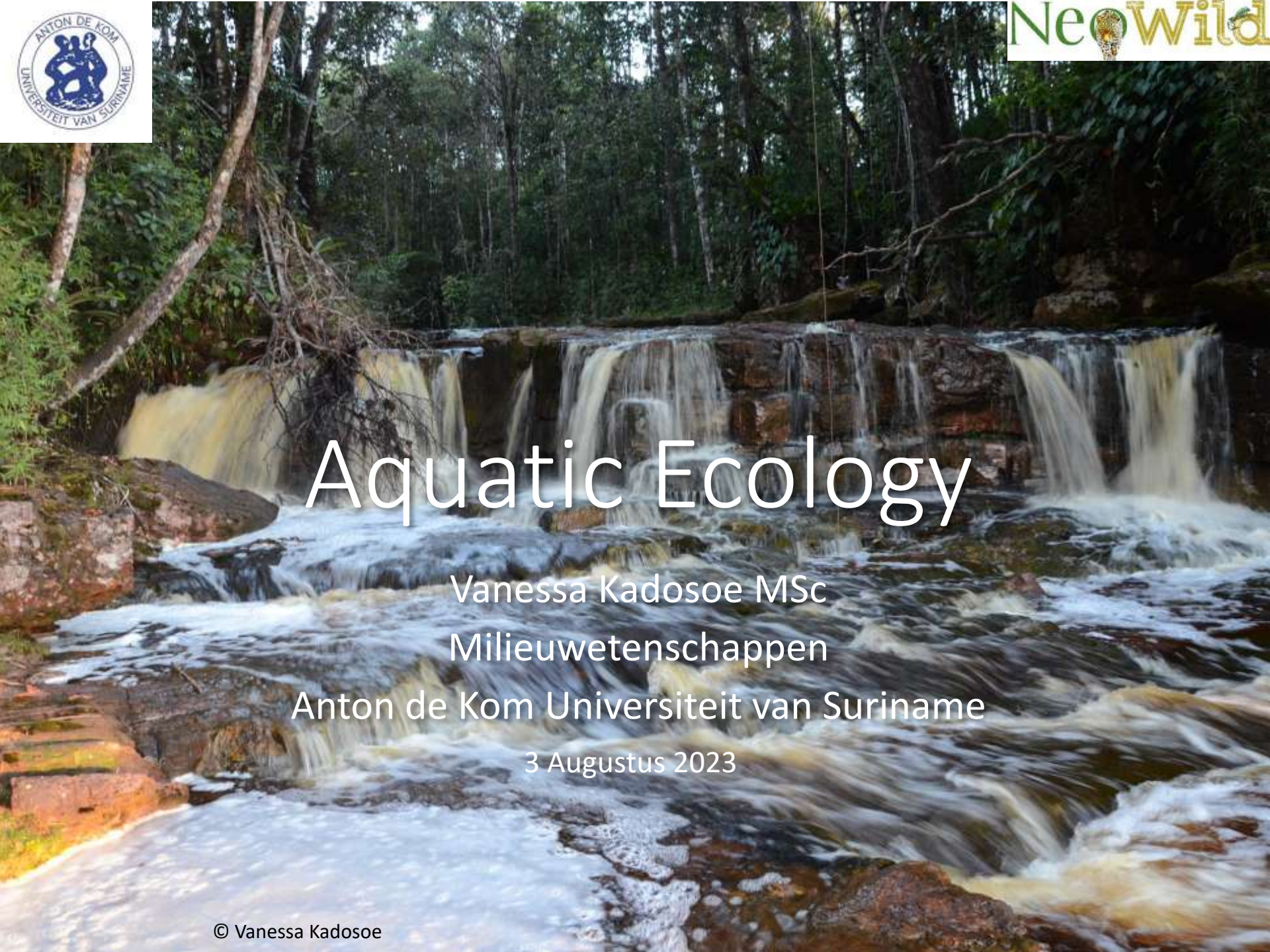


Aquatic Ecology

Vanessa Kadosoe MSc
Milieuwetenschappen
Anton de Kom Universiteit van Suriname

3 Augustus 2023

Agenda

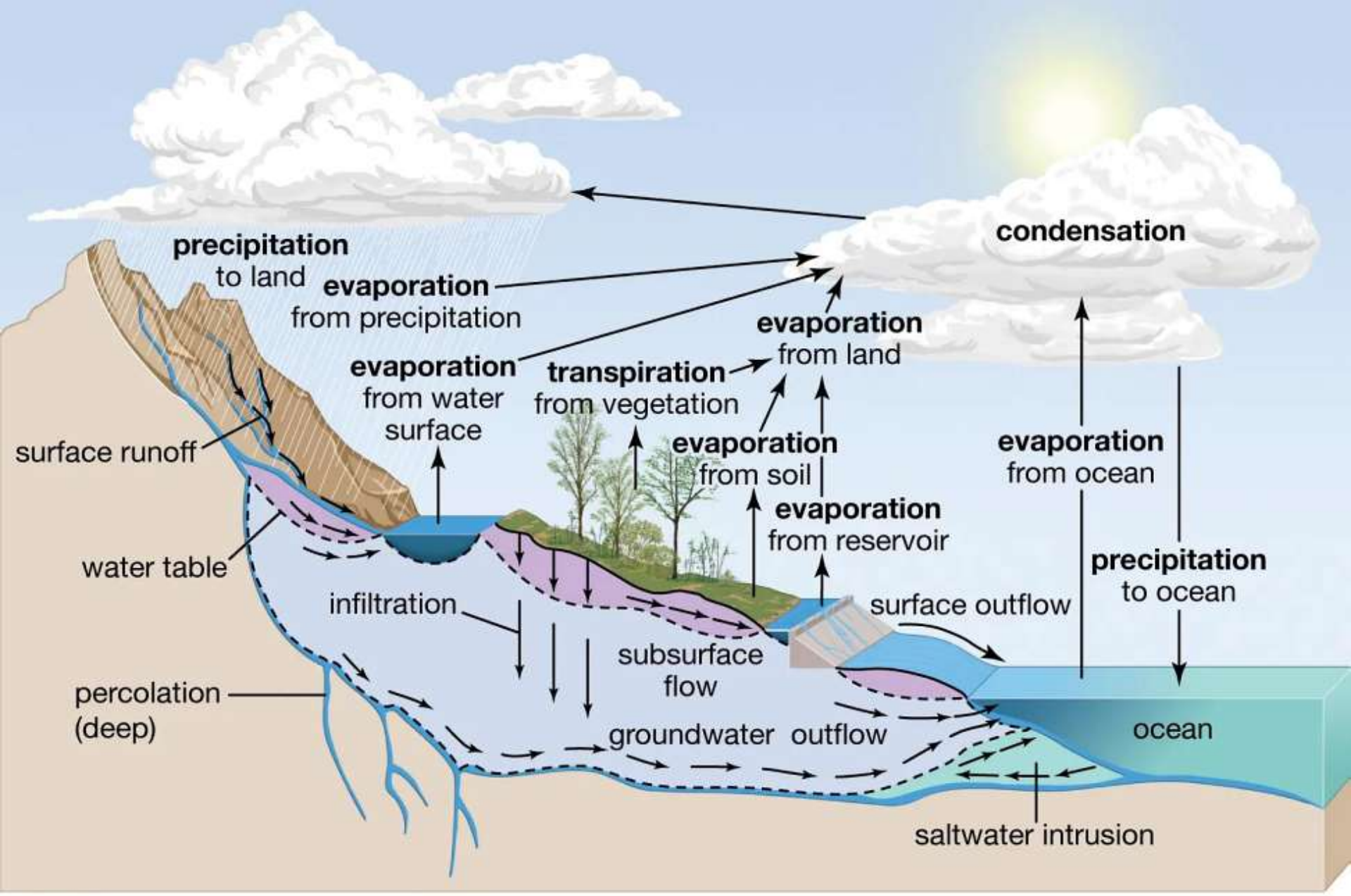
- Overview aquatic ecosystems
- Characteristics of aquatic ecosystems
  - Rivers, creeks, brooklets,
  - lakes, lagoons,
  - canals, trenches
- Species diversity and data collection
- Threats to aquatic ecosystems
  - Pollution
    - Brokopondo Lake
    - Gold mining
    - Sewage

Fields of aquatic ecosystems

- LIMNOLOGY: the study of inland waters, as ecological systems interacting with their drainage basins and the atmosphere.
  - stationary water bodies
  - running waters
  - groundwater

- HYDROLOGY: the science that encompasses the occurrence, distribution, movement and properties of water and their relationship with the environment within each phase of the hydrologic cycle
  - Limnology
  - Oceanology

- ECOLOGY: the study of the relationships between organisms and their physical environment
  - abiotic = physical-chemical characteristics
  - biotic = biotic characteristics



ocean covers 71 percent of Earth's surface
196,950,000 sq mi (510,000,000 sq km)

Overview aquatic ecosystems of Suriname

- Running waters
  - Freshwater streams (Rivers, Creeks and Brooklets)
  - Oceans
  - Canals and trenches
- Stagnant/open waters
  - Lakes and Lagoons
- Wetlands
  - Swamps and Swamp forests

Ouboter, 1993

Aquatic ecosystems

- Freshwater streams (brooklets, creeks, rivers)
- Lakes (natural and man-made)
- Underground reservoirs (freshwater)
- Freshwater swamps
- Puddles, pools, water-holes, etc.
- Canals, trenches (man-made)
- Mangrove swamps (brackish)
- Lagoons (brackish)
- Estuaries (brackish)
- Ocean (saline)

Characteristics of aquatic ecosystems

Freshwater streams

- Running waters
- Unidirectional
- Brooklets, Creek and Rivers
- Water types of Suriname
  - Clear water from interior
  - Black water
  - (White water)
- River continuum theory
- Turbidity and nutrients increase towards the coast (sediment, intrusion by sea at high tide)

Brooklets

Brooklets

Upstream brooklets

- High altitudinal gradient
- Swift current
- Usually, a solid rocky bottom
- Clear water with few nutrients
- High amount of dissolved oxygen
- Organisms specialized for life in swift current
- Usually good drinking water, but limited in supply

Lowland brooklets

- Low altitudinal gradient
- Slow to hardly any current
- Usually, a sandy bottom
- Clear water with few nutrients
- Low to high amount of dissolved oxygen
- Low to intermediate diversity
- Not very good for drinking water
- Sometimes high in humic acids

Rivers and creeks

Rivers and creeks

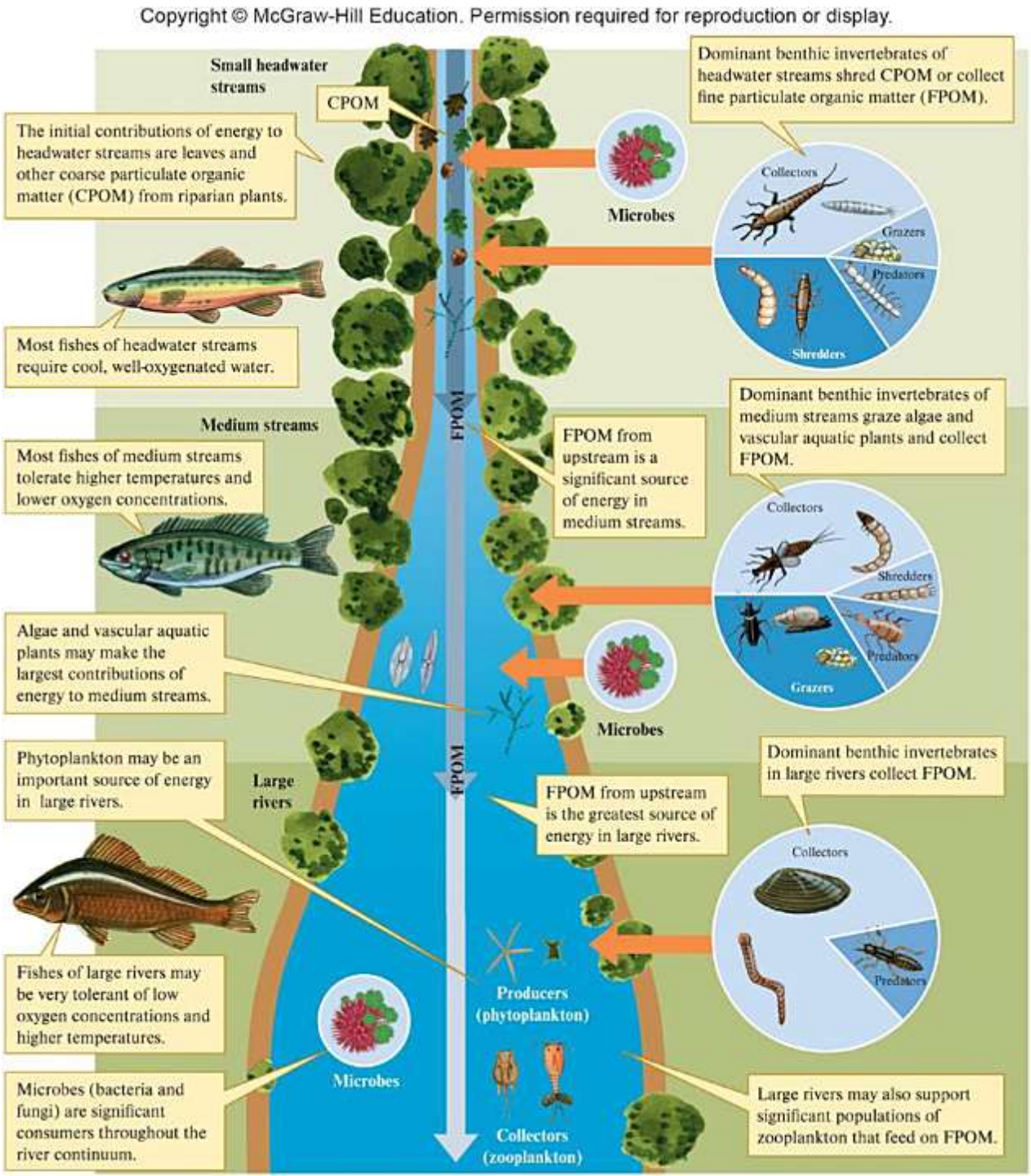
Rivers in Interior

- Varying intermediate to high altitudinal gradient and current
- Bottom sediment rocky to sandy
- Water clear to slightly turbid
- Few nutrients
- High in dissolved oxygen
- High biodiversity: specialized organisms and generalists
- Often suitable drinking water, but prone to pollution

Rivers in coastal plain

- Low altitudinal gradient and low current, near coast tidal zone
- Bottom sediment clayish
- Water slightly/very turbid
- Medium to high in nutrients
- Medium in dissolved oxygen
- Low biodiversity: mostly generalists, freshwater + brackish water
- Not suitable as drinking water, due to many human activities, prone to pollution

River continuum theory



Clear waters

- Clear water from interior
  - High DO, high visibility, low nutrients, low conductivity
  - Adapted aquatic life relies on allochthonous nutrients from land

Black waters

- Black water from savanna belt and from sandstone (Tafelberg) with humic acids
  - Dark (“Coca cola”) color, low visibility, very low DO
  - Aquatic life is adapted to low DO

White waters

- White water from Amazon river/Andes;
  - Erosion water from Amazon visible at the coast
- In Suriname, white waters as a result of heavy rain fall or pollution

Canals and Trenches

- Man-made for supply and disposal of water.
- Often polluted
  - Run off from industries (Saramacca kanaal)
  - In urban areas connected with sewage system
  - Household waste
- Overload of nutrients can result in explosive vegetation growth, stagnation and flooding

Lakes and Man-made reservoirs

Lakes

- Few natural lakes, man-made Brokopondo Lake
  - No gradient and hardly any current
  - Bottom sediment sandy to clayish
  - Water clear to slightly turbid
  - Intermediate nutrients
  - Natural accumulation of heavy metals
  - Intermediate in dissolved oxygen
  - Some generalists remaining, low biodiversity
  - Not very good drinking water, polluted with mercury

Swamps and swamp forests

Swamps and Swamp forests

- Water usually stagnant
- Open and forested areas with (natural) seasonal flooding
- Most abundant in the coastal plains, also occurring in Savanna Belt and Interior
- Often with high concentration of humic acids (clear/black water)
- Bottom sediment clayish with plant material
- Low to high amount of nutrients
- Low to high in dissolved oxygen
- Important habitats for fish reproduction, therefore important for food



Aquatic fauna of Suriname




Data collection of aquatic biodiversity

Aquatic biodiversity sampling methods

Threats to aquatic ecosystems

Types of threats

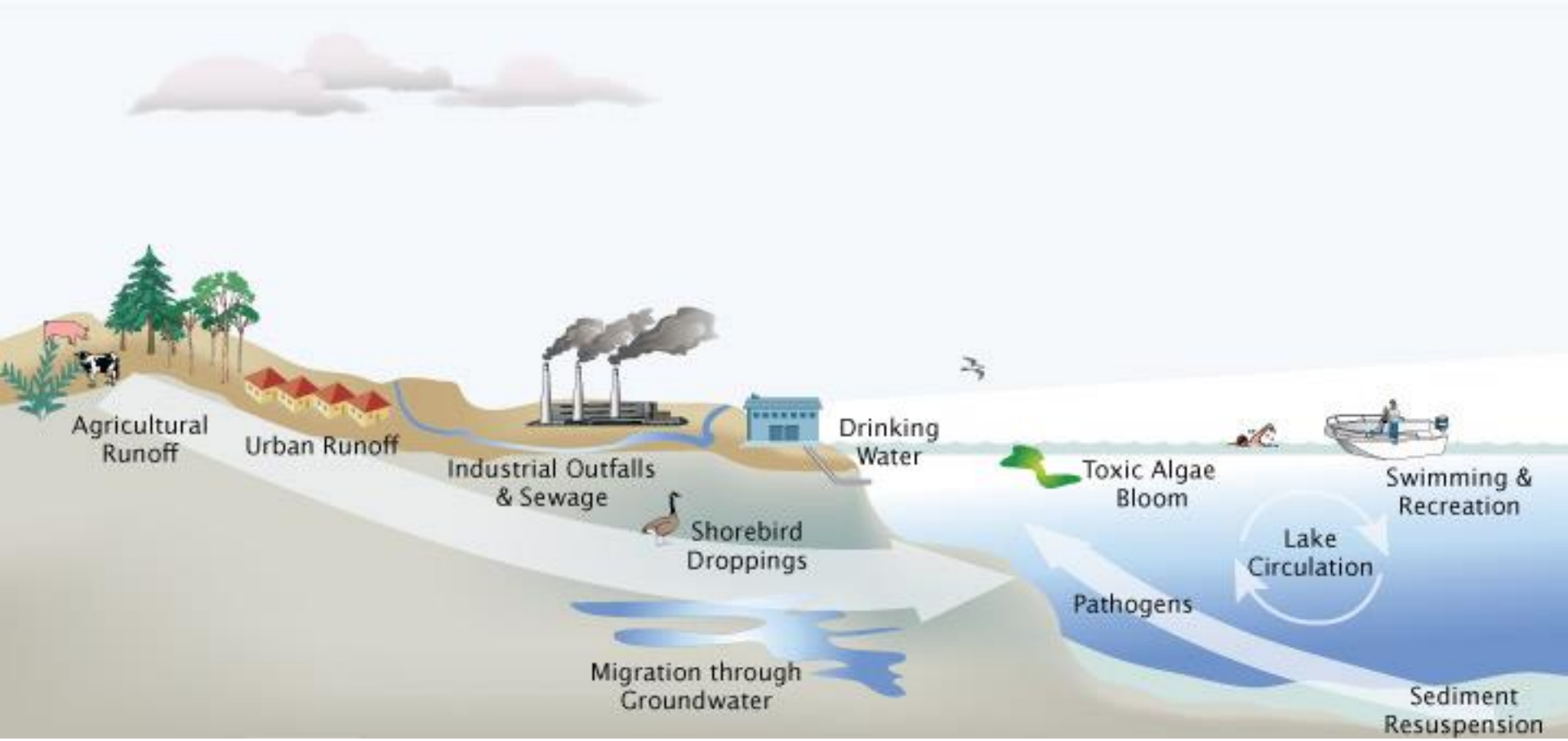
- Water pollution
- Man-made reservoirs
- Mining
- Nutrients
- Climate change

Water pollution

Types of water pollution

- Urban pollution
  - **Sewage: nutrients, bacteria**
  - Household waste
- Agricultural pollution
  - Pesticides
  - Fertilizers
- Industrial pollution
  - Heavy metals
  - Oils (PCB, PAK)
- Mining
  - Cyanide
  - **Mercury**
  - **Turbidity**
  - **Nutrients**
  - **Caustic soda**

Water pollution

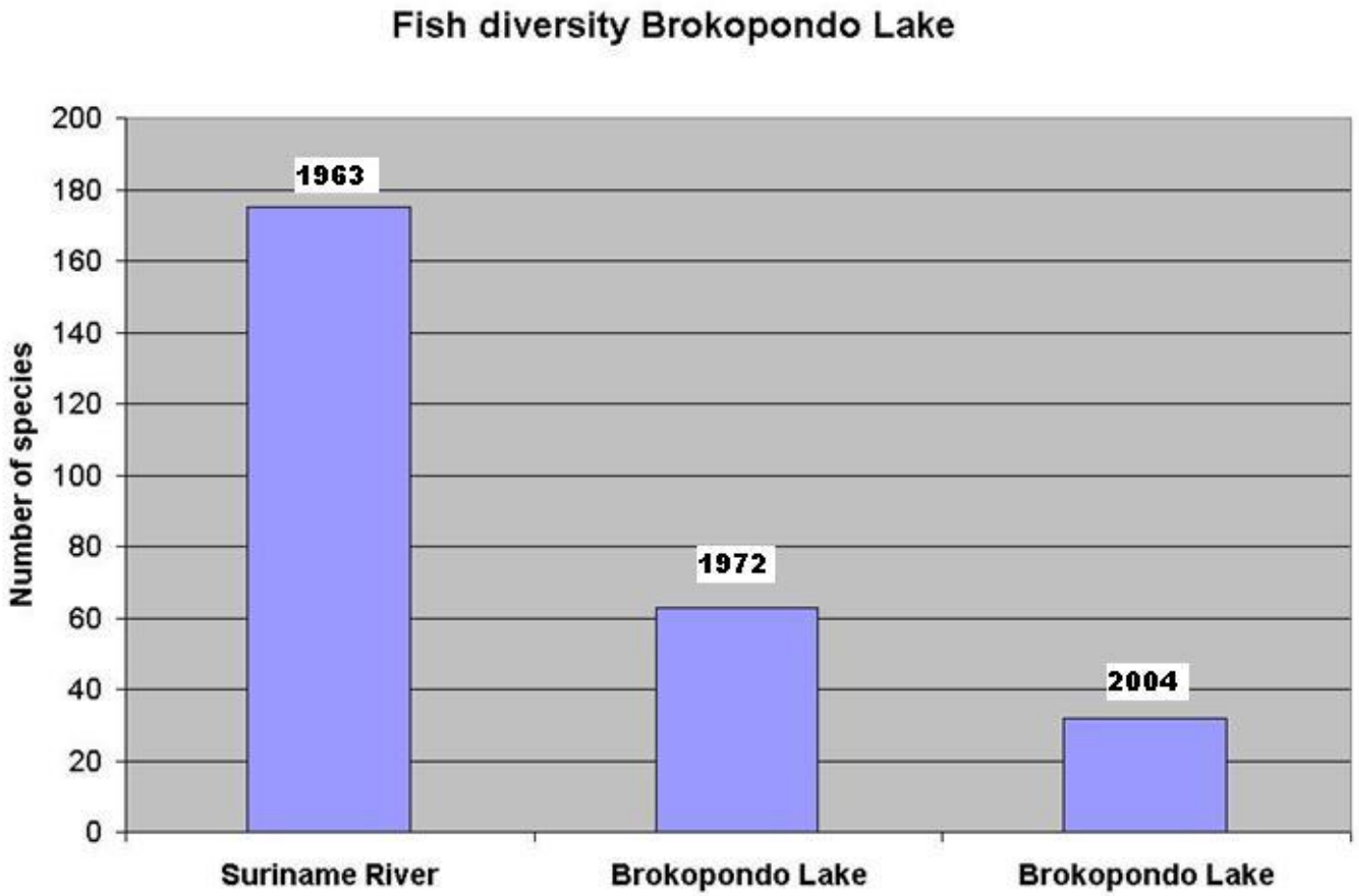


Brokopondo Hydro-power Lake

Forest decomposition

- Explosive water hyacinth growth

Impact Brokopondo hydropower dam on fish fauna



Mol et al., 2007

Mining

Turbidity

Turbidity from gold mining at confluence Goliath Creek and Boven-Coesewijne River, BCNR

Turbidity from gold mining at Brokopondo Hydropower Lake

Shorting of the durability of the dam

Witti Creek

Moeder Creek

Ancistrus sp.

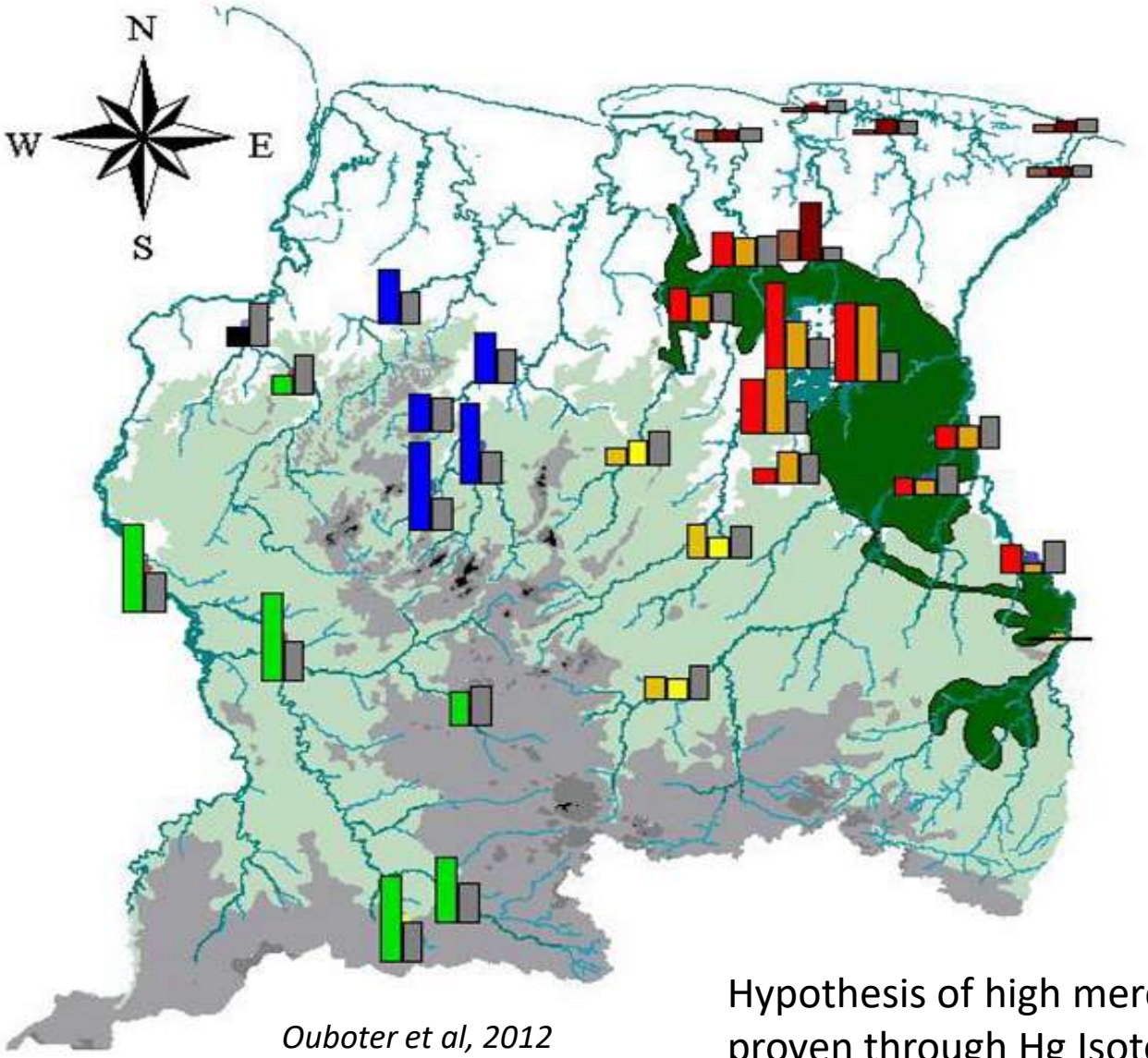
Impact of turbidity on biodiversity

- Water transparency low → visually foraging fish disappear; increase of knife fish and certain catfish
- Substratum covered by sediment → reproduction of certain species decreases
- Worst case scenario: extermination of all macro-life

Fish species clean creek vs polluted creek

Mol & Ouboter, 2004

Mercury levels in piscivorous fish



Ouboter et al, 2012

Dark gray bar: threshold mercury in fish for human consumption

Yellow bar: measurements upstream of gold mining

Red/Orange: measurements in rivers and lakes in Greenstone belt

Brown bar: measurements downstream gold mining areas

Green bar: measurements in Coeroeni, Sipaliwini and Zuid river

Black bar: measure in Kabalebo river

Blue bar: Upper Coppename and Saramacca river

Hypothesis of high mercury levels in pristine areas is proven through Hg Isotopes

Impact of biologically available mercury

- US EPA calculated a wildlife criterion for total mercury in freshwater: 0.01 µg/L
- Most freshwater in Suriname is **likely** above this norm
- Highest levels in fish measured in Brokopondo Lake and Coppename River
- Wildlife likely to be affected:
  - Giant otter & Neotropical otter
  - Herons, Cormorans (duikelaars) & Kingfishers
  - Caimans & Freshwater turtles
  - Jaguars?

Caustic soda

- Used in Alumina (bauxite) industry
- Spill of caustic soda at Suralco plant at Paranam
- Impacts on surrounding swamp, Topibo swamp
  - Increased pH >11
  - Palustrine vegetation disappeared
  - Aquatic fauna diversity changed
  - Only few species adapted to new circumstances
  - Swamp visited by coastal birds (skimmers, snipes)

Ouboter & De Dijn, 1993

Figure 2. Aerial photograph of the Topibo area (photograph by Centraal Bureau Luchtkartering Paramaribo).

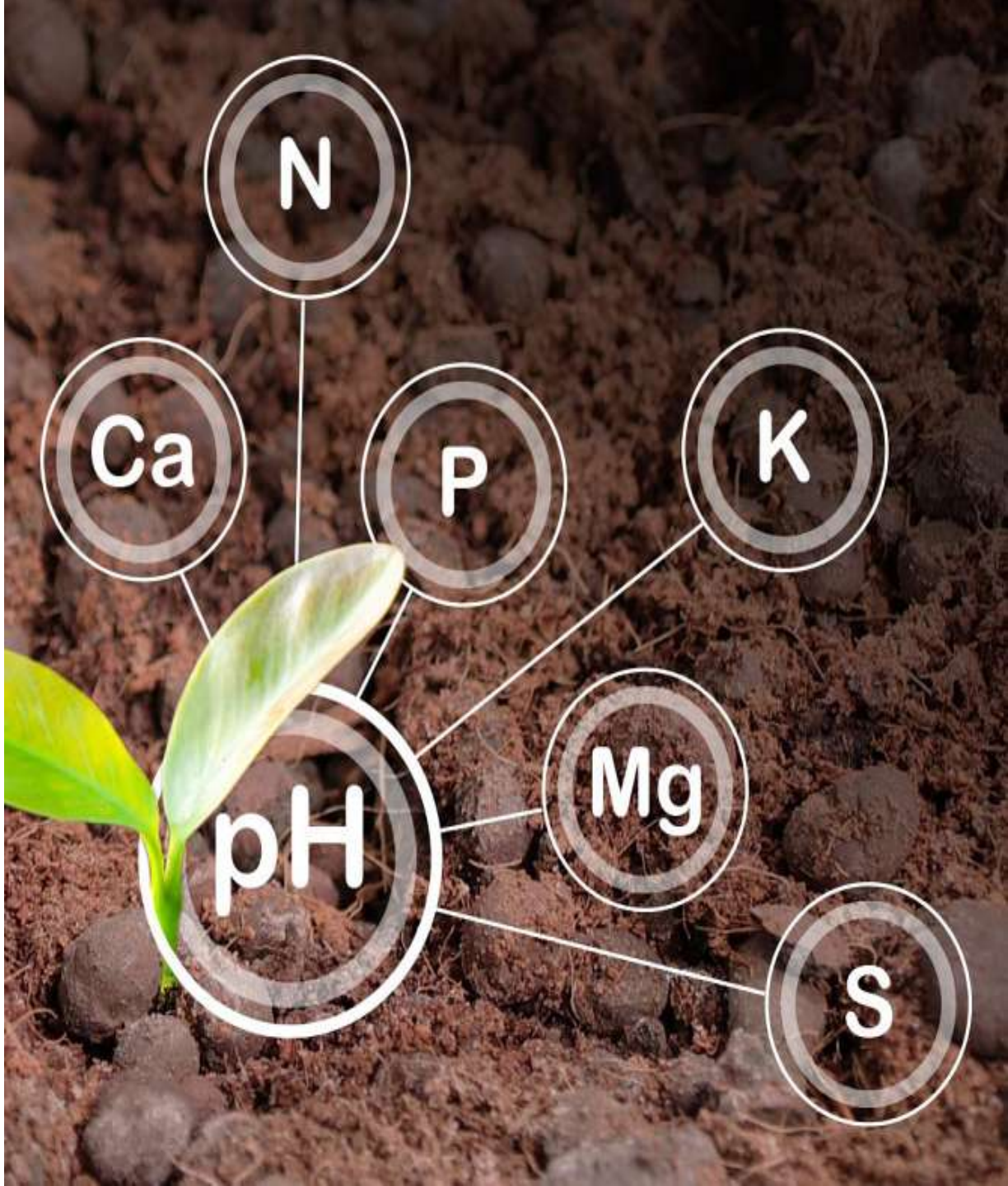
Cyanide

- Used in gold mining (small and large scale)
- Kept in solution in LS mining at pH >11
- Degrades under sunlight into relatively harmless molecules (e.g. NH_3 en HCO_3-, CO_2)
- Deadly for most aquatic life
- In case of accident may become deadly for terrestrial fauna, including humans
  - (CN binds with red blood cells, suffocation)

Cyanide

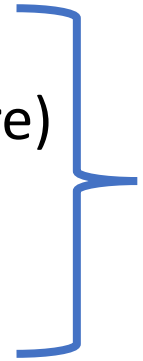
- *Malone et al., 2023*
  - Cyanide application is becoming more popular in small-scale gold mining
  - Often used in combination with mercury
  - HgCN increases mobility of mercury, increasing mercury pollution
- Cyanide is more efficient than mercury in processing gold. This may inspire miners to extent their activities to areas with lower deposits of gold

Nutrients



Nutrients in aquatic ecosystems

- Nutrients from:
  - Erosion
  - Churning of soil (mining, logging, agriculture)
  - **Sewage**
  - Fertilizers (agriculture)



Eutrophication

Eutrophication

Impacts:

- Eutrophication
  - Algae bloom
    - Decrease in DO
    - Decrease of water visibility
    - Fish mortality >>
  - Simplification of the ecosystem and dominance of specific species

Sewage

High abundance of fecal matter (E. coli bacteria or other pathogens)


Solutions
©Vanessa Kadosoe

Solutions

- **Catchment area protection**
- Wastewater treatment systems
- **Sustainable energy production**
- **Stricter mining regulations and control**
- Alternative mercury-free and turbidity-limiting methods for gold mining
- Water quality regulations for industry and recreational water

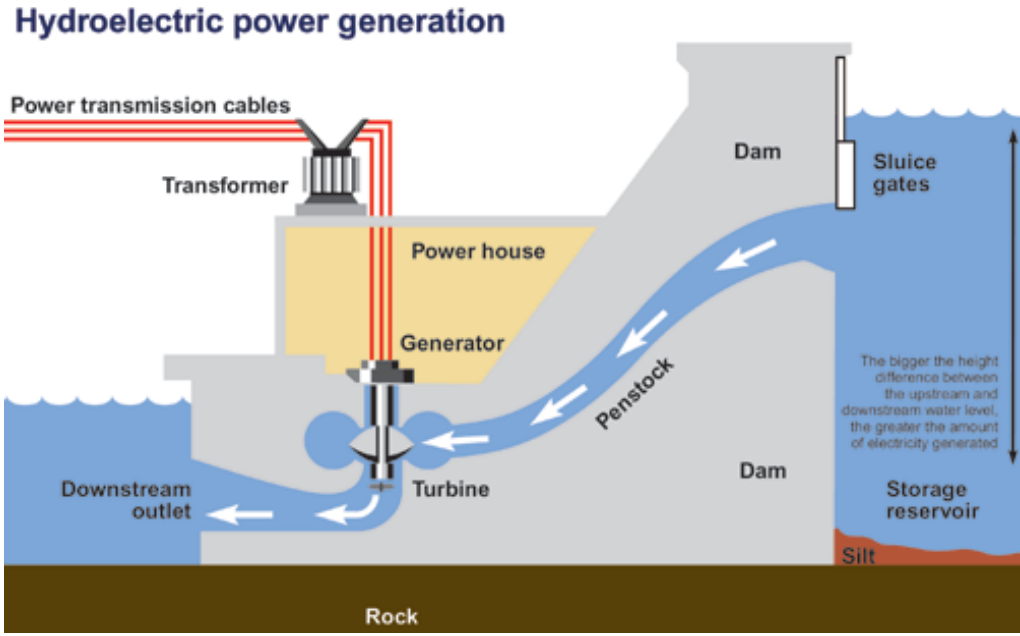
Solutions

- Enforcement of pesticide regulations
- Proper recycling and/or disposal of waste (plastic bags, batteries, hazardous chemicals, medicines).
- Awareness for farmers and the general public
- EIA's incl. biodiversity
- Prepare for climate change
- **Research**

Catchment area protection

- Protect upstream areas of all major rivers
  - Prohibit mining, forestry, industries
- Promote non-destructive practices e.g., ecotourism
- Special regulations for local communities (e.g., HKV's)

Sustainable energy production



Sustainable energy production

- Promote **actual green energy** production
- Prevent pollution from oil and gas industry e.g., offshore
- Prohibit creation of hydro-electric lakes, unless
  - Efficiency in relation to megawatts/km^2
  - Transmigration of communities only with full consent
  - Exclude areas with endemic or endangered species
  - Clearance of all vegetation beforehand
  - Rescue operation for drowning animals
  - Use oxygen increasing structure

Stricter mining regulations and control

- Regulations regarding hydrology, erosion and forest clearing
- Protection of biodiversity hotspots in concessions
- Ban hunting and logging in mining concessions
- “Wildlife bridges” for roads
- Mandatory use of tailing ponds
- Environmental monitoring
- Mine closure plan
- Ban the use of mercury
- Organization and training of small-scale gold miners

Research

- Continue research on:
  - Mercury pollution in freshwater and marine environment and local communities
  - Impacts of climate change
  - Pesticide residues in vegetables and in relation to health issues in Suriname
  - Impacts turbidity in various streams

References and additional literature

- Haripersad-Makhanlal, A. & **Ouboter**, P.E. (1993): Limnology: physico-chemical parameters and phytoplankton composition. In: P.E. Ouboter (ed.), Freshwater Ecosystems of Suriname, pp. 53-75. Kluwer Academic Publishers, Dordrecht.
- Legg, E.D., P.E. **Ouboter** & M.A.P.Wright (2015): Small-scale gold mining related mercury contamination in the Guianas: a review. WWF Guianas report.
- Malone, A., L. Figueroa, W. Wang, N.M. Smith, J.F. Ranville, D.C. Vuono, F.D. Alejo Zapata, L. Morales Paredes, J.O. Sharp & C. Bellona, 2023. Transitional dynamics from mercury to cyanide-based processing in artisanal and small-scale gold mining: Social, economic, geochemical, and environmental considerations. Science of the Total Environment 2023. *https://doi.org/10.1016/j.scitotenv.2023.165492*
- Mol, J.H., B. de Merona, P.E. **Ouboter** & S Sahdew (2007): The fish fauna of Brokopondo Reservoir, Suriname, during 40 years of impoundment. Neotropical Ichthyology 5(3): 351-368.
- Mol, J.H.A. & P.E. **Ouboter** (2004): Downstream Effects of Erosion from Small-Scale Gold Mining on the Instream Habitat and Fish Community of a Small Neotropical Rainforest Stream. Conserv. Biol. 18(1): 201-214.
- **Ouboter**, P.E. (1993): Part 1: Basic features. In: P.E. Ouboter (ed.), The Freshwater Ecosystems of Suriname, pp. 7-12. Kluwer Academic Publishers Dordrecht.
- **Ouboter**, P.E. & De Dijn, B.P. (1993): Changes in a polluted swamp. In: P.E. Ouboter (ed.), The Freshwater Ecosystems of Suriname, pp. 239-260. Kluwer Academic Publishers, Dordrecht.
- **Ouboter**, P.E., G. Landburg, J. Quik, J. Mol & F. v.d. Lugt (2012). Mercury Levels in Pristine and Gold Mining Impacted Aquatic Ecosystems of Suriname, South America. Ambio 41(8): 873-882.
- **Ouboter**, P.E., G.A. Landburg, G.U. Satnarain, S.Y. Starke, I. Nanden, B. Simon-Friedt, W.B. Hawkins, R. Taylor, M.Y. Lichtveld, W. Zijlmans, E. Harville, S. Drury & J. K. Wickliffe (2018). Mercury levels in women and children from interior villages in Suriname. Int. J. Environ. Res. Public Health 15, 1007: 1-13.
- Wickliffe, J., M. Lichtveld, W.C.W.R. Zijlmans, S. MacDonald-Ottevanger, M. Shafer, C. Dahman, E. Harville, S.S. Drury, G.A. Landburg & P.E. **Ouboter (**2020). Exposure to total and methylmercury among pregnant women in Suriname: sources and public health implications. Journal of Exposure Science and Environmental Epidemiology. DOI: 10.1038/s41370-020-0233-3
- Wickliffe, J.K, Lichtveld, M.Y., Zijlmans, C.W., MacDonald-Ottevanger, S., Shafer, M., Dahman, C., Harville, E.W., Drury, S., Landburg, G. & **Ouboter**, P.E. (2021). Exposure to total and methylmercury among pregnant women in Suriname: sources and public health implications. Journal of exposure science & environmental epidemiology 31(1): 117-125.

Blue – references

Black – additional readings


Any questions