Tropical systems: rivers

Review key aspects of zonation and habitat

Vegetation features and affects on local distributions

Riverine ecosystems in the tropics

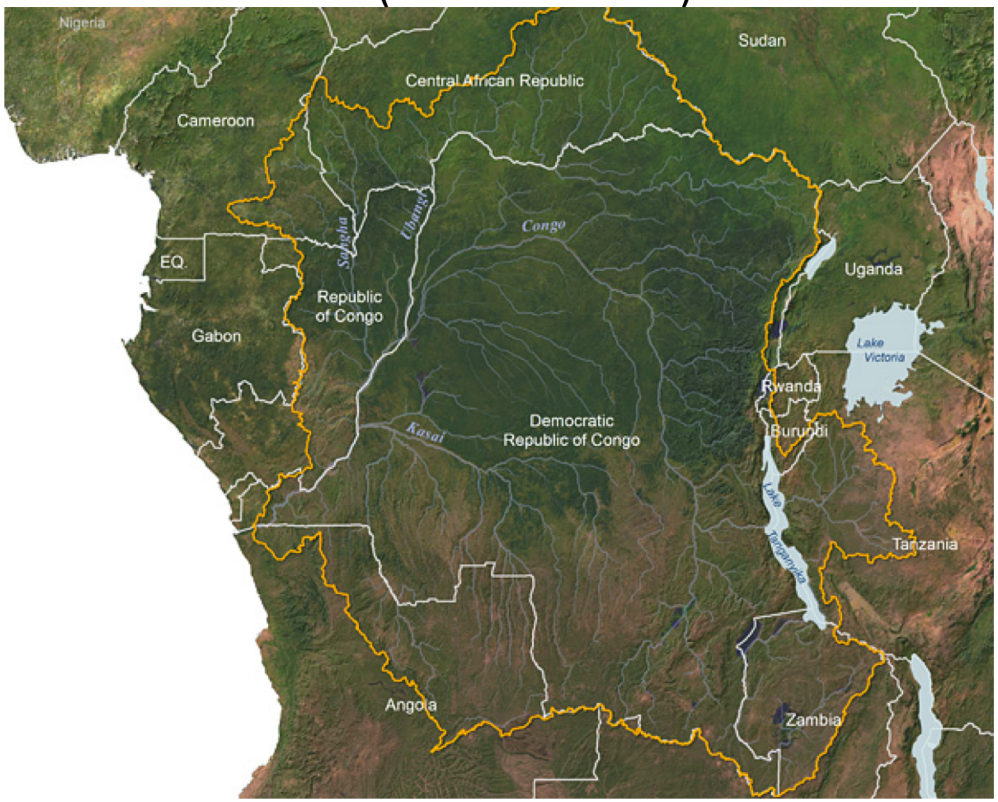
Due to wet/dry seasonality and annual flooding cycles, tropical river systems greatly impact bordering ecosystems

Nearby habitats include swamps, marches, streams, oxbow lakes and river islands – all of which add significantly to habitat complexity and regional diversity

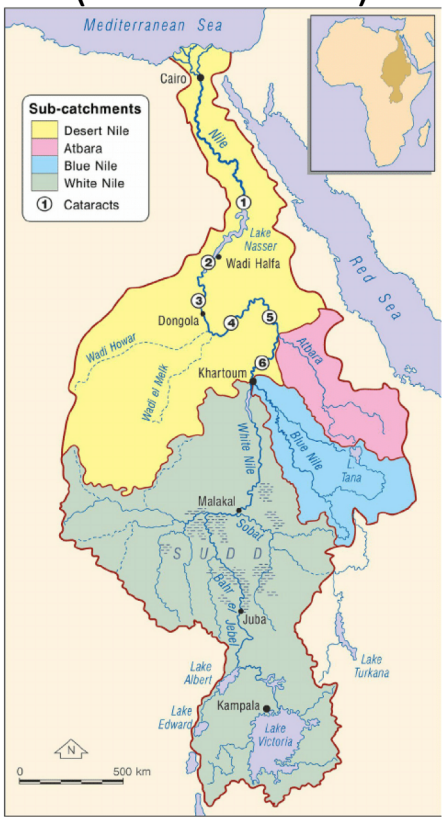
Some river systems of the tropics

Nile (Eastern Africa) and Congo (Western Africa) River basins

Congo River basin
(Western Africa)

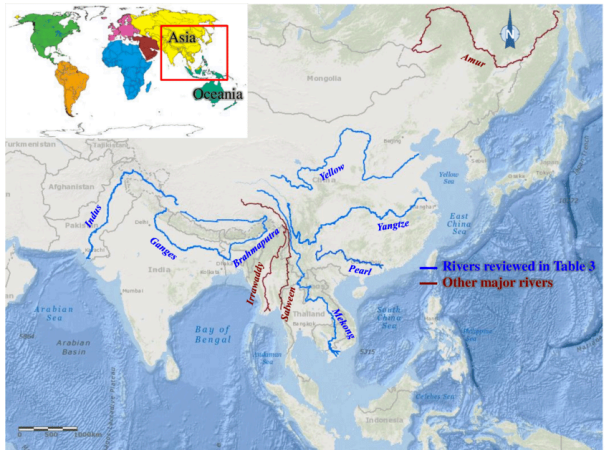


Nile River basin
(Eastern Africa)



Some river systems of the tropics:

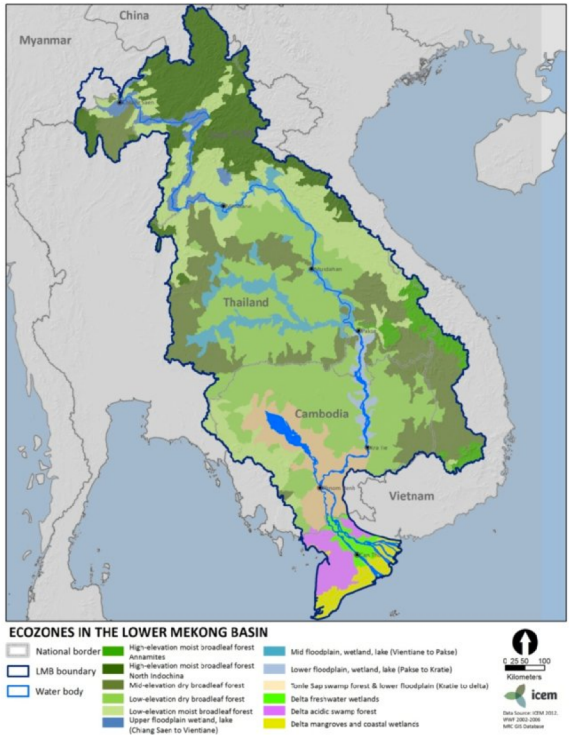
Mekong (China, Laos, Cambodia, Vietnam), Ganges (India)



Ganges River basin (India)

https://www.bbc.co.uk/news/resources/idt-aad46fca-734a-45f9-8721-61404cc12a39

Mekong River basin (China - Vietnam)



Two major Neotropical rivers: Orinoco & Amazon

Orinoco River: ~ 2,560 km long

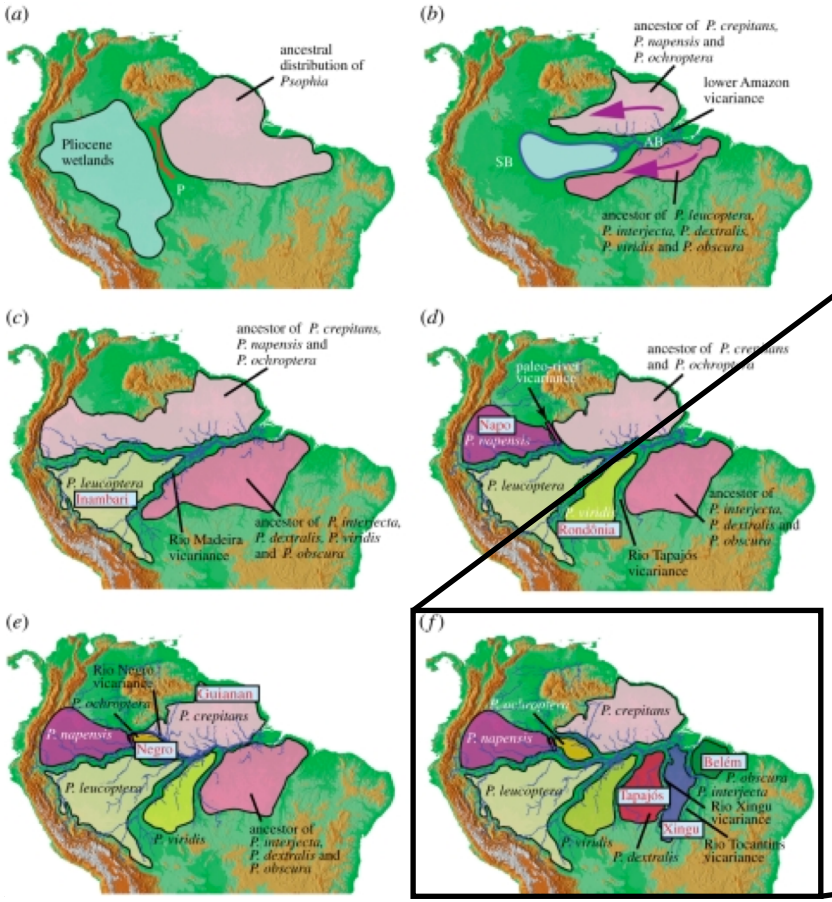
Flows northeast from Rio Guaviare in eastern Colombia, bisecting Venezuela before exiting to Atlantic

Amazon River: ~ 6,437 km long

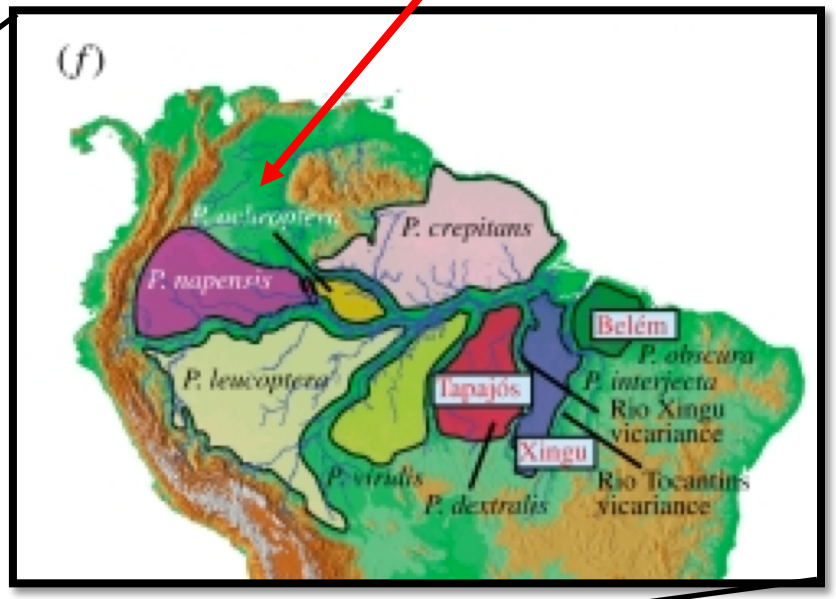
Forms at the confluence of the Maranon and Ucayali rivers west of Iquitos, Peru, flowing east to the Atlantic

Recall: hypothesized historical biogeography of trumpeter complex

Diversification of trumpeters influenced by large rivers

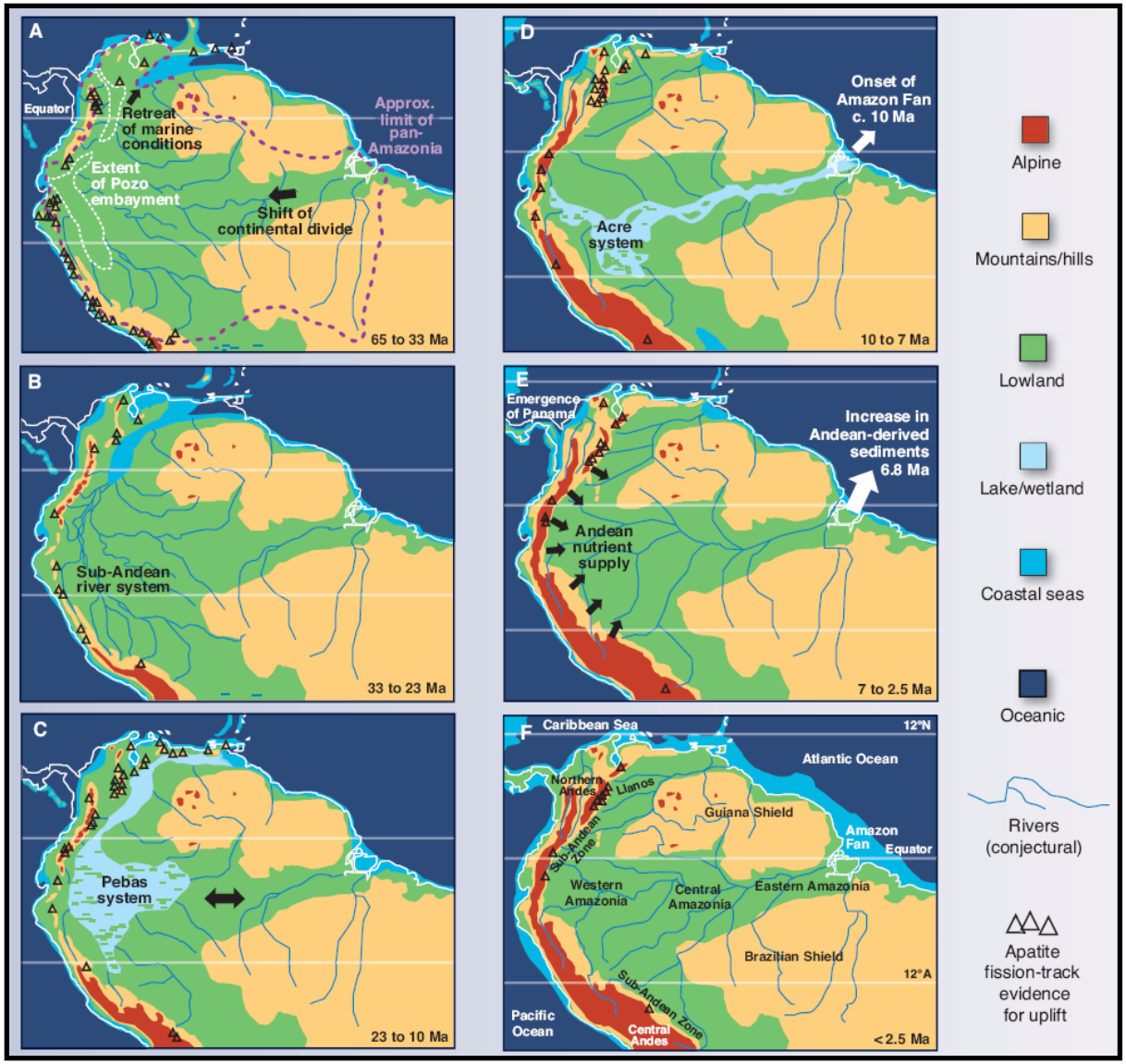


We've largely ignored the northern part of South America – the Orinoco basin



Ribas et al. 2012

Recall: proposed historical biogeography of tropical South America



The Amazon River originally flowed in the opposite direction, draining toward the Pacific (then northward)

Shifted to east course following uplift of the Andes only ~10 mya

Hoorn et al. 2010, *Science*

Two major Neotropical rivers: Orinoco & Amazon

Orinoco River: ~ 2,560 km long flows northeast from Rio Guaviare in eastern Colombia, bisecting Venezuela before exiting to Atlantic

Bisects two distinct geological areas:

The right (south) bank borders Precambrian bedrock from the Guianan Shield

The left (north) bank is geologically recent, from sediments washed from the Andes across the *Llanos*

The Guianan Shield & the Llanos

The Guianan Shield is among the oldest geological formations on Earth

- Tributaries from the shield are stable, constrained by bedrock, with rapids and waterfalls
- Tributaries from the Llanos are unstable with shifting channels formed by alluvial deposits

Los Llanos of Venezuela and Colombia

Seasonal wet savanna, with pronounced dry season through most of (northern) winter

The Guianan Shield & the Tepuis

Tributaries from the shield are stable, constrained by bedrock, with rapids and waterfalls

Electric blue tarantula, Ischnocolinae

Stefania evansi (Groete Creek Carrying Frog), Guyana

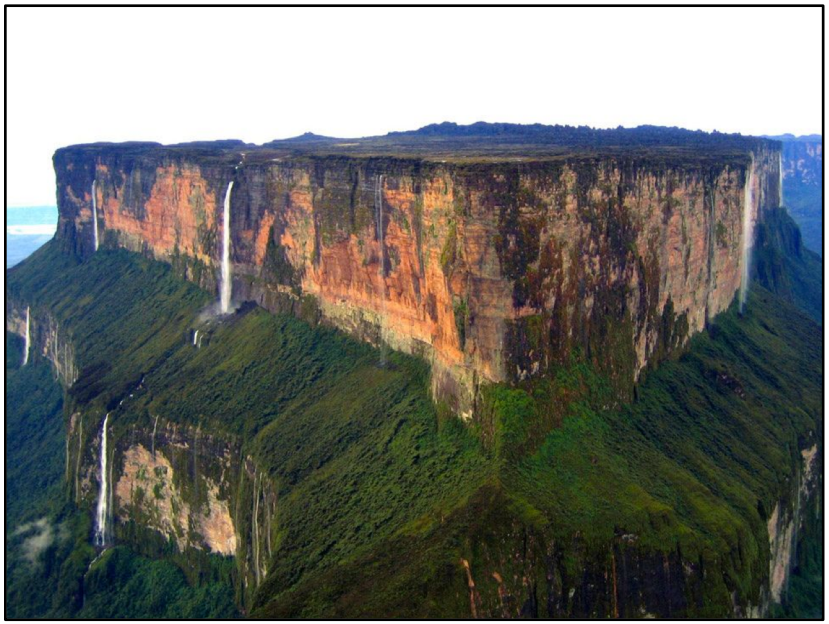
The Guianan Shield & the Tepuis

The Orinoco River strongly influenced the geology of the region, cutting channels through parts of the Guianan Shield, contributing to the isolated flat-topped table mountains: *the Tepuis*

As featured in: Pixar's "*Up*" https://www.youtube.com/watch?v=KSvustBUBv0

The Guianan Shield & the Tepuis

The Tepuis represent some of the most ancient rock formations in South America, with some sandstone and quartzite rocks dating to 1.8 billion years



Between 250-400 mya, the Tepui region would have been in close proximity to Africa in low elevations

~70-180 mya (with dinosaurs abundant), the future tepuis was the Roraima Plateau, which began to experience erosion, and the flattened tabletops are what remain

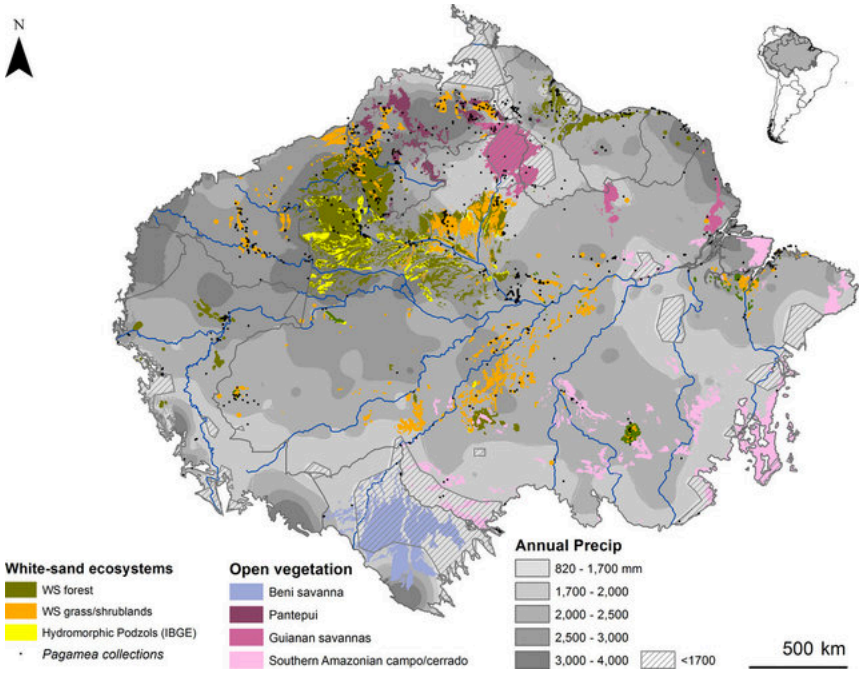
About half of the ~10,000 plant species found in the Tepuis are endemic (with 61 species of orchid found on one tepui alone), supports soil-impoverished habitats

The Guianan Shield & White-sand Forest

Recall: We talked about white sand forest as a case where top-down forces, like herbivory, may promote specialization

White sand forest is a unique nutrient poor soil habitat that occurs in patches throughout the Amazon basin

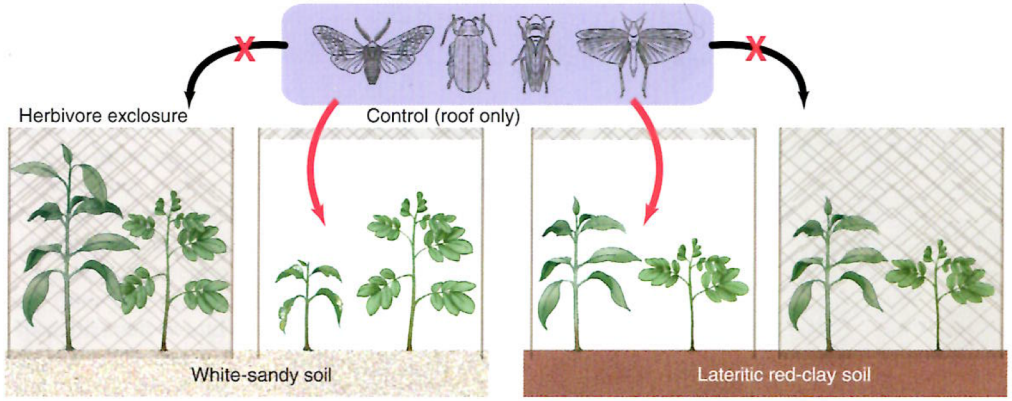
White sand forest near Iquitos, Peru



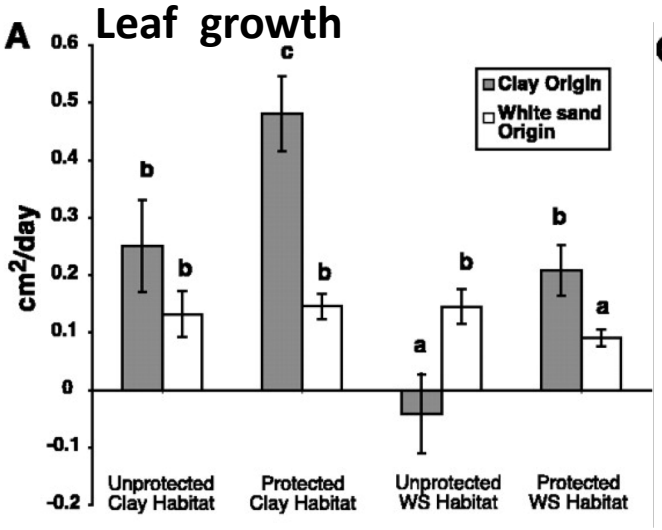
The Guianan Shield & White-sand Forest

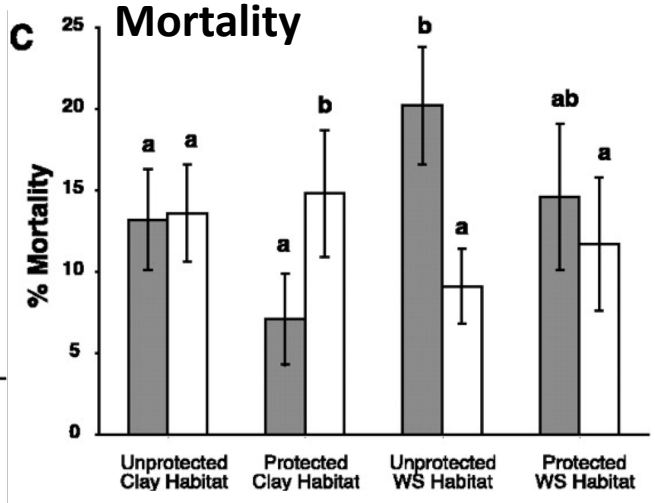
Top-down forces, like herbivory, may actually promote specialization.

Transplant experiments of clay-soil and sandy-soil saplings to opposite soil type:



Clay-soil species grew *better* than WS species in white sand habitat when herbivores were excluded, but fared poorly when herbivores were not excluded





Speciation on white sands may have resulted from **strong selection for defense compounds**

Fine et al. 2004, *Science*

Two major Neotropical rivers: Orinoco & Amazon

Amazon River: ~ 6,437 km long

Forms at the confluence of the Maranon and Ucayali rivers west of Iquitos, Peru, flowing east to the Atlantic

(officially called the Amazon from Manaus, Brazil eastward, considered the Solimoes River west of Manaus)

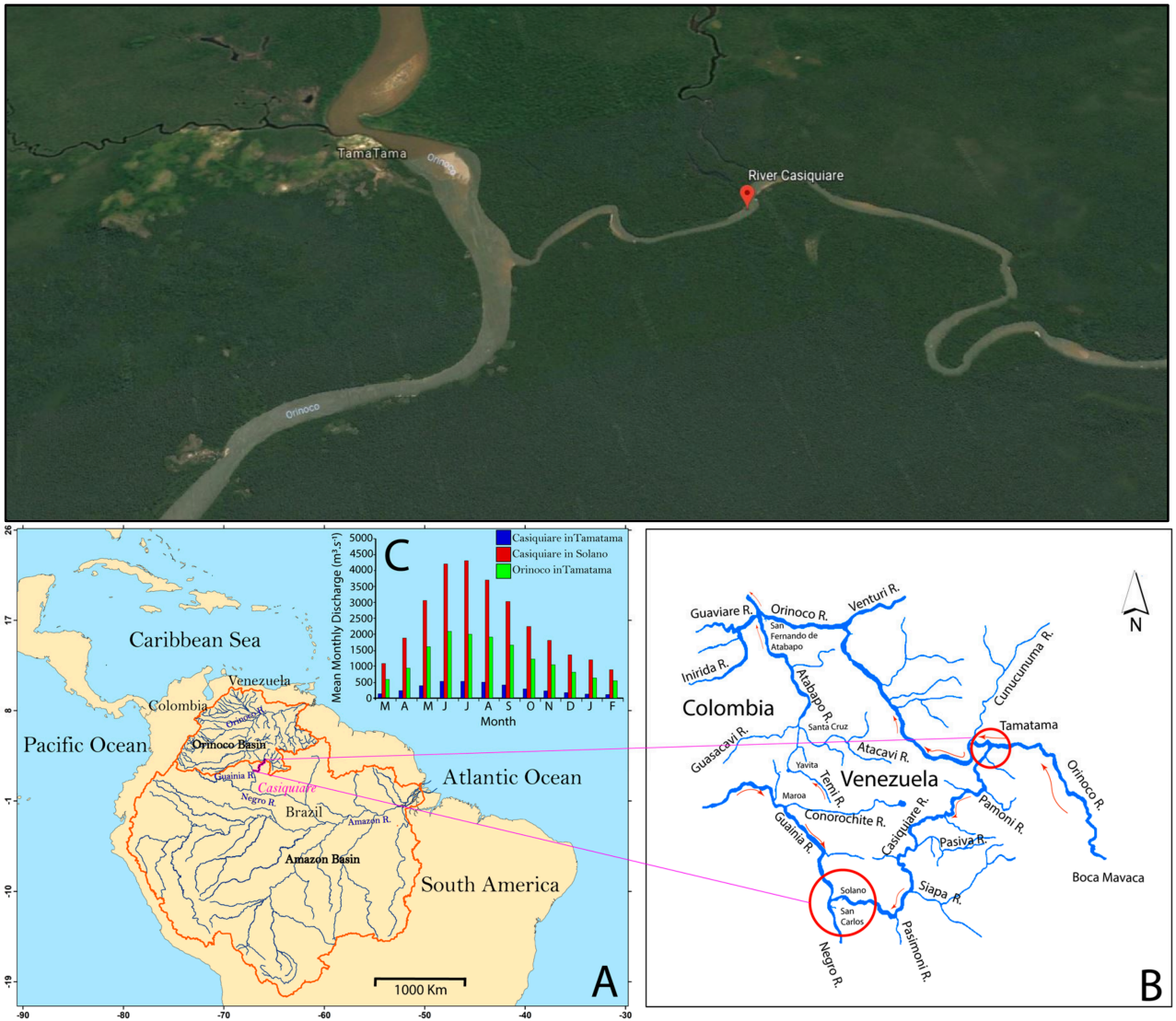
Approximately 1,100 tributaries service the main river

Two major Neotropical rivers: Orinoco & Amazon

Amazon river at one of its widest areas

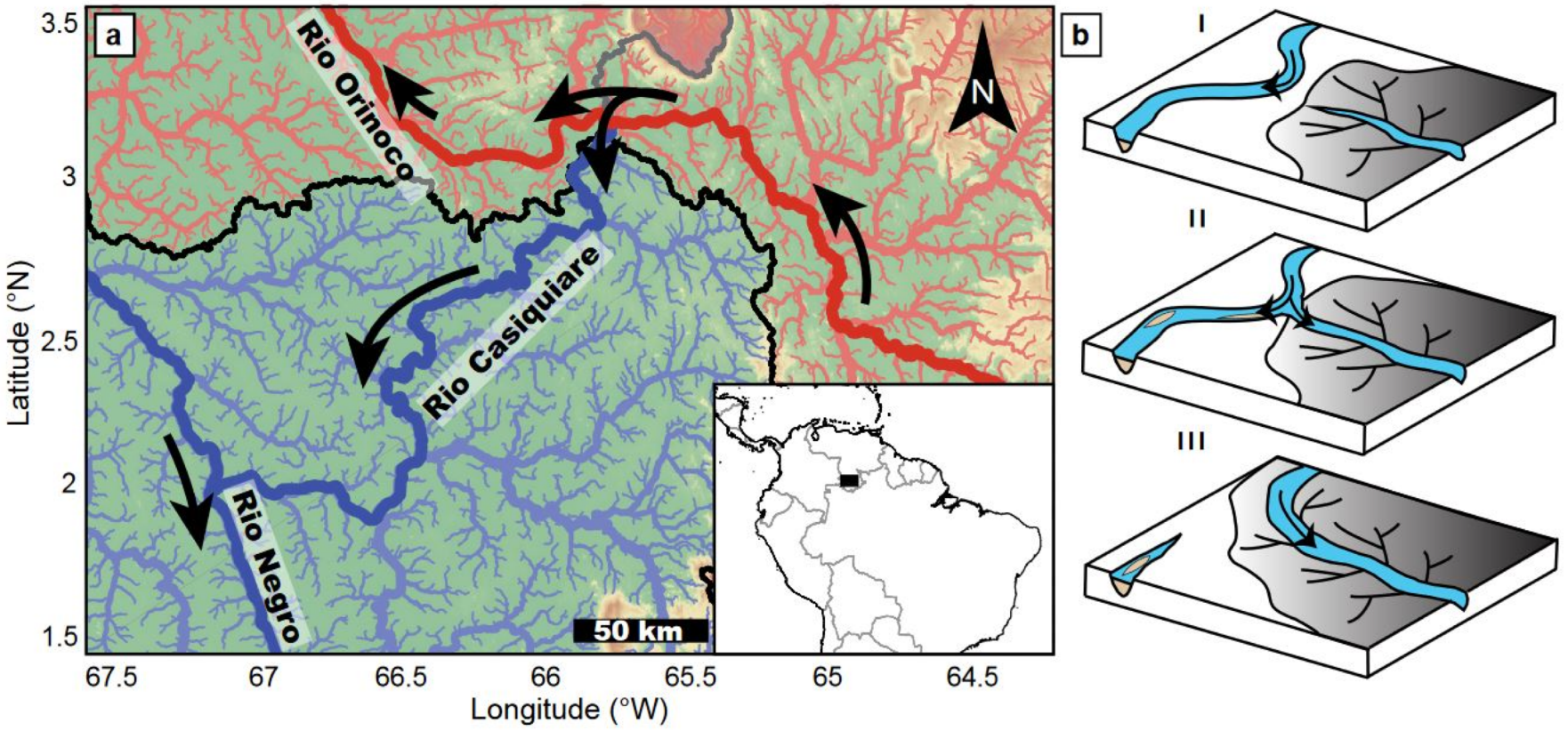
River piracy: Tributary or *dis*tributary?

- Rio Casiquiare is a rare *dis*tributary of the upper Rio Orinoco (left), flowing south to meet the Rio Negro in the Amazon Basin
- The Casiquiare diverts ~ 1/4 of the Orinoco's water
- Eventually the Rio Casiquiare will conduct all of the flow away from the upper Orinoco and into the Amazon!



River piracy: Tributary or *dis*tributary?

Current river flow connections and the hypothesized capture process:
(I) pre-capture, (II) present bifurcation, and (III) future complete capture.



Black line marks the present boundary between the Orinoco River basin (north) and the Amazon River Basin (south). https://blogs.agu.org/geospace/2018/08/15/amazon-pirating-water-from-neighboring-rio-orinoco/

Blackwater and whitewater rivers

Amazon tributaries vary in color, depending on where they originate and chemical properties:

- White sandy soils are usually drained by *Blackwater* rivers (water appears tea-like, dark and clear, colored by tannins)
- *Whitewater* rivers drain nutrient- and sediment-rich Andean soils (water appears cloudy, loaded with sediments)

Blackwater river distribution

Whitewater river distribution

“Wedding of the waters”

At the confluence of the Rio Negro and the Amazon River near Manaus, Brazil

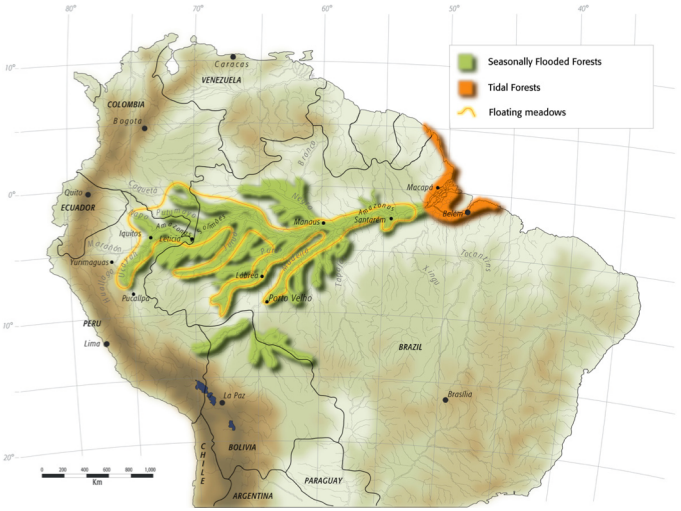
The clear, dark Rio Negro (blackwater), a major tributary draining the white-sand soils of the ancient Guiana shield meets the muddy whitewater Amazon, rich in nutrients and sediments draining from the younger Andes

Flooded forest: “Varzea” and “Igapo”

Flooded *igapo* forests are associated with blackwater rivers and show low nutrient levels and lower pH (5 to 6.5)

Varzeas are whitewater floodplains with high loads of suspended sediments, higher dissolved salts (potassium, calcium, magnesium) and near neutral pH

Floodplain forests occupy a significant portion of the Amazon basin



Amazonian Fish Diversity

Over 2400 fish species inhabit the Amazon and its tributaries (hundreds to be discovered)

(a)

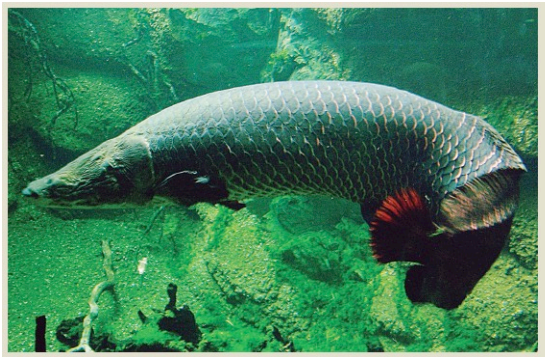
FIGURE 12-7
The Amazon has an amazing diversity of fish species.

(b)

40% of species are characins and catfish

Other groups include relatives of red piranha and electric eels

Large fish species include the pirarucu (*Arapaima*) and arawana (important fish for Amazonian people)



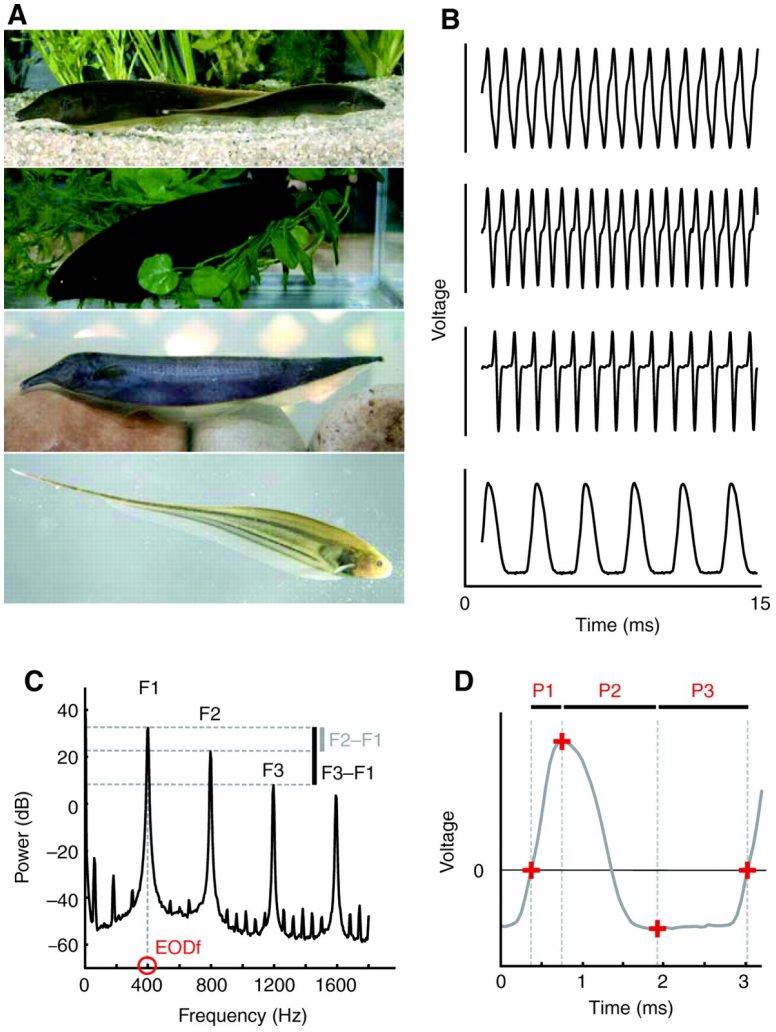
Amazonian Fish Diversity: Signaling in Electric fish (Gymnotiformes)

Over 2400 fish species inhabit the Amazon and its tributaries (hundreds to be discovered)

Electric knifefishes - Gymnotiformes

Neotropical South American weakly electric fish that produce electric organ discharges (EOD) for orientation, foraging and communication

EOD signal properties vary widely across species and could be used in species recognition



From Fugere & Krahe 2010, Journal of Experimental Biology

Amazonian Fish Diversity: Signaling in Electric fish (Gymnotiformes)

Over 2400 fish species inhabit the Amazon and its tributaries (hundreds to be discovered)

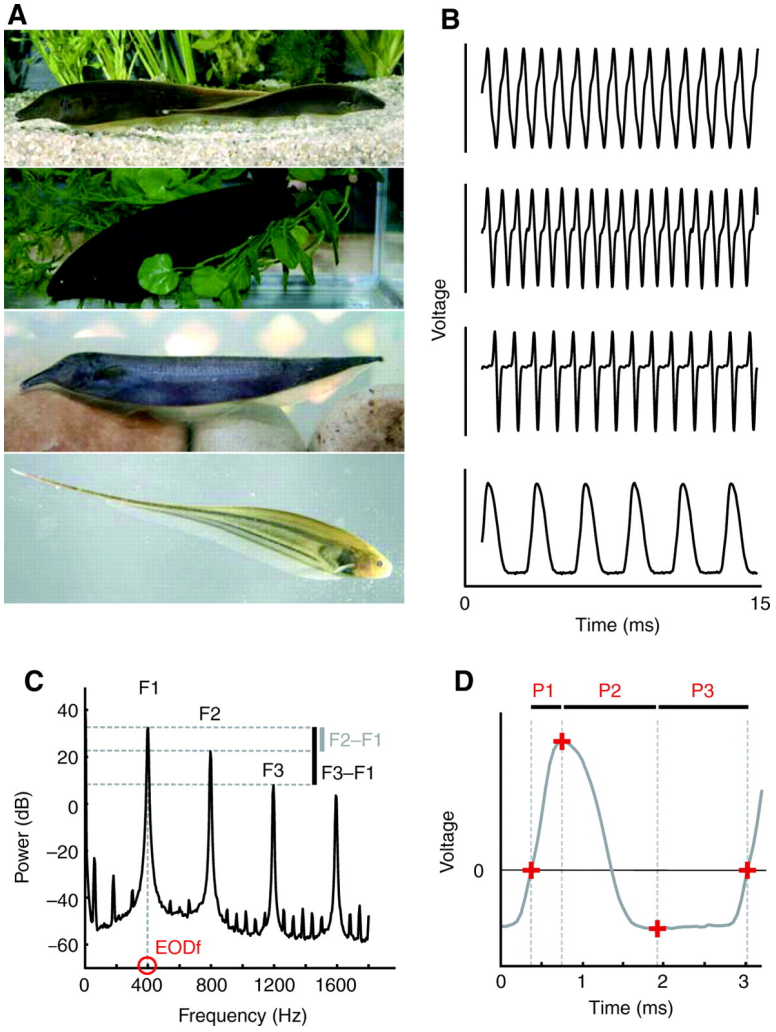
Electric knifefishes - Gymnotiformes

EOD signal transmission also varies depending on the water chemistry

- Blackwater areas have *low conductivity*
- Whitewater areas have *high conductivity*

OXYGEN	ELECTRICAL COND. *	TEMP.		BIOTOPE COMPLEX
ALWAYS HIGH	HIGH	HIGH	1	WHITEWATER RIVER VÁRZEA PARANÁ AT LOW WATER
	LOW	HIGH	2	BLACKWATER LAKE / FLOODED FOREST
		LOW	3	TERRA FIRME STREAM
SOMETIMES LOW (Variable at low-water and persistently low at high-water)	HIGH	HIGH	4	VÁRZEA LAKES / CANOS / FLOODED FOREST VÁRZEA PARANÁ AT HIGH WATER

From Crampton 1999

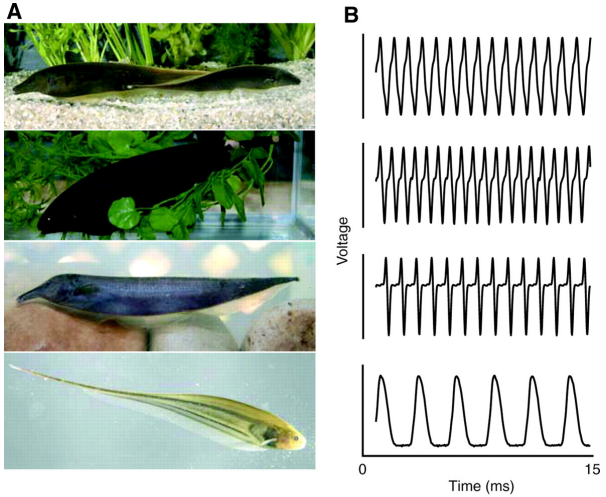


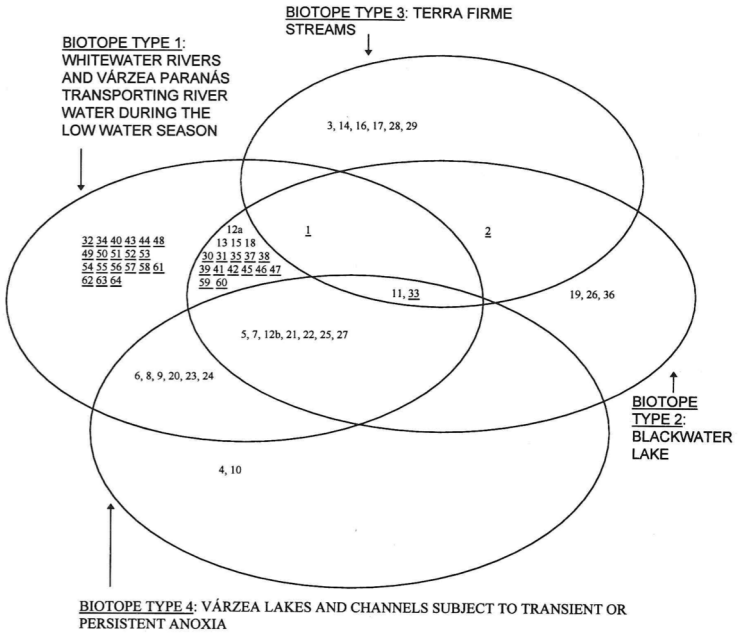
Amazonian Fish Diversity: Signaling in Electric fish (Gymnotiformes)

Over 2400 fish species inhabit the Amazon and its tributaries (hundreds to be discovered)

Electric knifefishes – Gymnotiformes

Conductivity, along with other water conditions (dissolved oxygen, temperature and transparency) affect the distributions of knifefish species





Circles represent different biotypes (blackwaters, whitewater, terra firme streams, varzea)

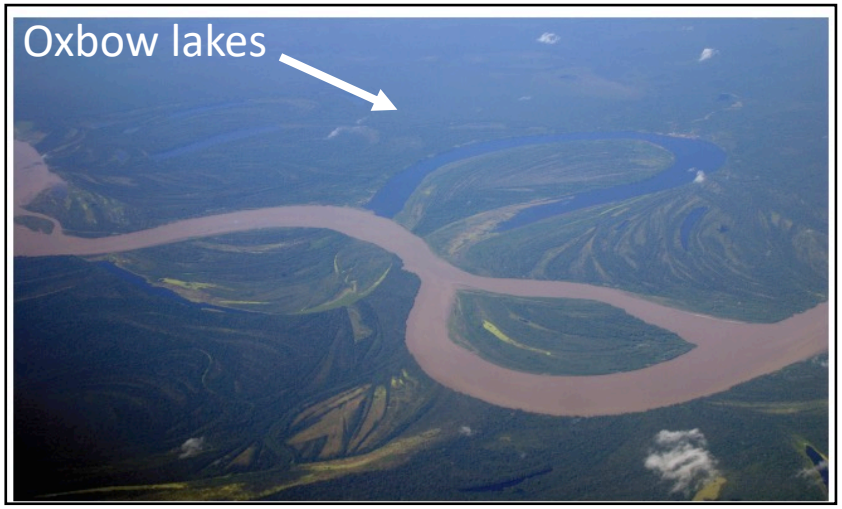
Fish species (identified by number) found within each biotype, which vary by dissolved O_2, temp, conductivity, transparency

From Crampton 1999

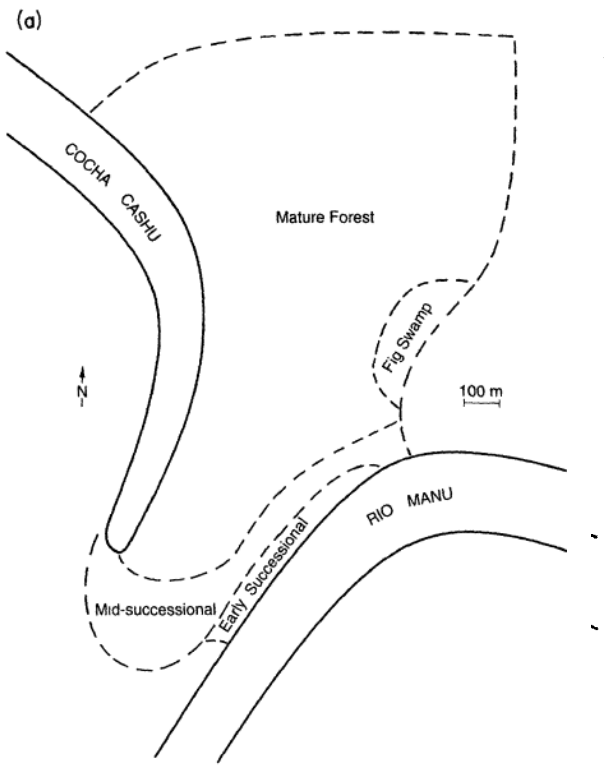
Riverine habitats

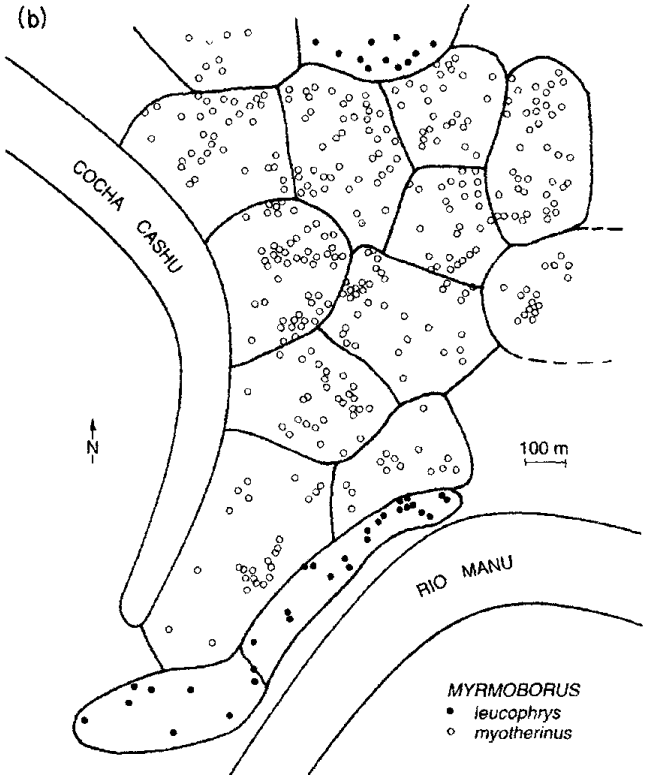
Ecological succession of habitats that track meandering path of rivers

Oxbow lakes are left when the river cuts a new channel, leaving a habitat of standing water



Habitat selection and community structure along gradients from river edges



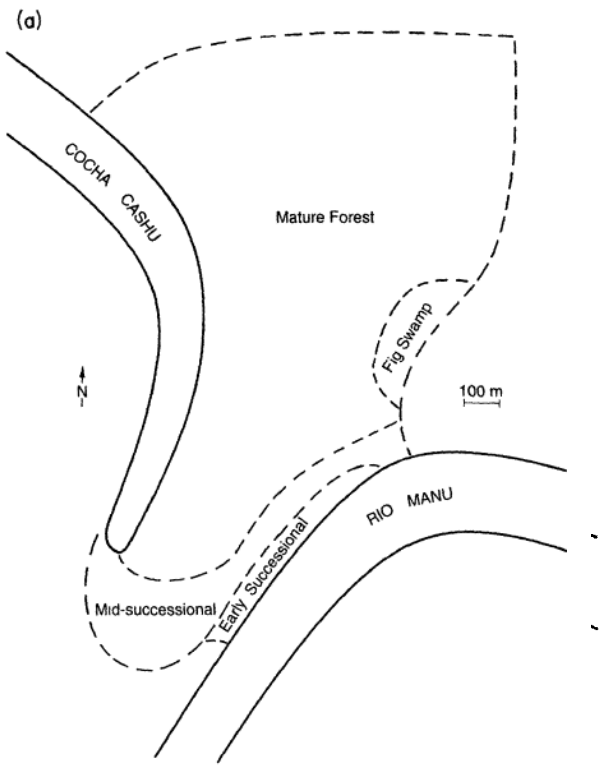


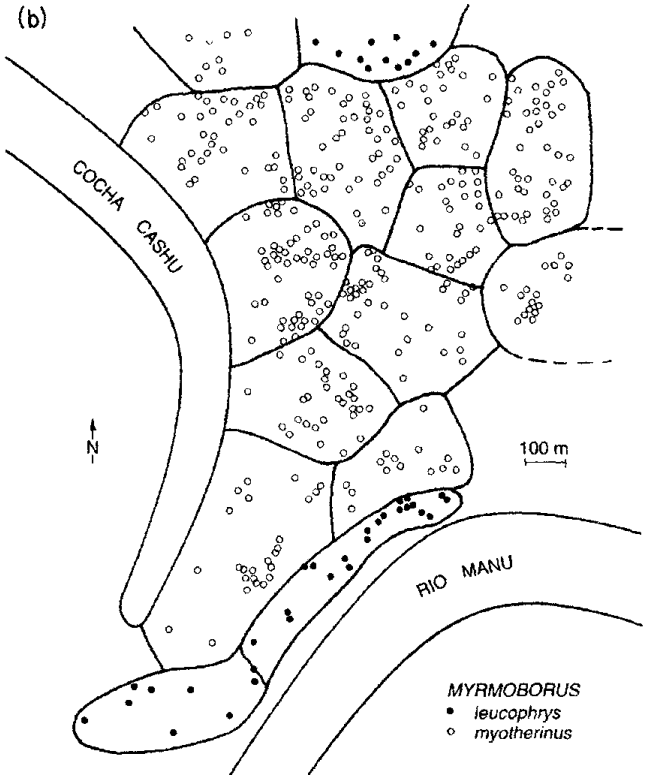
Closely related bird species inhabit different successional habitats, with non-overlapping territories aligned with abrupt transitions in vegetation

Territorial behaviors between closely related species segregate territories and local distributions along habitat boundaries

From Robinson & Terborgh 1995, *J. Anim. Ecol.*

Habitat selection and community structure along gradients from river edges





In many cases, the larger more aggressive species occupied the resource rich end of habitat gradients (supports despotic model that with competition, dominant species occupy more productive environments)

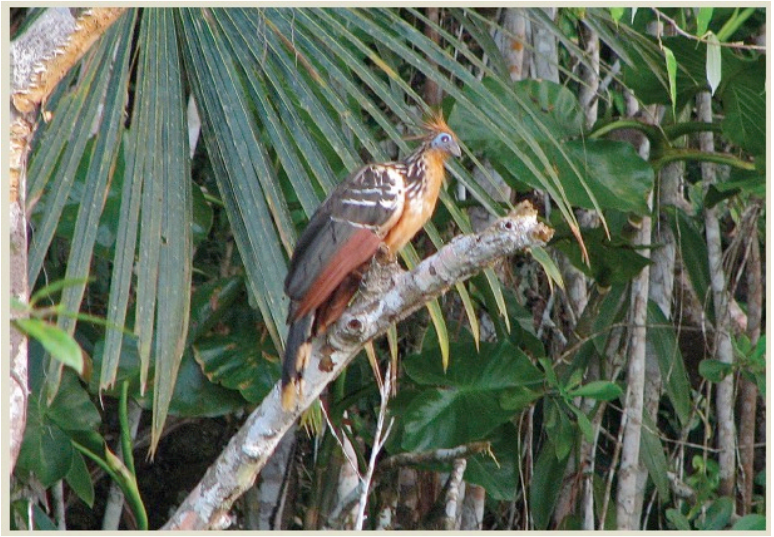
From Robinson & Terborgh 1995, *J. Anim. Ecol.*

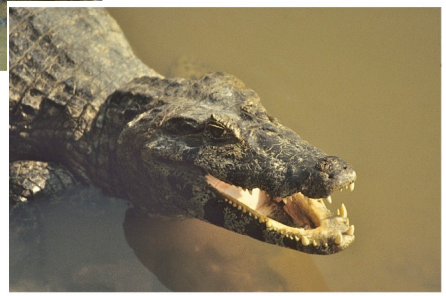
Oxbow Lake and River edge Residents

Hoatzins (one of the few folivorous birds) are common along meandering streams in and oxbows – communal breeders

Hoatzins feed on plants (often loaded with secondary compounds) which are digested using fermentation, microflora and bacteria, similar to bovines

Gives birds an unpleasant odor (beneficial since it makes them distasteful to human hunters)





Giant river otters and spectacled caiman are common along tributaries

Oxbow Lake and River edge Residents

Capybaras are the world's largest rodent, closely related to guinea pigs, ecologically similar to the African hippo
Usually found in family groups, but can reach herds of 50 – 100 in the Venezuelan Llanos or Brazilian Pantanal

Black-collared hawks are common along rivers and streams, feeding primarily on fish

Flooded forests are not created equal

Floodplain forests may border whitewater or blackwater rivers

Forest productivity varies with sediment loads
- Whitewater flooded forests are typically higher in stature and biomass (species richness?)
- Blackwater flooded forests are lower in stature and species richness

Flooded forests also vary depending on the frequency of flooding:
- Permanently waterlogged swamp forest
- Seasonally waterlogged swamp forest
- Lower, middle or upper floodplain forest
- Previous floodplain (e.g., now *terra firme*, but historically floodplain)

Landscape and water / flooding characteristics offer very high habitat heterogeneity, reflected in biogeography of Amazonian faunas