHNESS AND ENDEMISM



Fish species richness in rivers: no clear temperate-tropical gradient

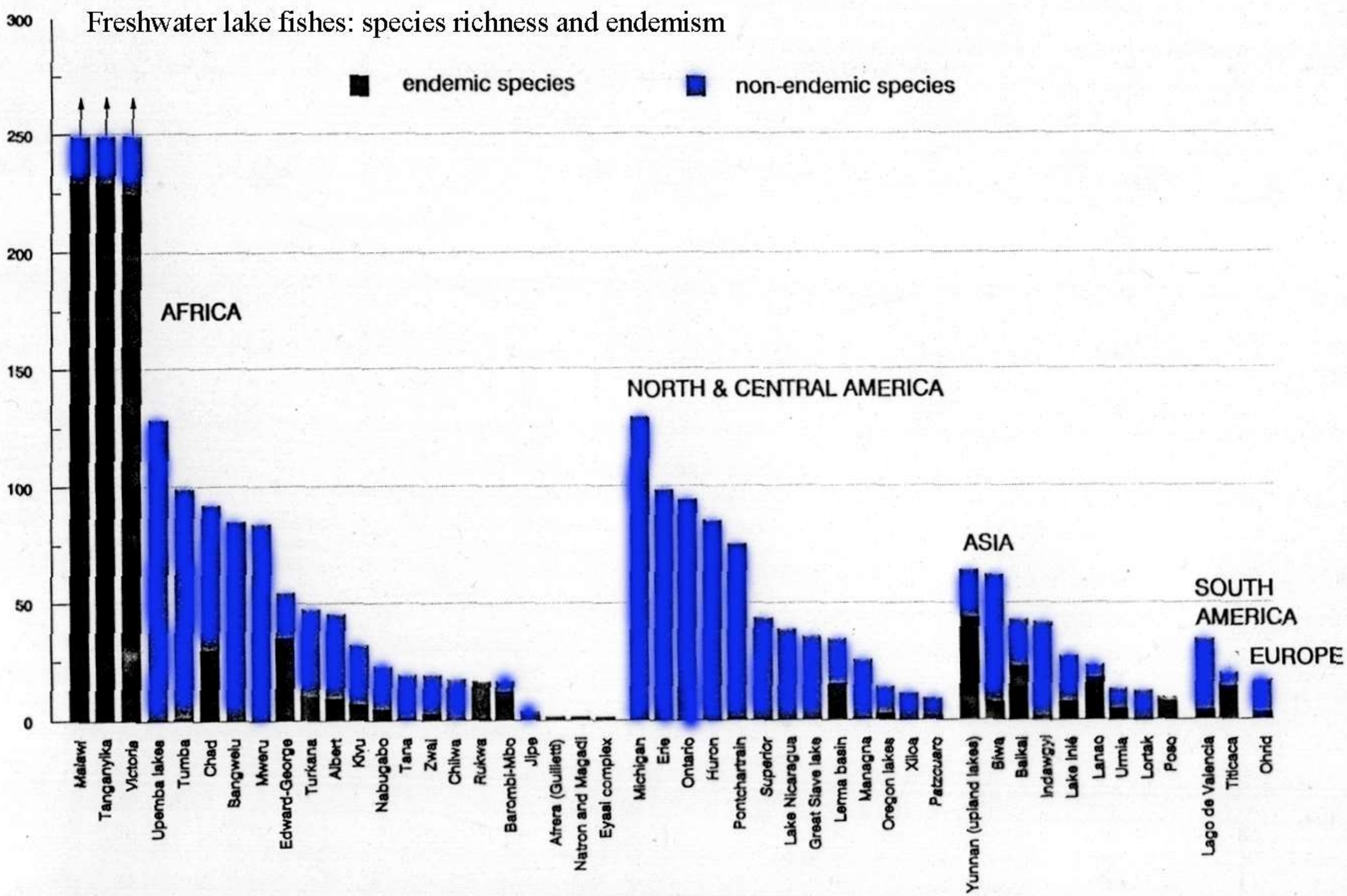


Number of fish species and river basin area

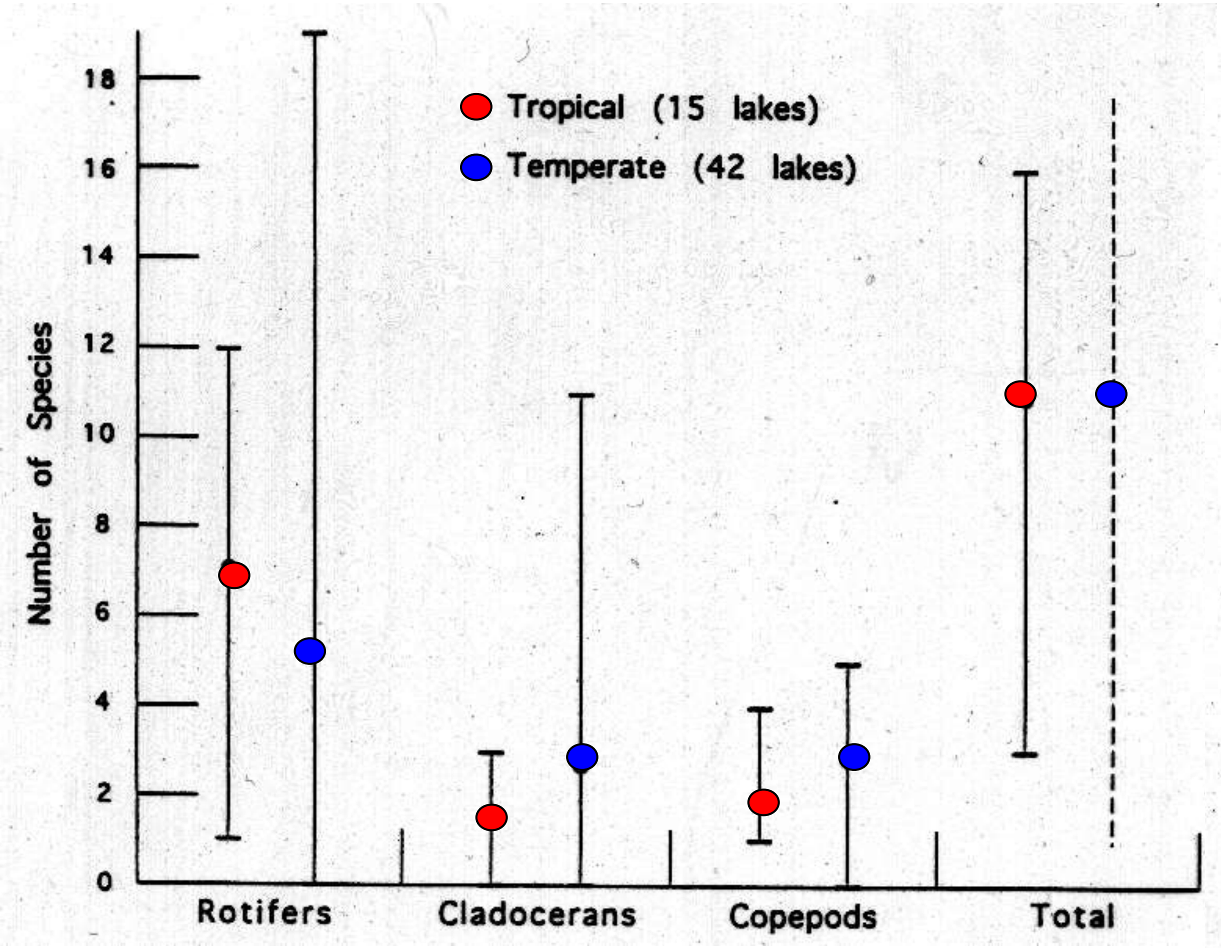


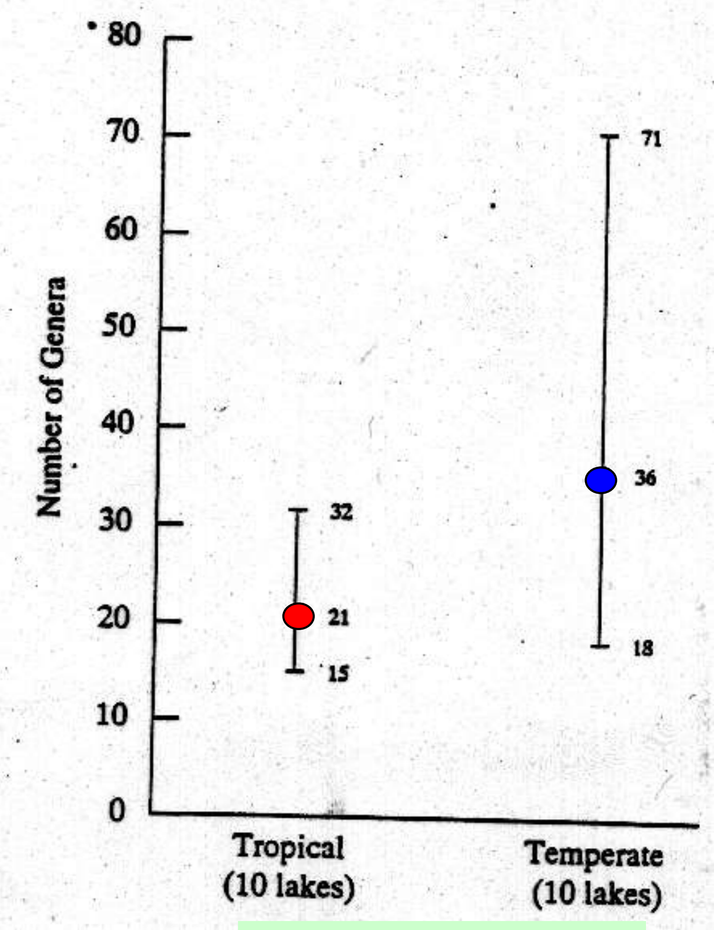
Mayflies in Australia and America:
no difference between temperate and tropical regions

Lake fishes: species richness and endemism



Species richness of plankton in temperate and tropical lakes: no big difference





zooplankton

phytoplankton

Fig. 18. Number of zooplankton species per sample for 16 tropical la
1957).

Fig. 16. Number of genera of phytoplankton in a selection of 10 tropical lakes and 10 temperate lakes (data from Lewis 1978a).

Species richness of benthos in temperate and tropical lakes: no big difference

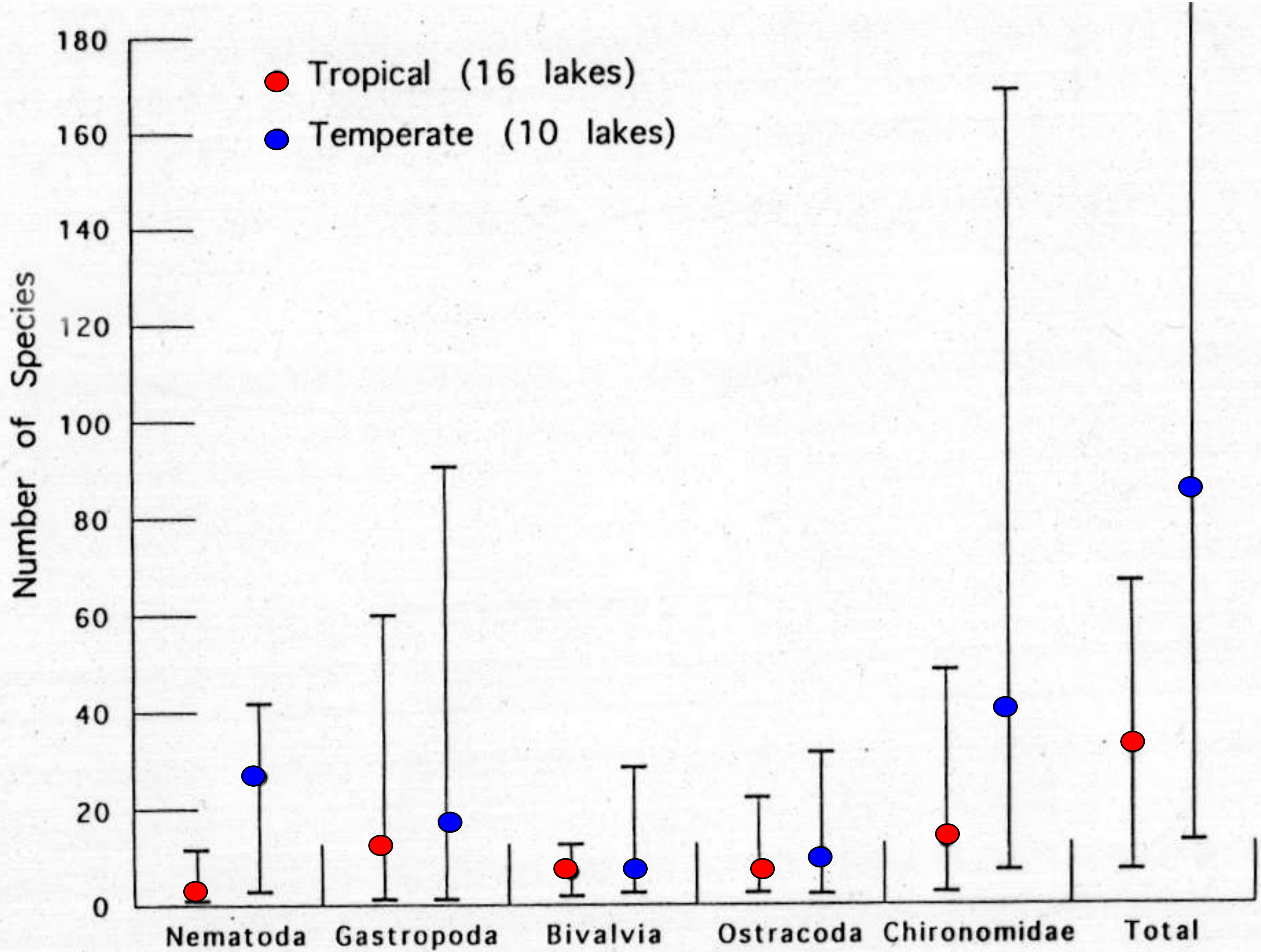
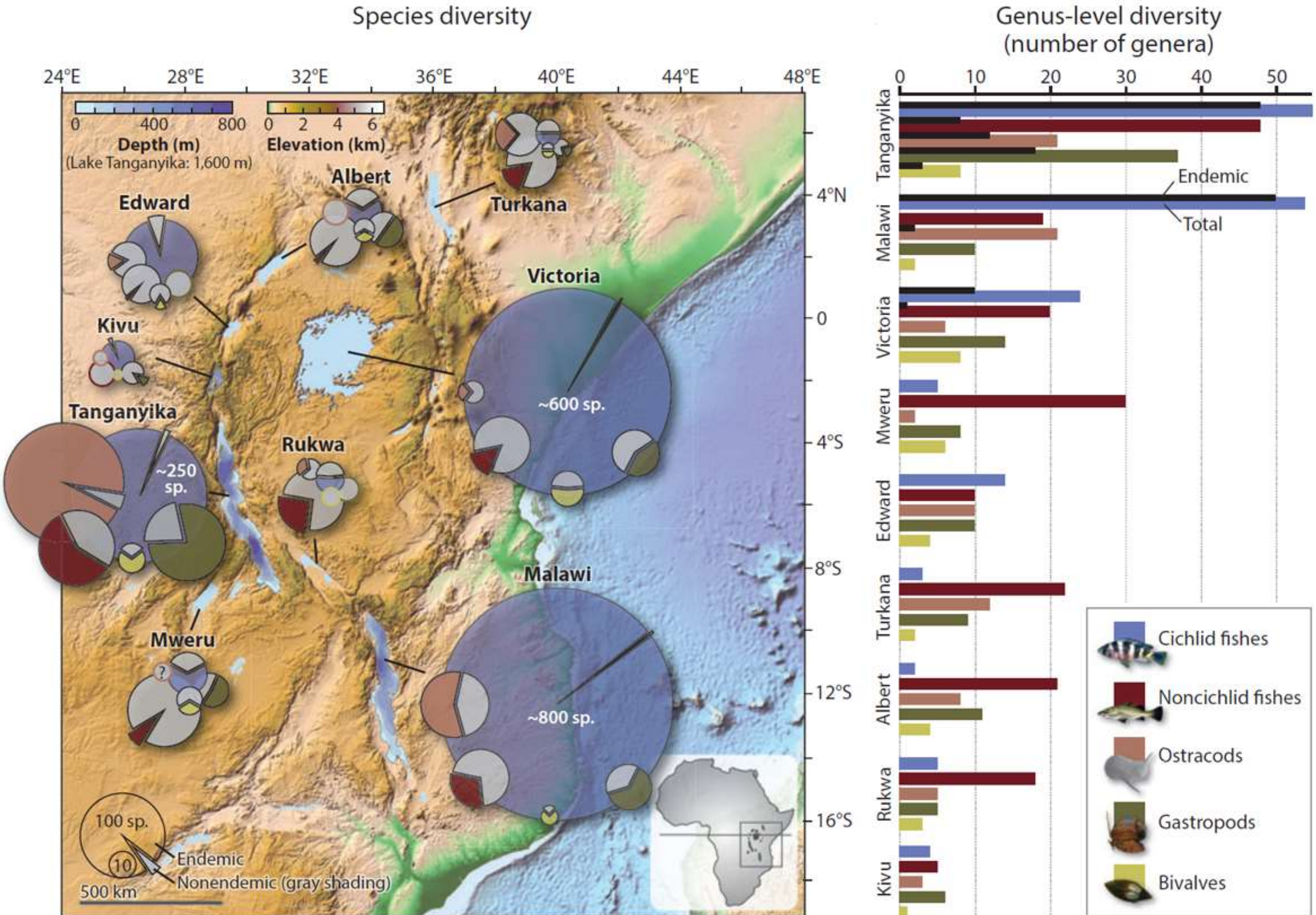


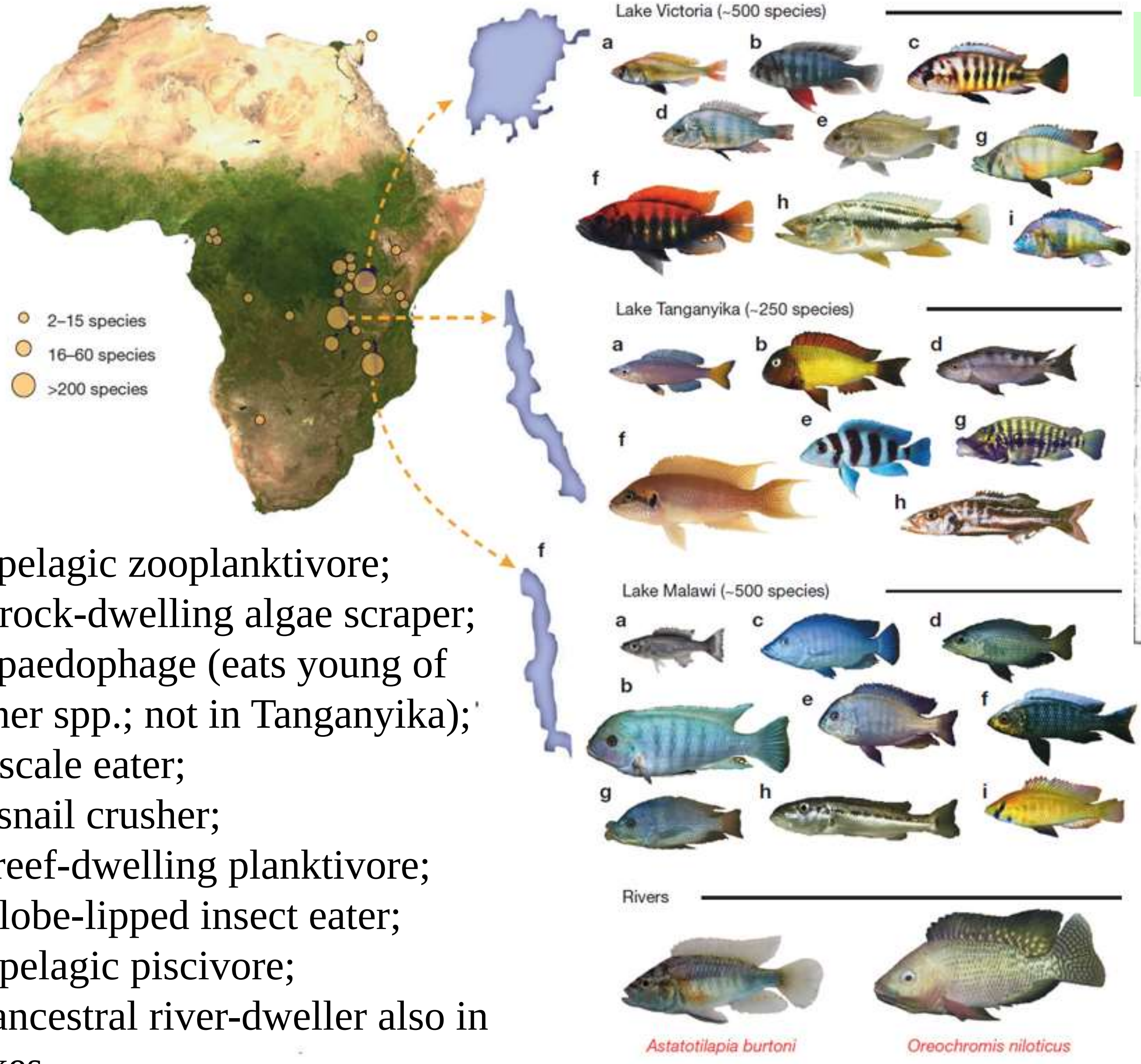
Fig. 1989).

Biodiversity in African rift lakes



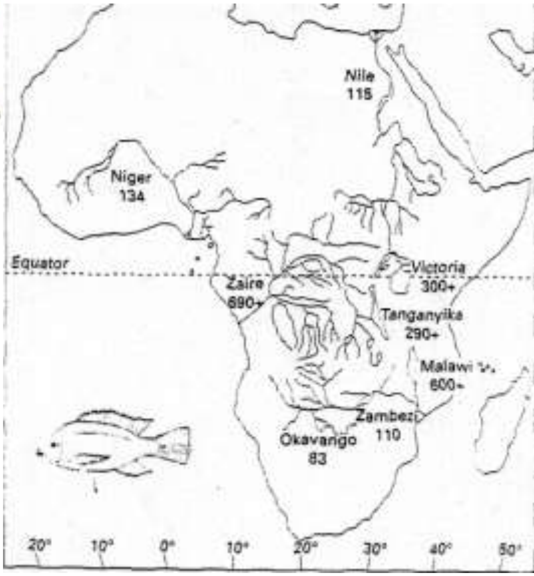
Salzburger et al. Annu. Rev. Ecol. Evol. Syst. 2014. 45:519–45

Freshwater fishes in rivers and lakes of Africa: cichlids

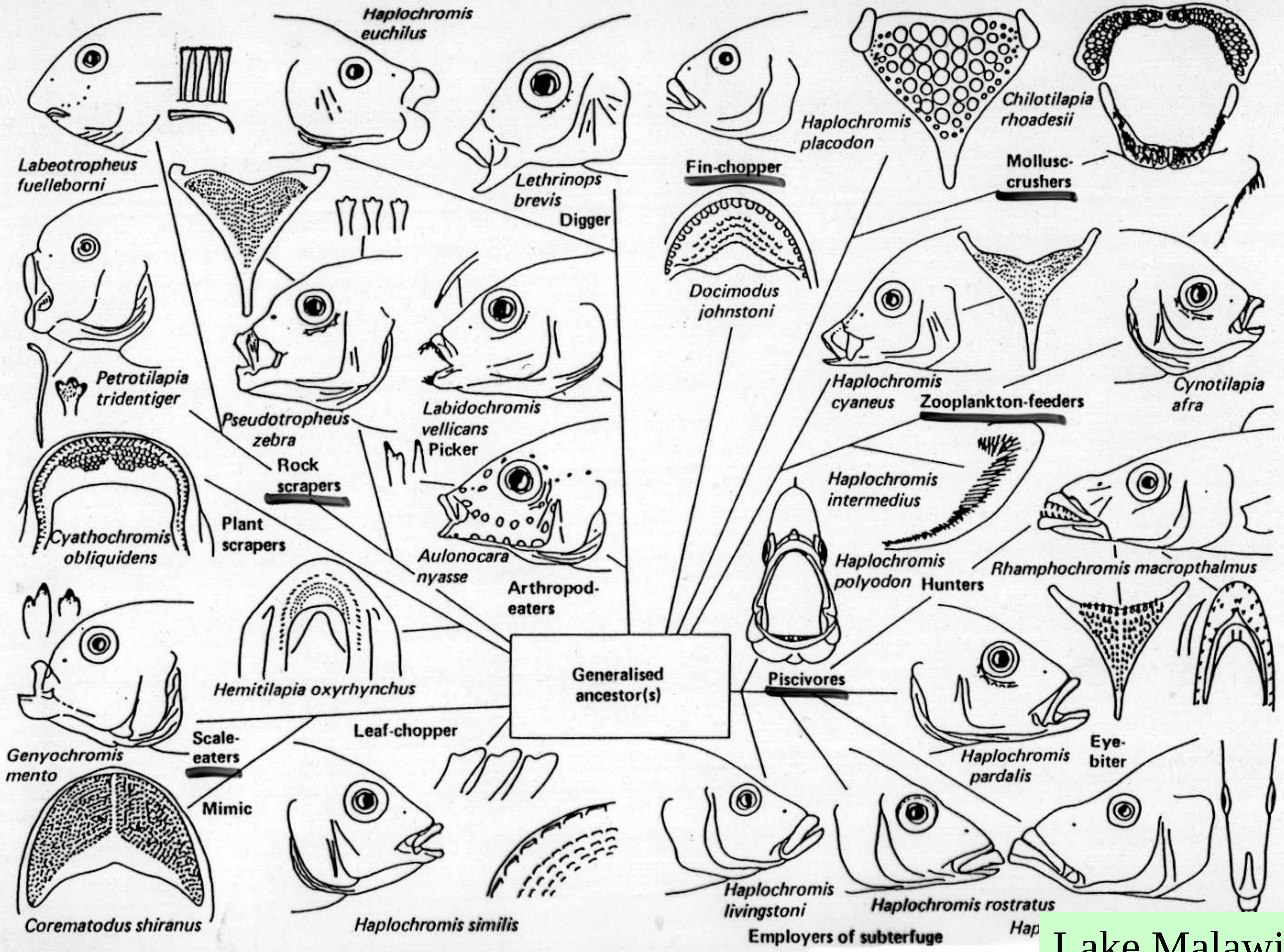


a, pelagic zooplanktivore;
b, rock-dwelling algae scraper;
c, paedophage (eats young of other spp.; not in Tanganyika);
d, scale eater;
e, snail crusher;
f, reef-dwelling planktivore;
g, lobe-lipped insect eater;
h, pelagic piscivore;
i, ancestral river-dweller also in lakes

All fish species:



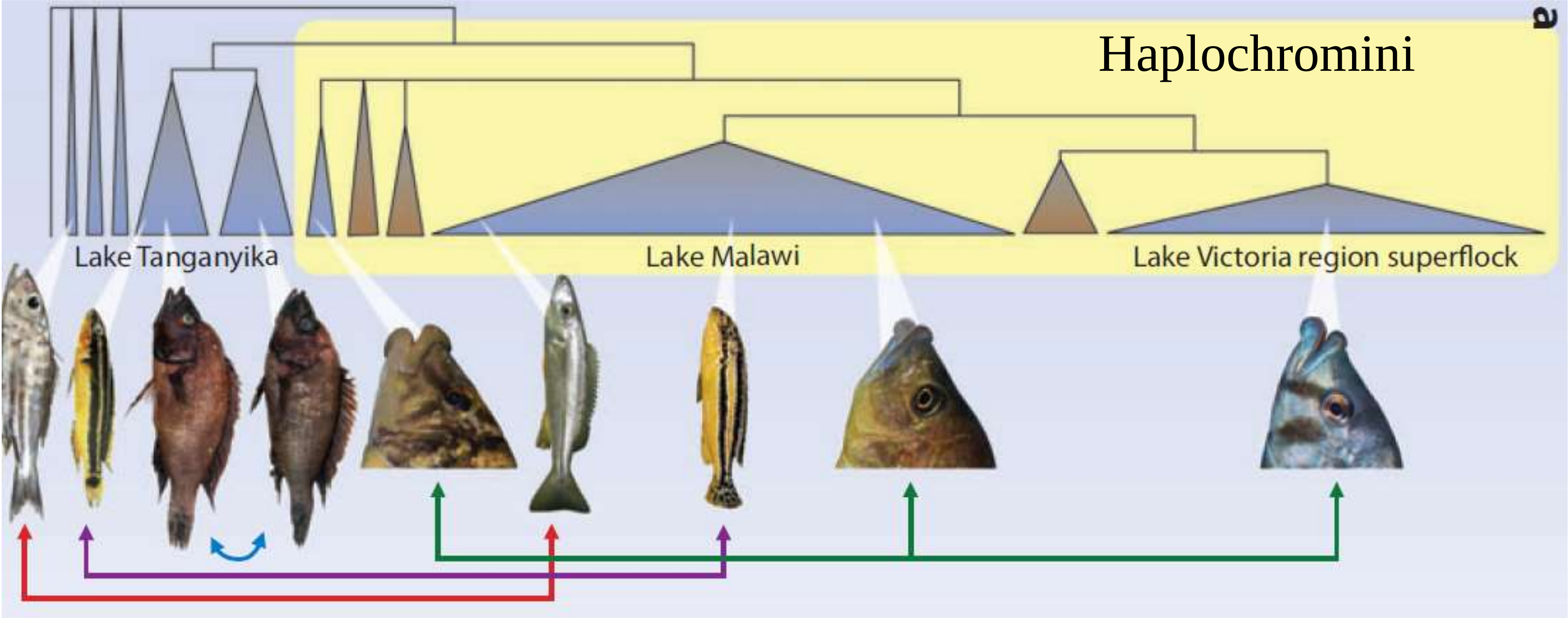
Brawand et al. 2014. Nature 375: 325



Lake Malawi

Figure 12.11 Examples of adaptive radiation in Lake Malawi's cichlids (after: Fryer and Iles, 1972)

Cichlid evolution in Africa

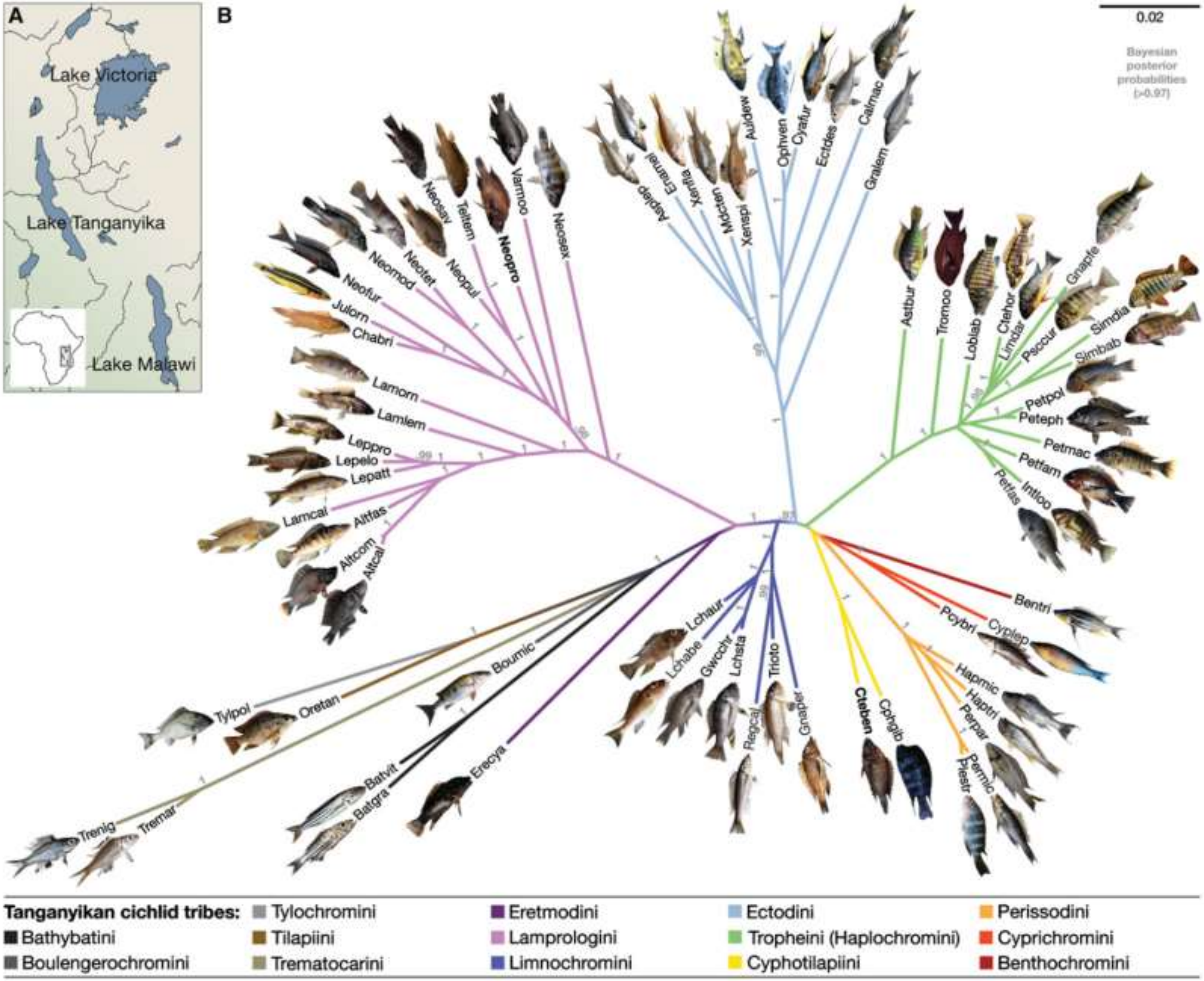


River and lake dwelling lineages shown in proportion to their species richness, arrows point to convergent evolution

Cichlids in three African rift lakes represent ~10% of the world's freshwater fish diversity (14,000 species)

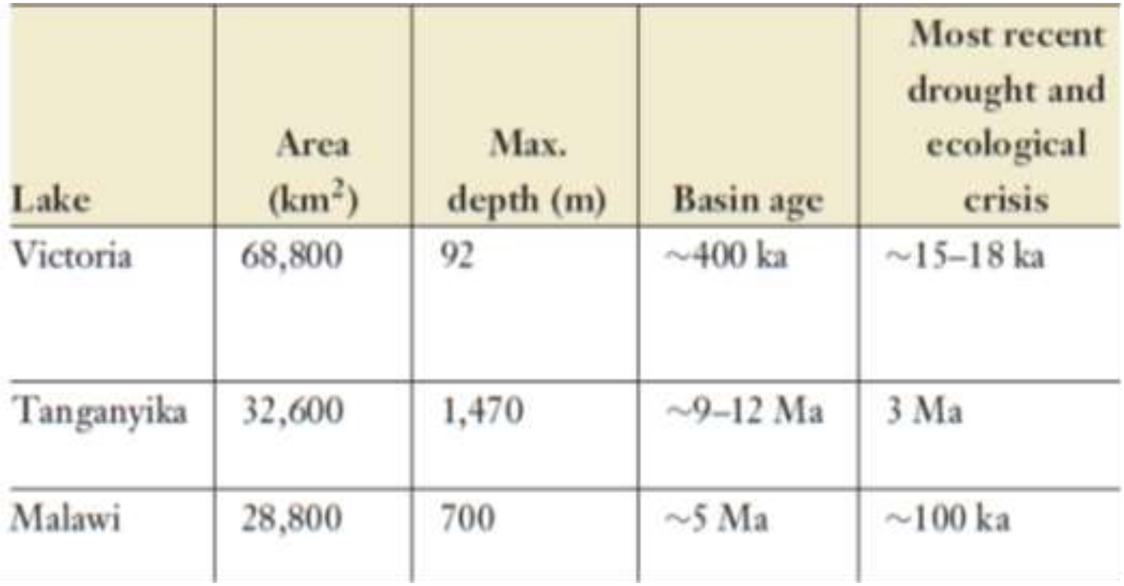
Salzburger et al. Annu. Rev. Ecol. Evol. Syst. 2014. 45:519–45

Cichlids of the Lake Tanganyika



Muschick et al. 2012, Current Biology 22, 2362–2368

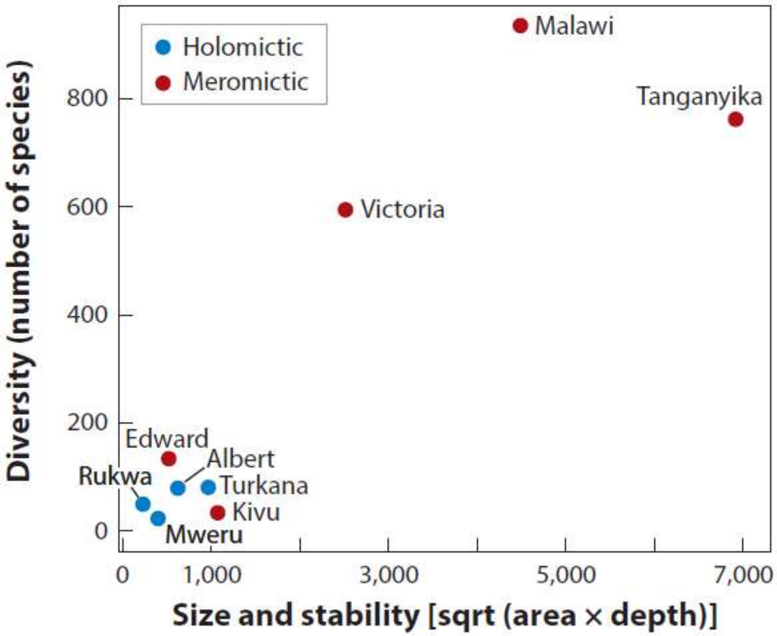
Why the Tanganyika, Malawi and Victoria lakes, and why the cichlids?



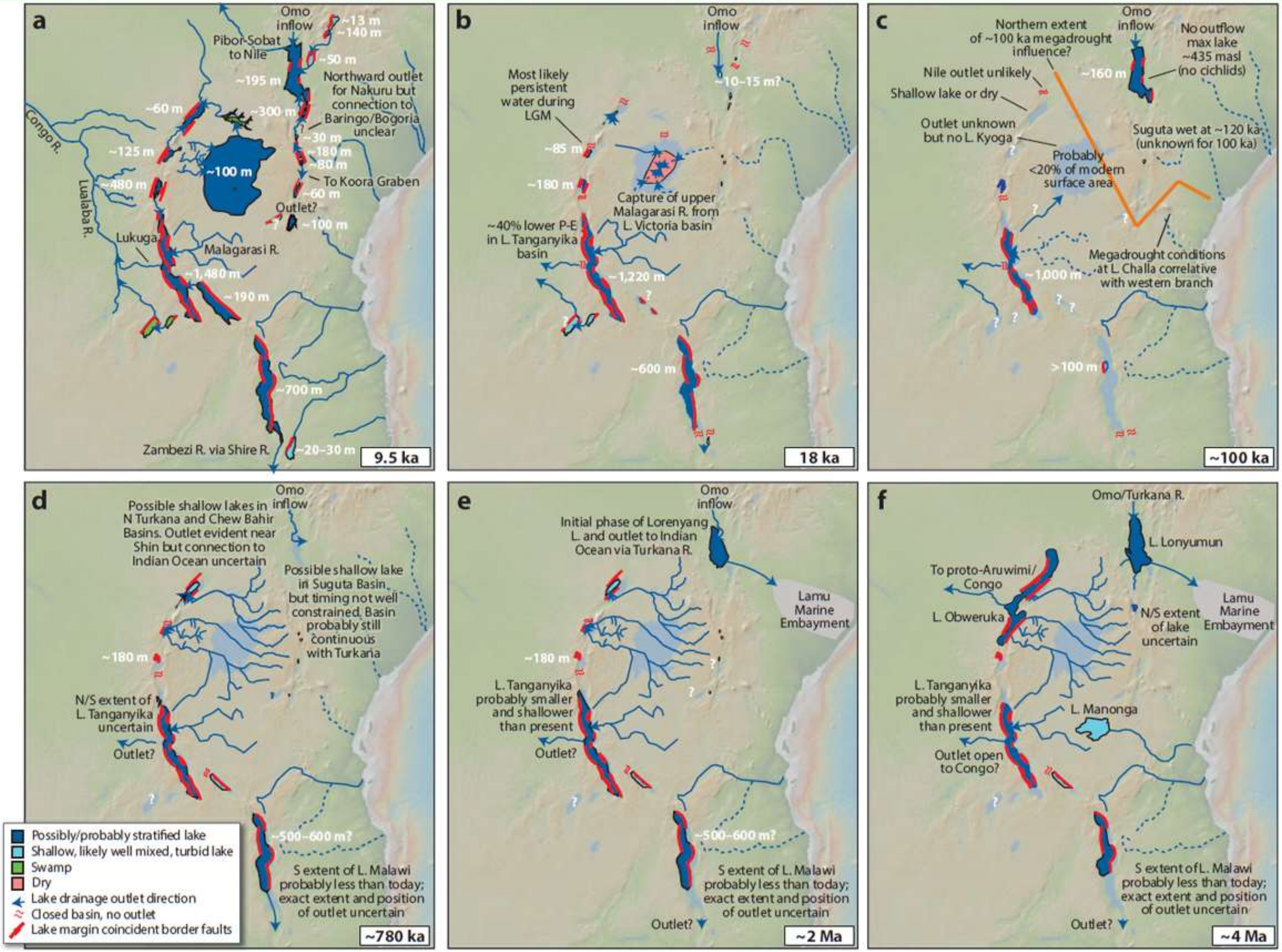
Lake	Area (km²)	Max. depth (m)	Basin age	Most recent drought and ecological crisis
Victoria	68,800	92	~400 ka	~15–18 ka
Tanganyika	32,600	1,470	~9–12 Ma	3 Ma
Malawi	28,800	700	~5 Ma	~100 ka

Lake size x depth (indicating also their stability in time) explain biodiversity

Lake Victoria cichlids



African rift lakes during the past 4 million years



Cichlid radiation:
a combination of habitat and trophic niche differentiation with sexual selection

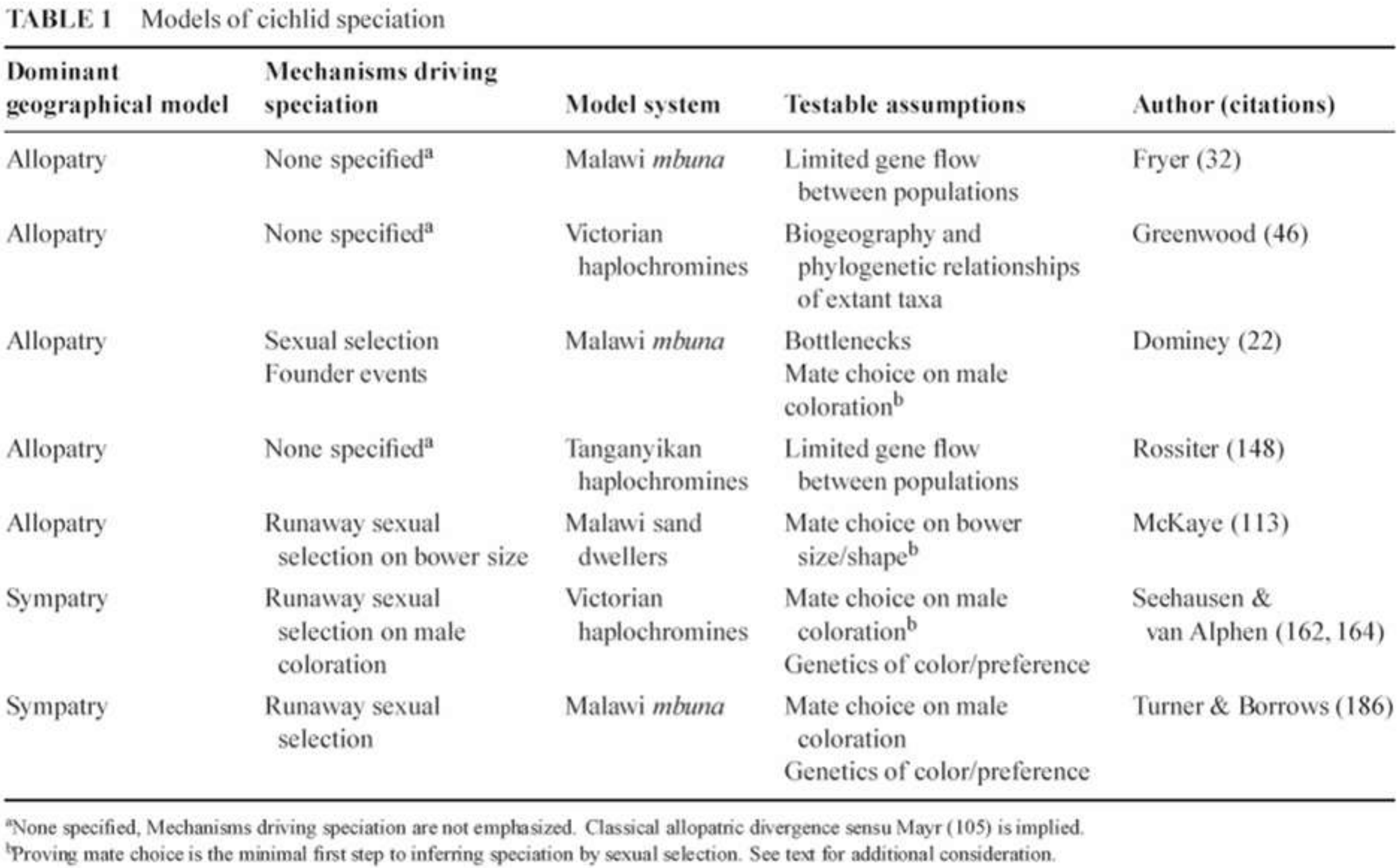


TABLE 1 Models of cichlid speciation

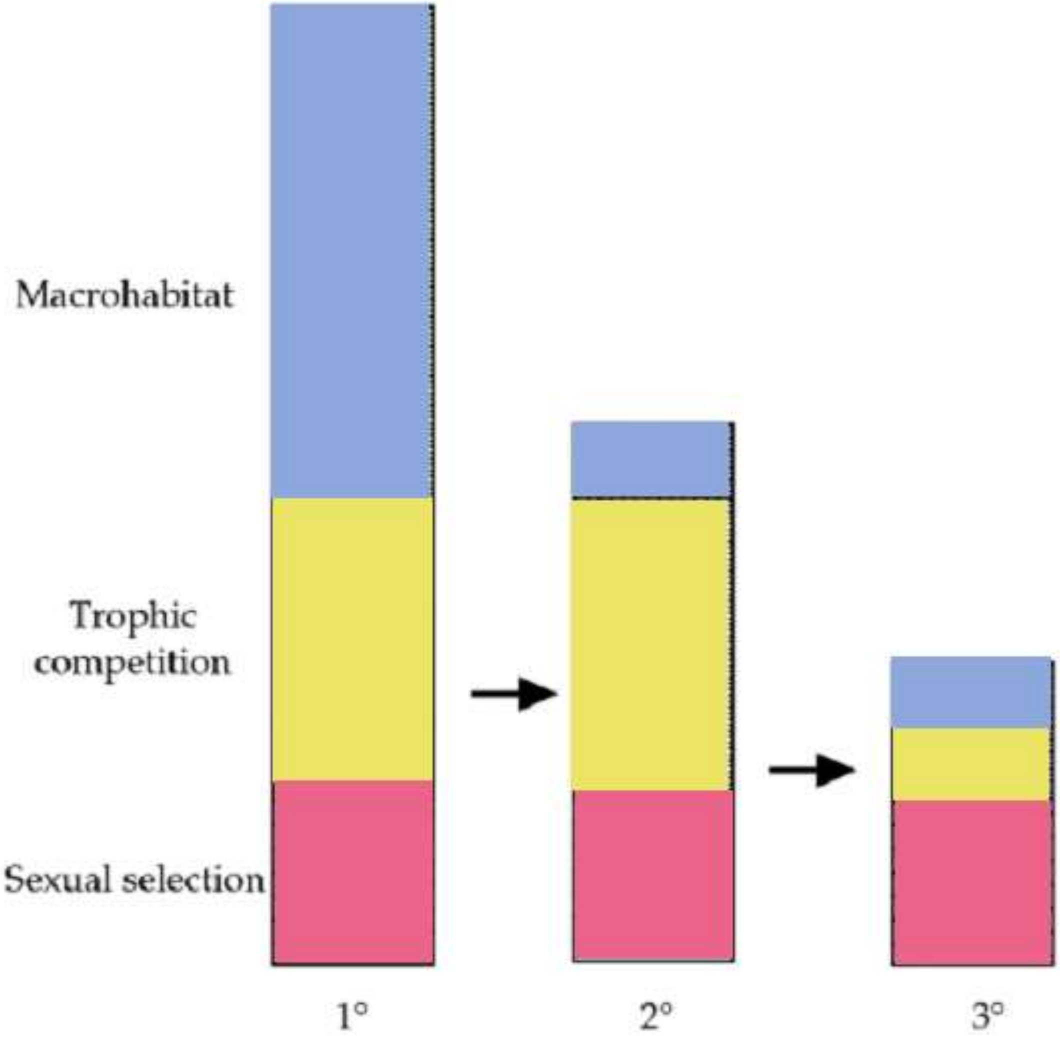
Dominant geographical model	**Mechanisms driving speciation**	**Model system**	**Testable assumptions**	**Author (citations)**
Allopatry	None specified[a]	Malawi *mbuna*	Limited gene flow between populations	Fryer (32)
Allopatry	None specified[a]	Victorian haplochromines	Biogeography and phylogenetic relationships of extant taxa	Greenwood (46)
Allopatry	Sexual selection Founder events	Malawi *mbuna*	Bottlenecks Mate choice on male coloration[b]	Dominey (22)
Allopatry	None specified[a]	Tanganyikan haplochromines	Limited gene flow between populations	Rossiter (148)
Allopatry	Runaway sexual selection on bower size	Malawi sand dwellers	Mate choice on bower size/shape[b]	McKaye (113)
Sympatry	Runaway sexual selection on male coloration	Victorian haplochromines	Mate choice on male coloration[b] Genetics of color/preference	Seehausen & van Alphen (162, 164)
Sympatry	Runaway sexual selection	Malawi *mbuna*	Mate choice on male coloration Genetics of color/preference	Turner & Borrows (186)

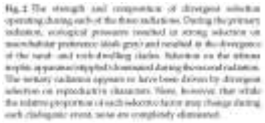
[a] None specified, Mechanisms driving speciation are not emphasized. Classical allopatric divergence sensu Mayr (105) is implied.

[b] Proving mate choice is the minimal first step to inferring speciation by sexual selection. See text for additional consideration.

Kornfield & Smith 2000

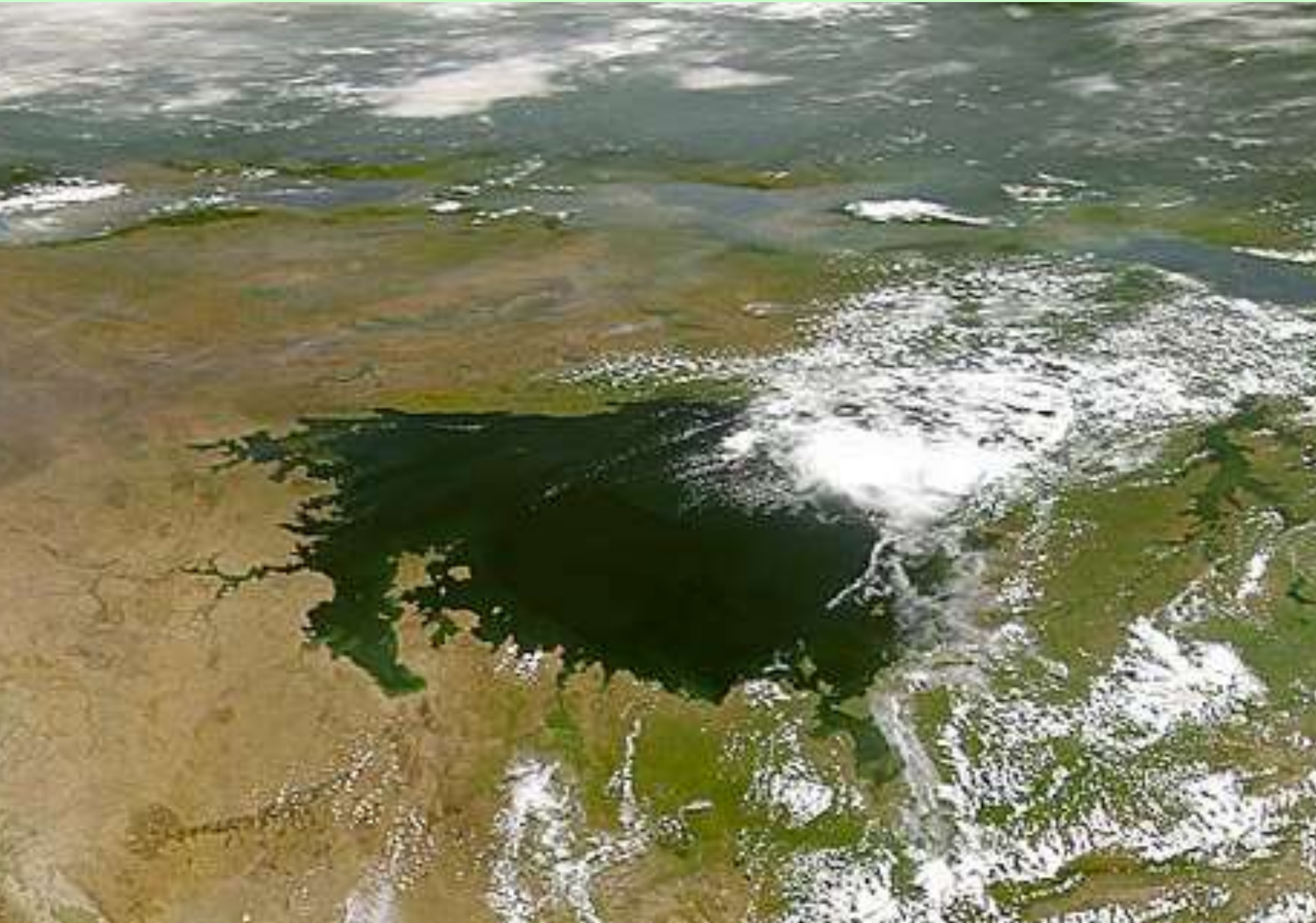
Malawi speciation: three stages combining different mechanisms



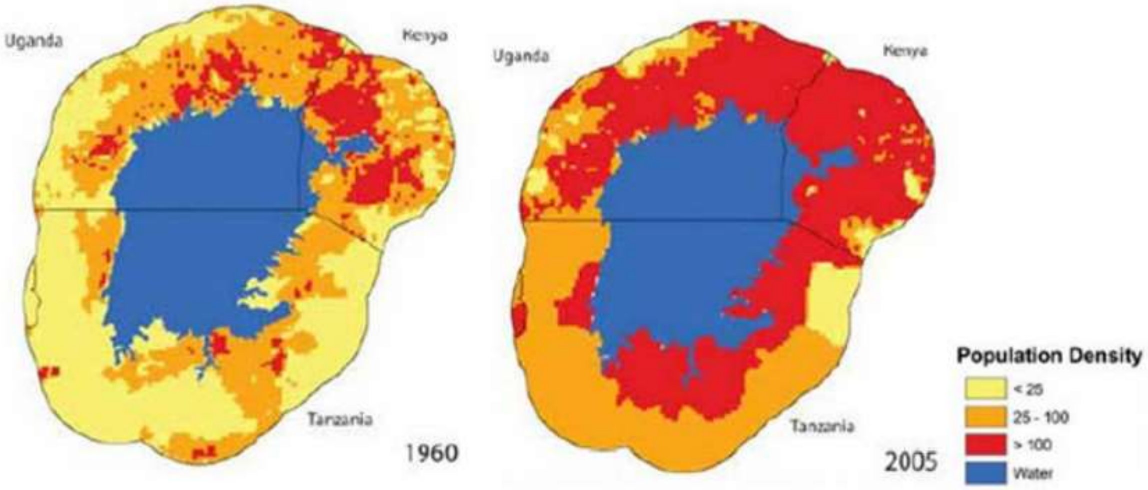


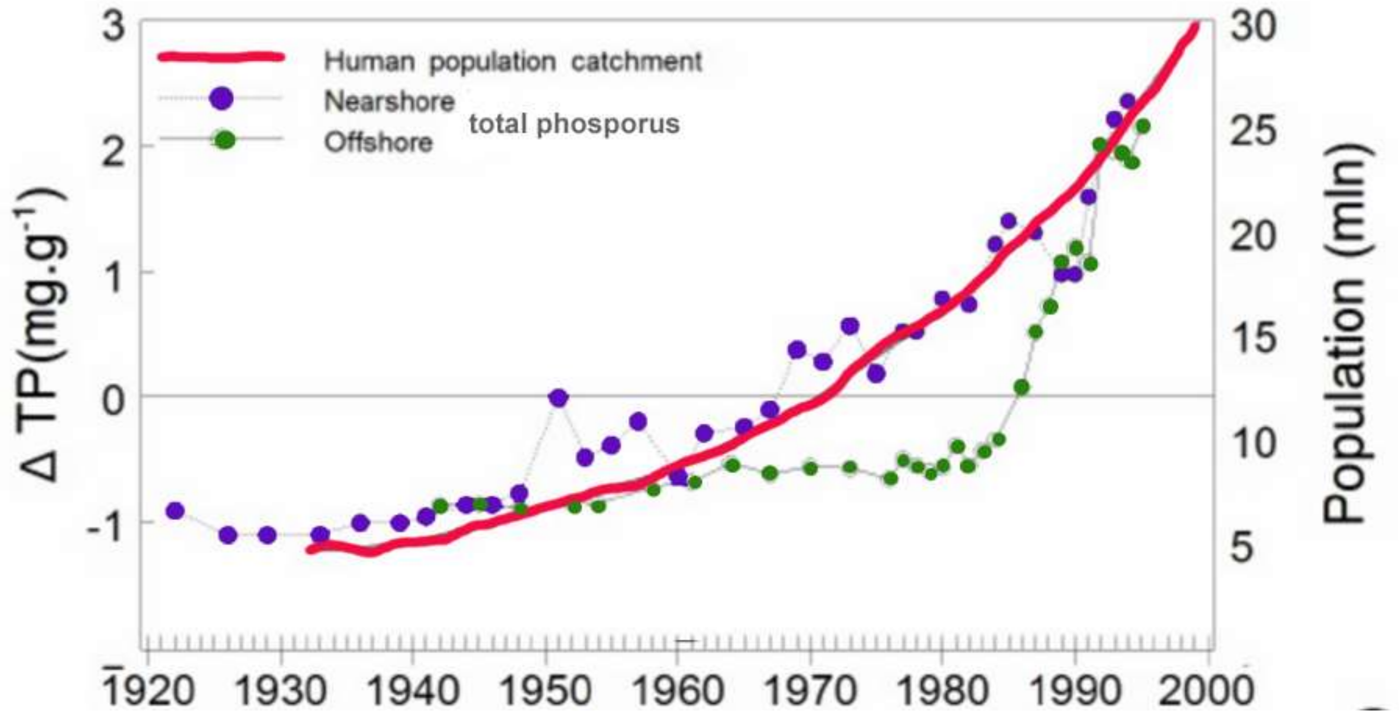
Danley & Kocher 2001 Mol. Ecol. 10, 1075

Lake Victoria: environmental problems

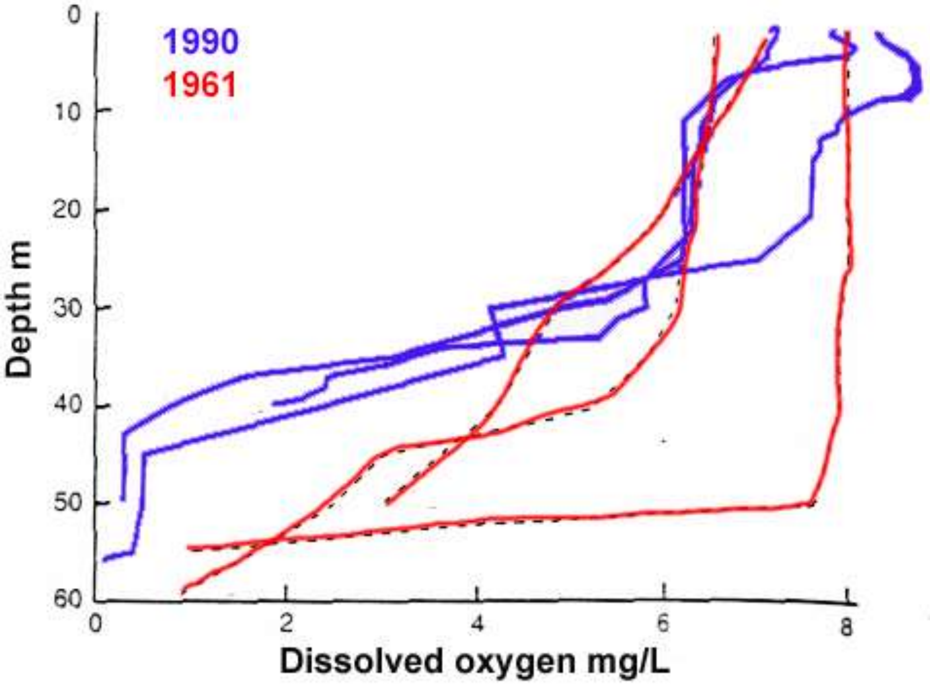


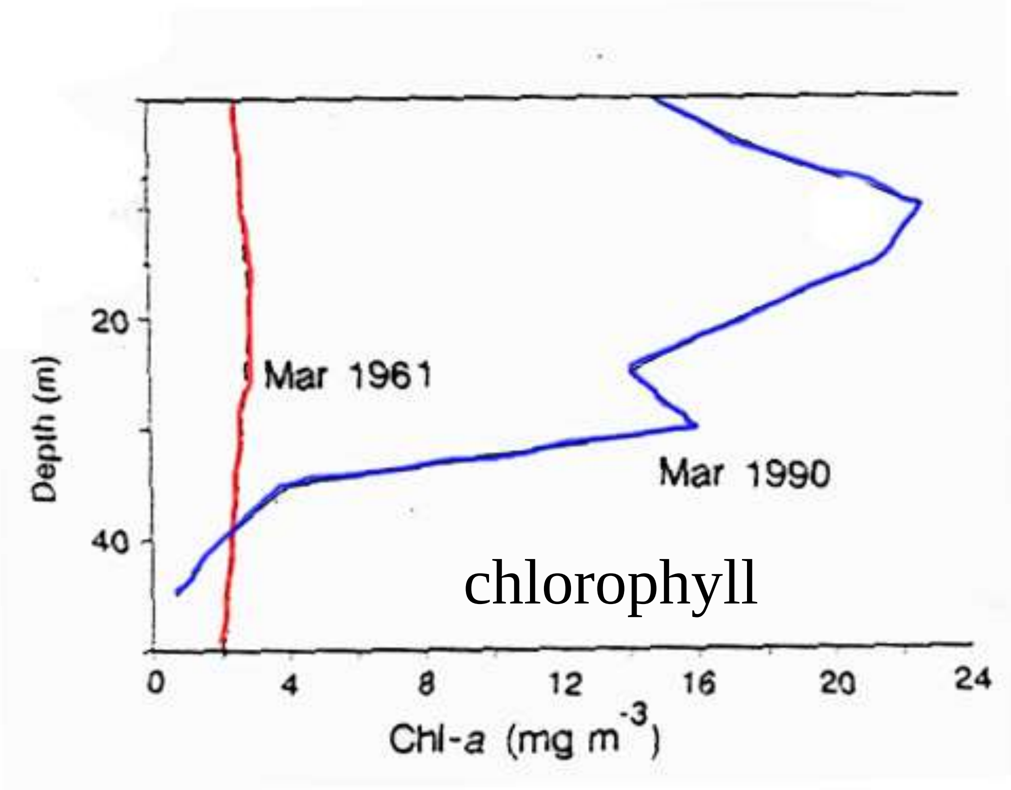
Lake Victoria: growing human population and eutrophication





Lake Victoria: dissolved oxygen and chlorophyll in 1961 and 1990





chlorophyll

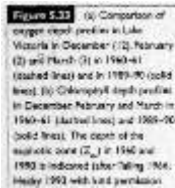
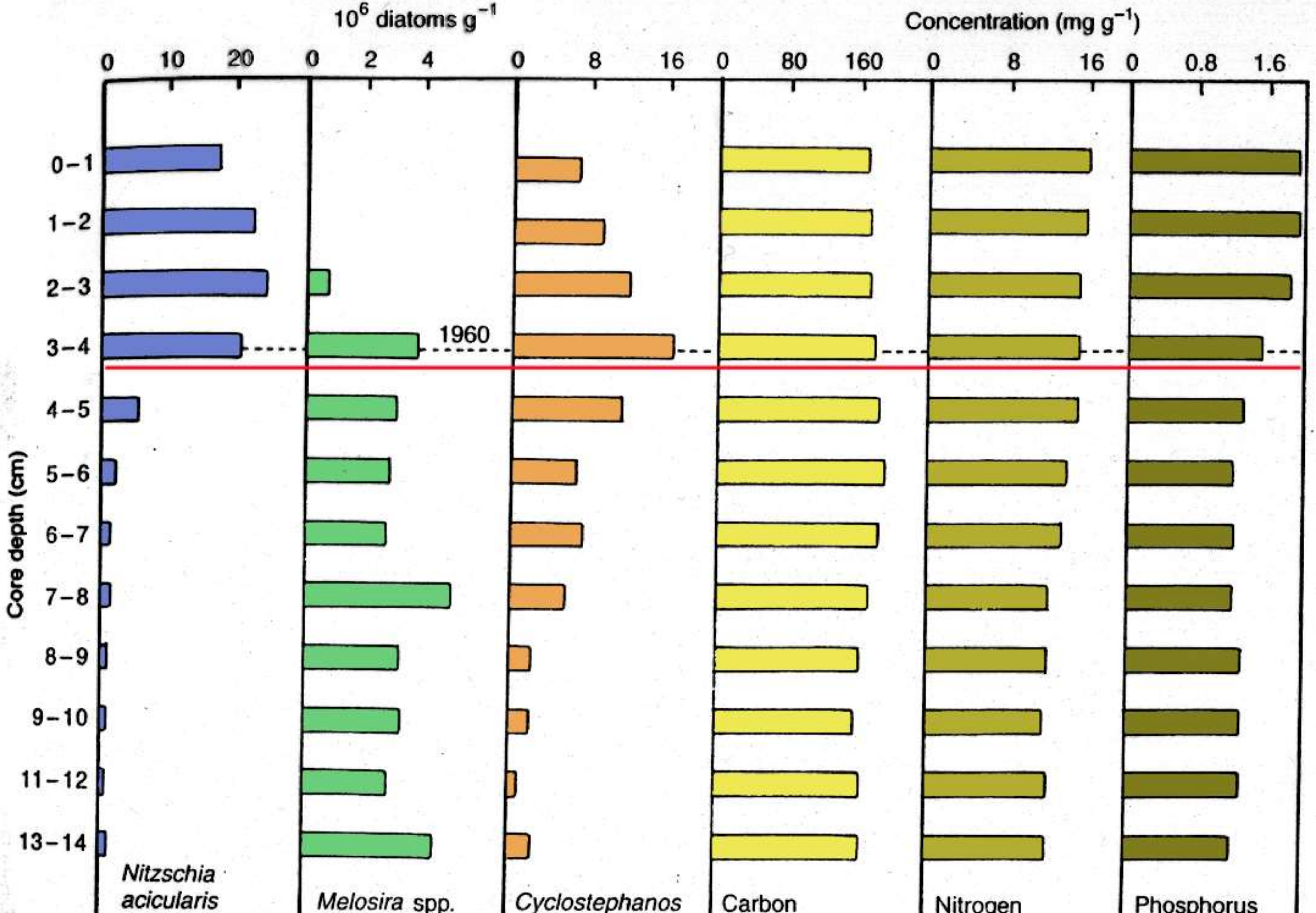
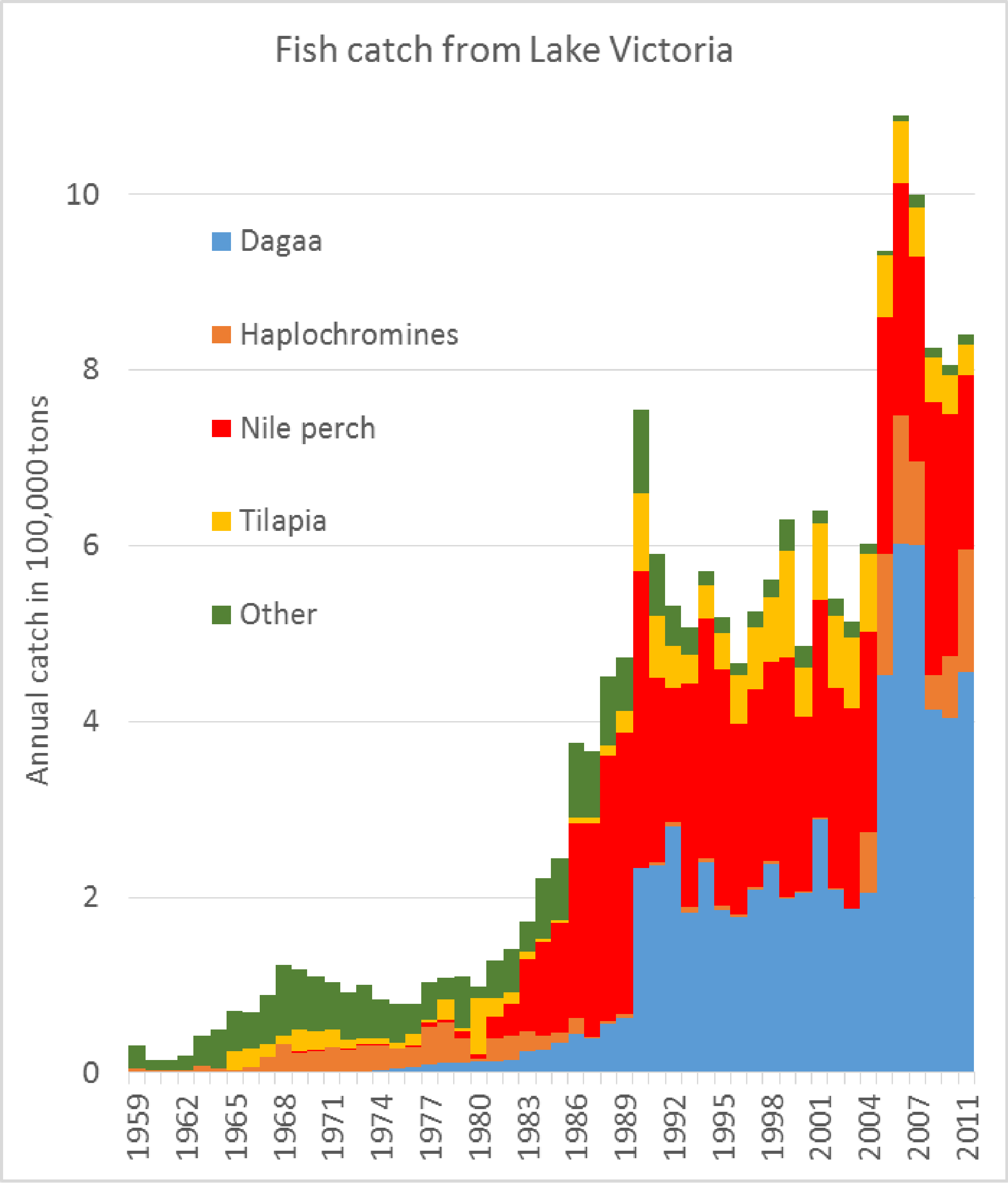


Figure 5.33 (a) Comparison of oxygen depth profiles in Lake Victoria in December (1), February (2) and March (3) in 1960–61 (dashed lines) and in 1989–90 (solid lines). (b) Chlorophyll depth profiles in December February and March in 1960–61 (dashed lines) and 1989–90 (solid lines). The depth of the euphotic zone (Z_{eu}) in 1960 and 1990 is indicated (after Talling 1966, Hecky 1993 with kind permission

Lake Victoria: change in N, P and diatoms in 1960s



Fishery in Lake Victoria: raise of perch, recently some recovery of Haplochromines



Rastrineobola argentea, dagaa, native

Haplochromine cychlids, native

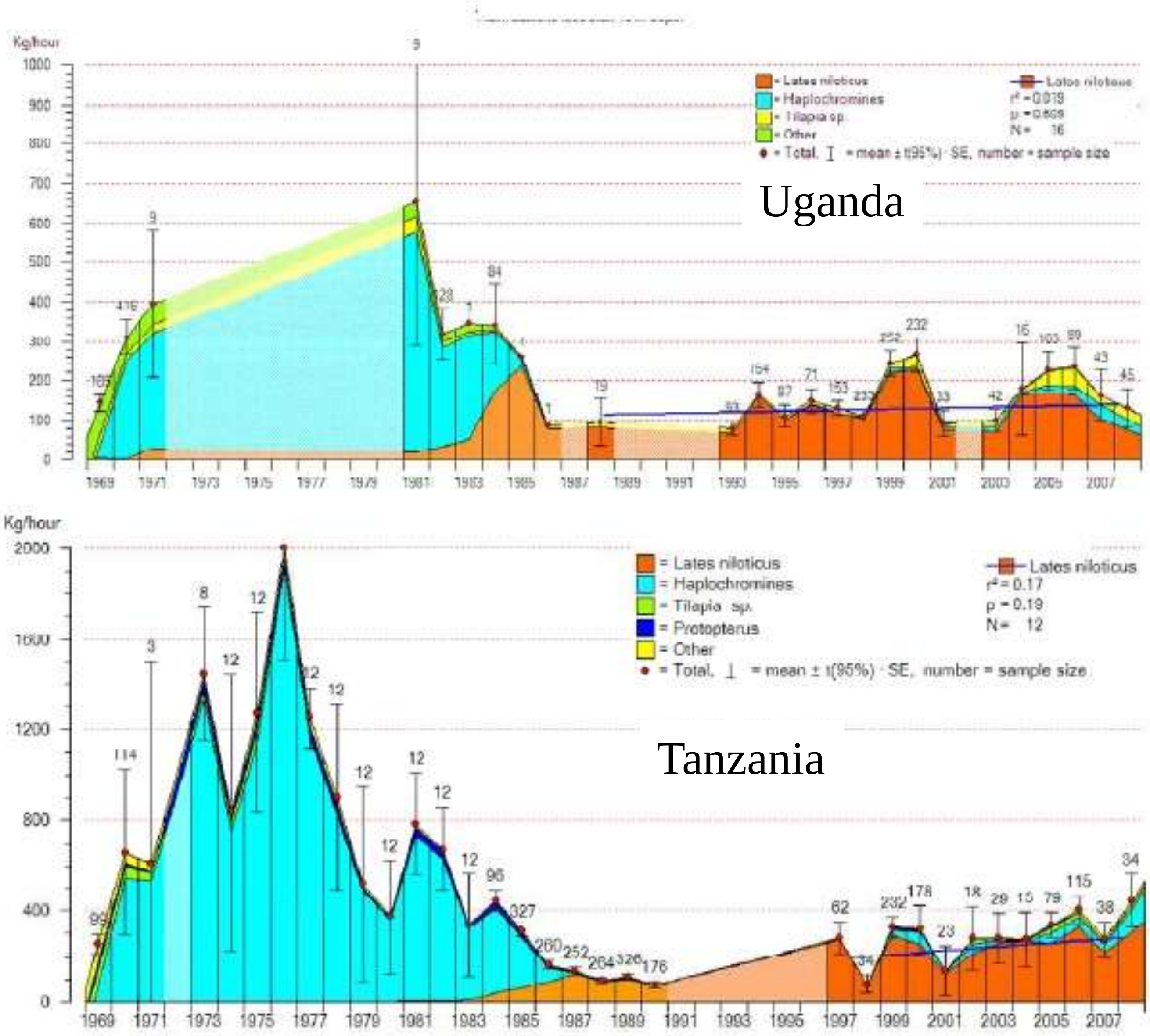
Lates niloticus, Nile perch, introduced

Oreochromis niloticus (tilapia), introduced

Data: Lake Victoria Fisheries Org., 2011

Abundance (kg/hour) of the major demersal stocks in experimental trawl surveys in Lake Victoria (Ugandan and Tanzanian waters) in 1969-2008.

Years with no information are interpolated (light colors).



Haplochromine cychlids

Lates niloticus, Nile perch

Oreochromis niloticus, tilapia

Kolding, et al. 2014. *In* Welcomme et al. *FAO Fisheries and Aquaculture Technical Paper 579*

Lake Victoria fishery: the usual story of increasing effort, with the relative yield first increasing, then collapsing

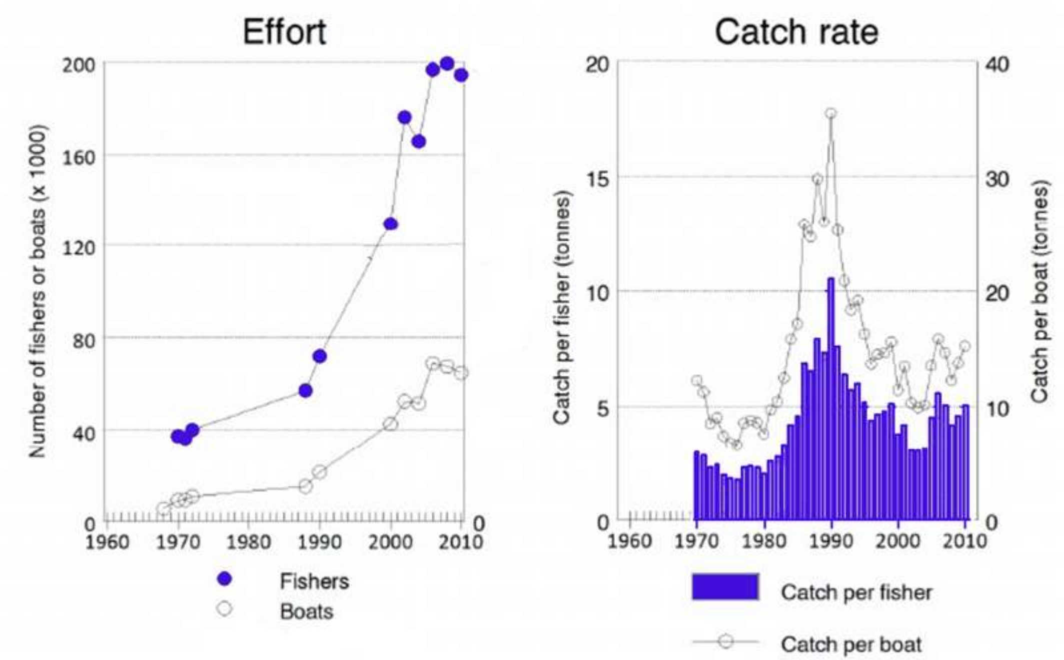
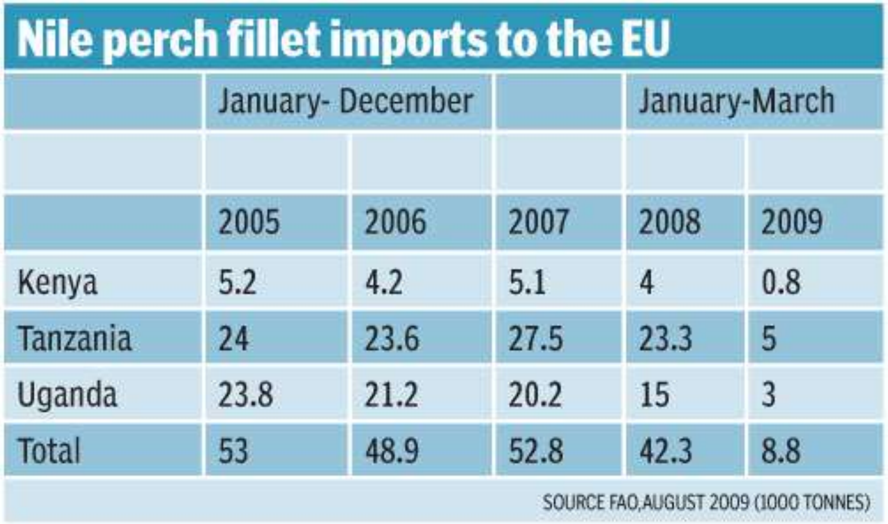


Image 3: Illegal monofilament nets, beach seine nets and gillnets confiscated by Tanzanian fisheries authorities.

22 Programme SmartFish Rapport SF/2011/12

Attempts to regulate the fishery



Nile perch fillet imports to the EU

	January- December			January-March	
	2005	2006	2007	2008	2009
Kenya	5.2	4.2	5.1	4	0.8
Tanzania	24	23.6	27.5	23.3	5
Uganda	23.8	21.2	20.2	15	3
Total	53	48.9	52.8	42.3	8.8

SOURCE FAO,AUGUST 2009 (1000 TONNES)

Nile perch is also exported:
Brings financial benefits, but
endangers endemic cichlid species

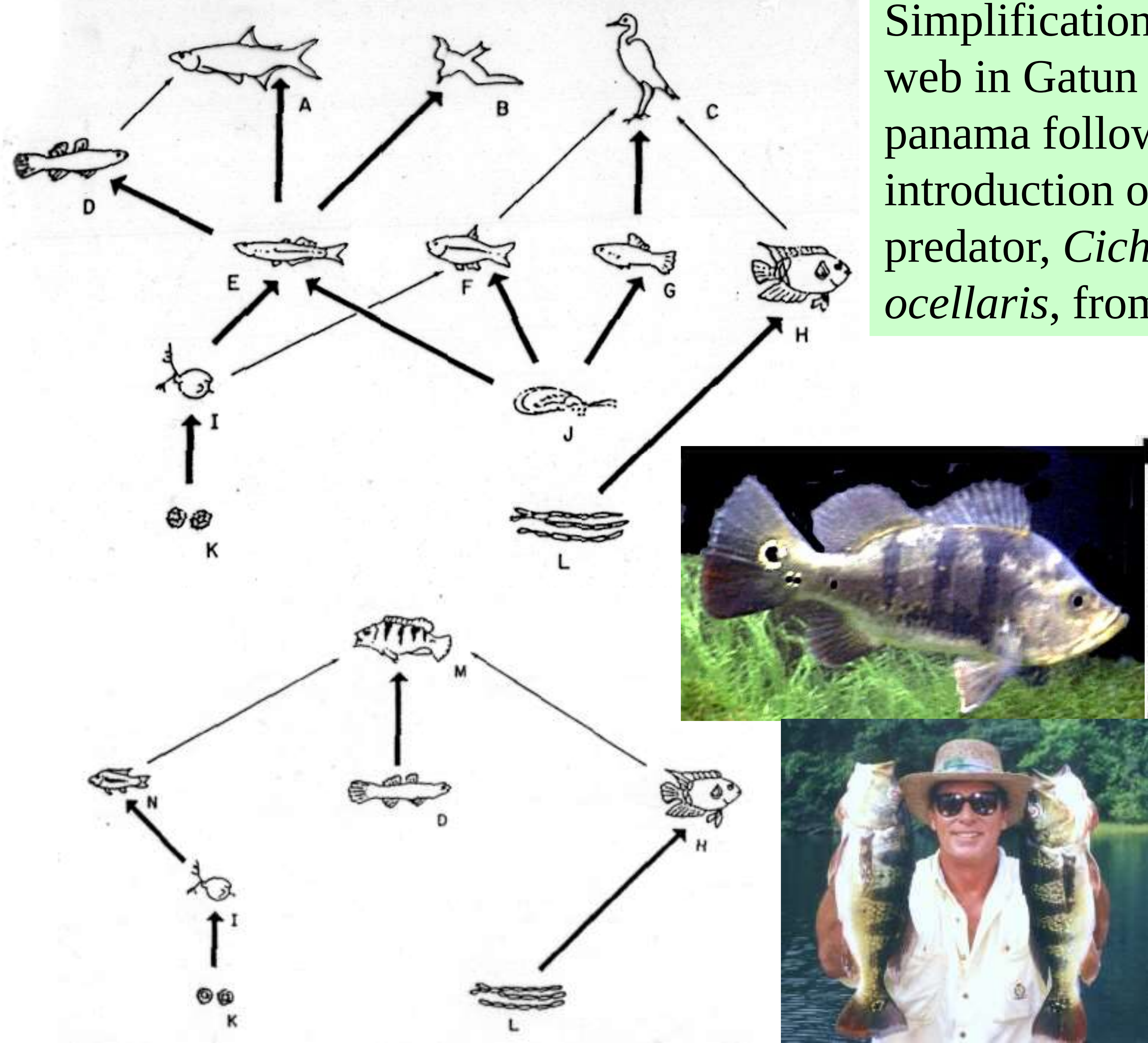
Freshwater plant species – some of the most serious aliens

Eichhornia crassipes (water hyacinth), Lake Victoria, Madagascar (and elsewhere)

Neocheria eichhorniae weevil as a biological control agent

Salvinia molesta
and
Cyrtobagous salviniae

Simplification of trophic web in Gatun lake, panama following introduction of top predator, *Cichla ocellaris*, from Amazon



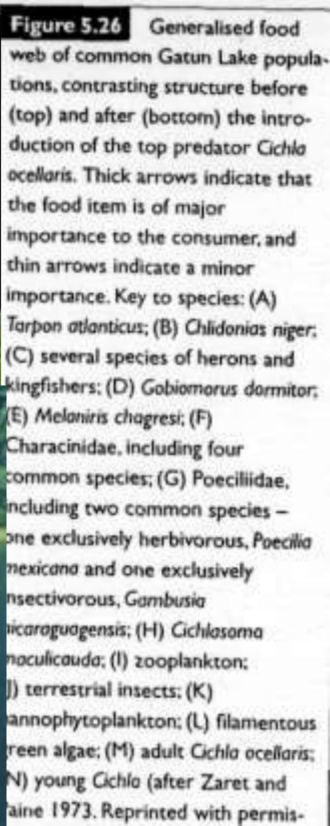


Figure 5.26 Generalised food web of common Gatun Lake populations, contrasting structure before (top) and after (bottom) the introduction of the top predator *Cichla ocellaris*. Thick arrows indicate that the food item is of major importance to the consumer, and thin arrows indicate a minor importance. Key to species: (A) *Tarpon atlanticus*; (B) *Chlidonias niger*; (C) several species of herons and kingfishers; (D) *Gobiomorus dormitor*; (E) *Melaniris chagresi*; (F) Characinidae, including four common species; (G) Poeciliidae, ncluding two common species – one exclusively herbivorous, *Poecilia nexicana* and one exclusively nsectivorous, *Gambusia icaraguagensis*; (H) *Cichlasoma naculicauda*; (I) zooplankton; J) terrestrial insects; (K) annophytoplankton; (L) filamentous reen algae; (M) adult *Cichla ocellaris*; N) young *Cichla* (after Zaret and aine 1973. Reprinted with permis-