

Introduction to Ecology



Ecology: scientific study of interactions between organisms and their environment



Spans scales from individuals to the biosphere



Distinct from environmentalism—evidence-based, not advocacy



Rooted in Haeckel's 1866 coinage; now integrates molecular biology and data science



Ecological literacy underpins conservation, resource management, and corporate sustainability



The Hierarchy of Ecological Organization



Organism: a single grizzly bear in its habitat



Population: all interbreeding grizzlies in Yellowstone



Community: grizzlies, elk, pines, wolves, and other species interacting



Ecosystem: the community plus soil, water, and climate



Emergent properties arise at each level, unpredictable from the level below



Core Principles: Energy Flow in Ecosystems



- Solar energy enters ecosystems via primary producers (photosynthesis)



- Only ~10% of energy transfers between trophic levels (Lindeman's Rule)



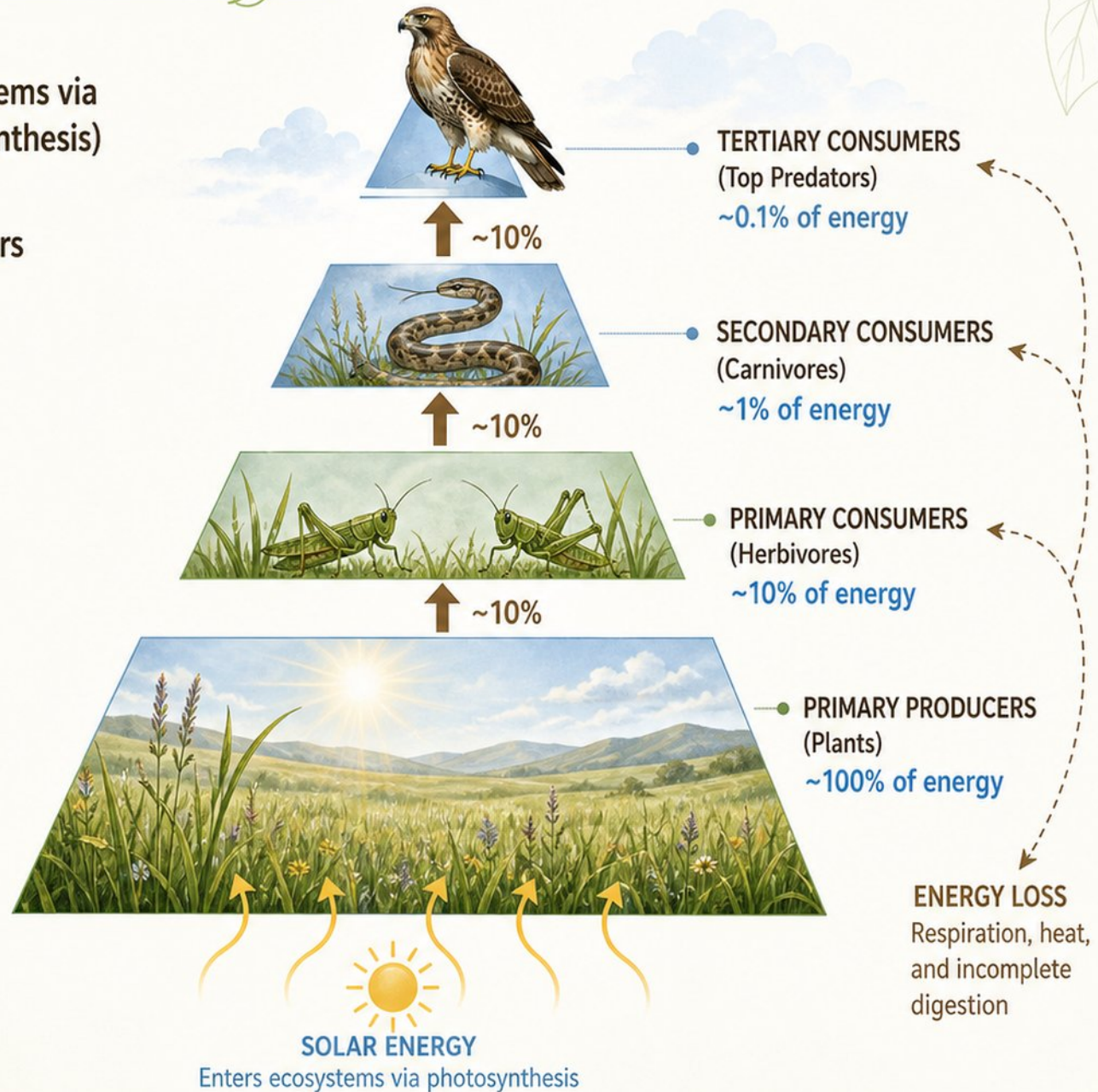
- Energy loss is driven by respiration, heat, and incomplete digestion



- Pyramids of energy are always upright; biomass pyramids can invert

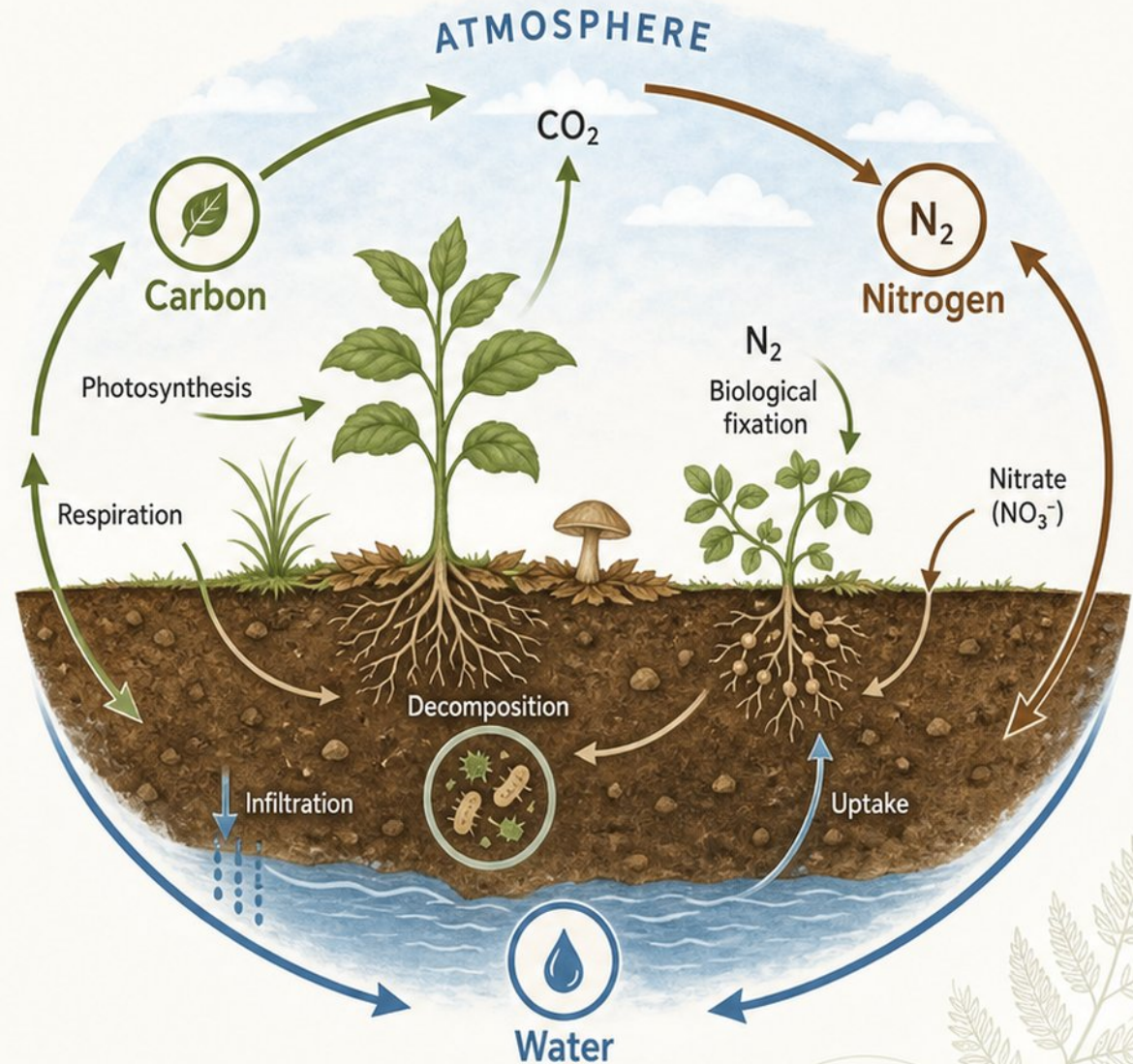


- Limits food chain length; makes high-trophic-level food inefficient



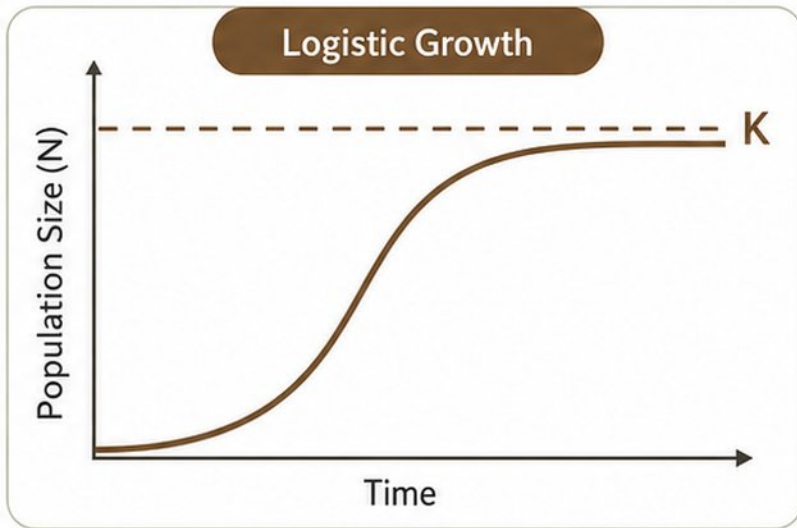
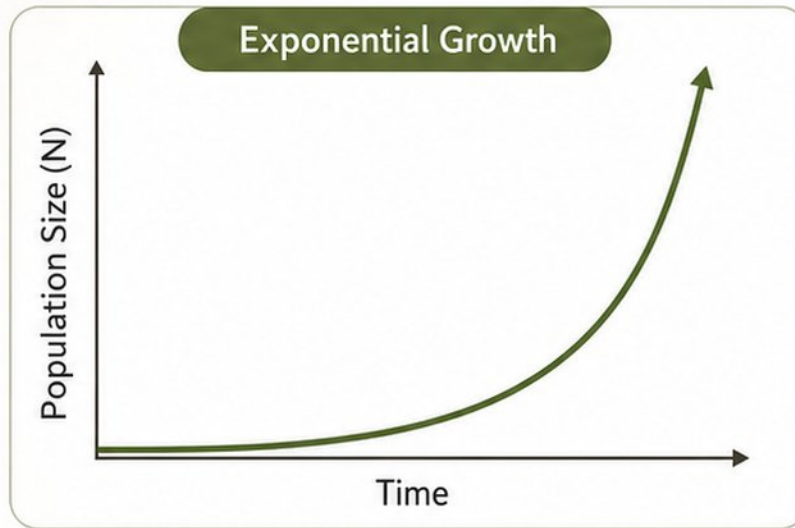
Core Principles: Matter Cycling and Biogeochemical Cycles

- “Matter recycles; energy flows and dissipates as heat”
- “Carbon, nitrogen, and water cycles sustain ecosystem function”
- “Excess nitrogen from agriculture disrupts aquatic and terrestrial systems”
- “Rising CO_2 intensifies climate change and ocean acidification”
- “Nutrient limitation constrains primary productivity in ecosystems”



Population Ecology:

Growth, Limits, and Life Histories



Population parameters: size, density, distribution, and age structure



Exponential growth is unlimited; logistic growth levels off at carrying capacity (K)



r-selected species reproduce quickly; K-selected species invest in fewer offspring



Reindeer on St. Matthew Island show exponential growth followed by crash

Community Ecology: Species Interactions and Niche Dynamics



- Competition, predation, herbivory, mutualism, commensalism, parasitism



- Niche: species' role; competitive exclusion limits coexistence



- Resource partitioning enables similar species to persist



- Specialist pollinator decline disrupts plant reproduction networks

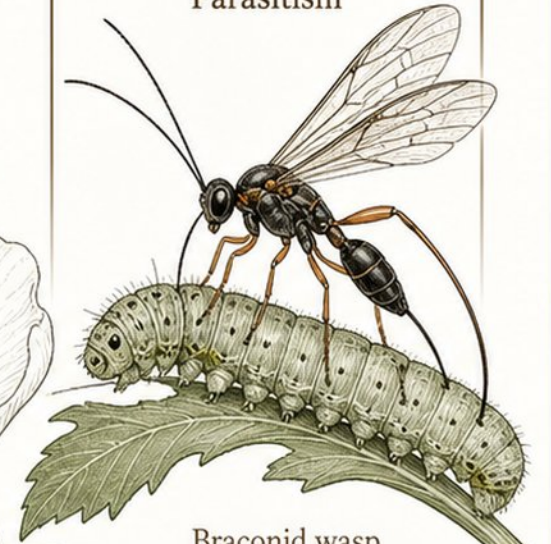
SPECIES INTERACTION WEB (KEY)

- Mutualism / Beneficial
- Antagonism / Harmful
- - - Neutral / Commensal
- Species / Population

Pollination



Parasitism



Braconid wasp parasitizing a caterpillar



Keystone Species, Trophic Cascades, and Ecological Succession



“Keystone species have outsized impact relative to their abundance”



“Trophic cascades: predators reshape entire communities (e.g., Yellowstone wolves)”



“Primary succession begins on bare substrate; secondary follows disturbance”



“Modern view: disturbance regimes maintain dynamic, non-equilibrium states”



LESS GRAZING
PRESSURE



REDUCED ELK
BROWSING

ENERGY FLOW



PRODUCERS
(Plants)



PRIMARY CONSUMERS
(Herbivores)



SECONDARY CONSUMERS
(Carnivores)



DECOMPOSERS
(Nutrients recycled)

Biodiversity: Components, Measurement, and Value



- “Genetic, species, and ecosystem diversity form biodiversity’s three pillars”



- “Species richness, evenness, and indices like Shannon’s quantify diversity”



- “Complementarity effect: diverse communities use resources more fully”



- “Insurance hypothesis: redundancy stabilizes function amid disturbance”



- “Biodiversity underpins pollination, water purification, carbon storage, and cultural value”



GENETIC DIVERSITY



SPECIES DIVERSITY



ECOSYSTEM DIVERSITY

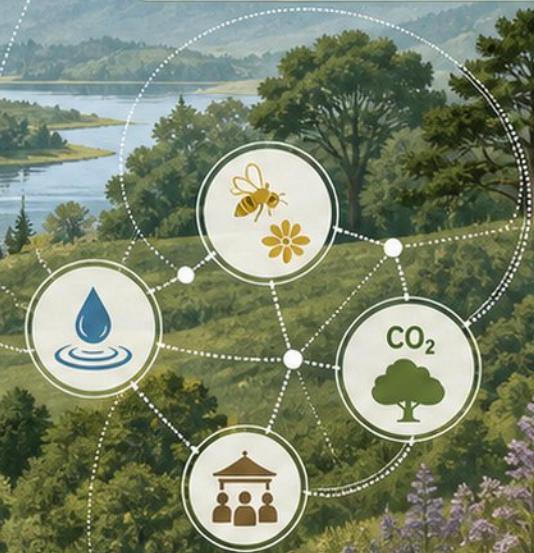
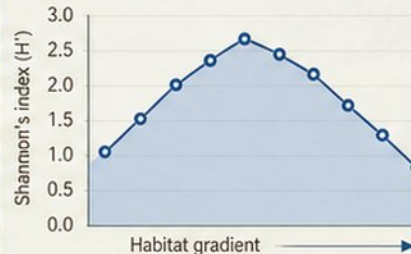
SPECIES RICHNESS



EVENNESS (PIELOU'S J)



DIVERSITY (SHANNON'S INDEX)



ECOSYSTEM SERVICES



POLLINATION



WATER PURIFICATION



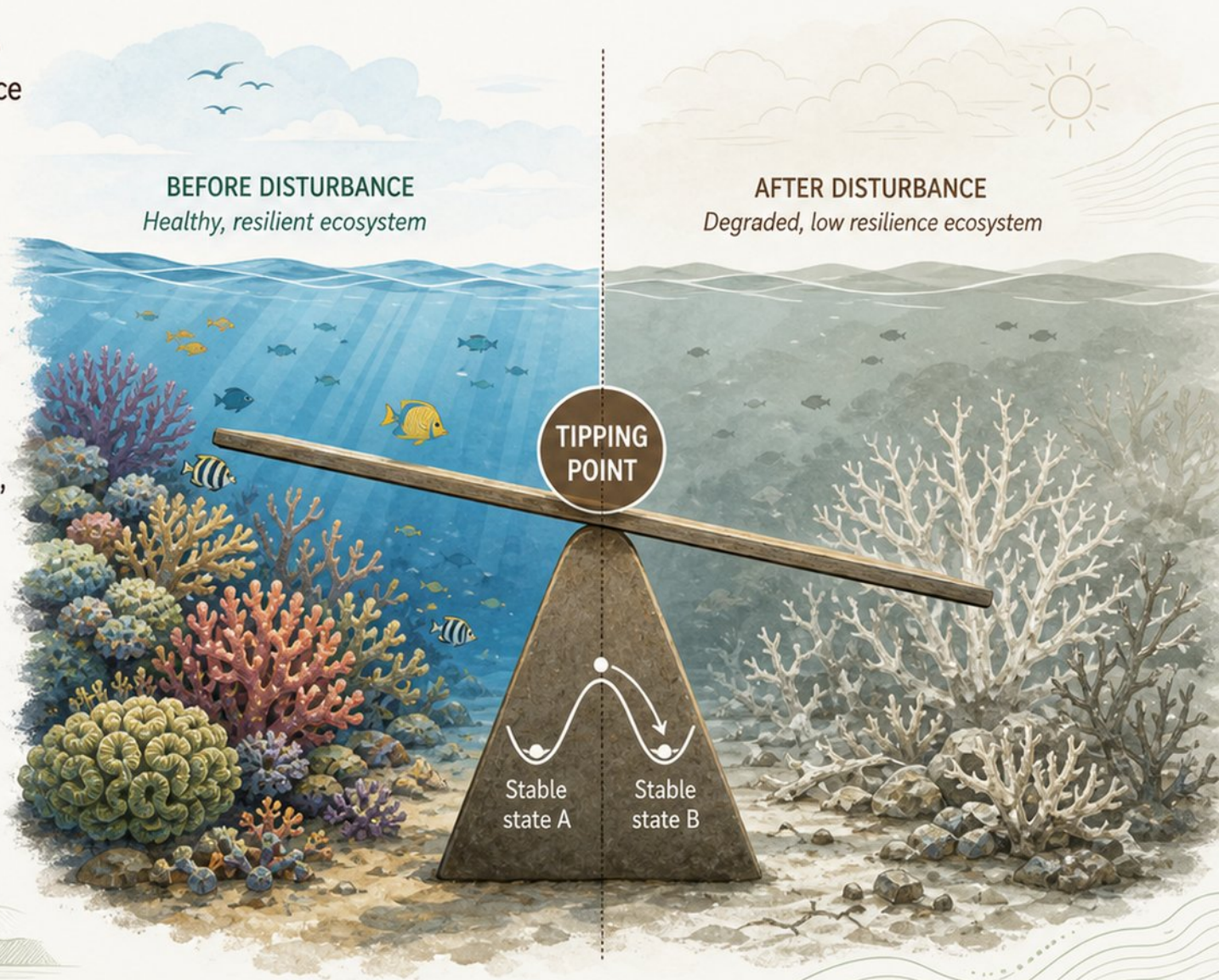
CARBON STORAGE



CULTURAL VALUE

Ecosystem Stability, Resilience, and Tipping Points

- Stability dimensions: resistance withstands disturbance, resilience enables recovery
- Temporal variability indicates lower stability
- Finnish taxa study confirms positive biodiversity-stability link
- Thresholds cause regime shifts: coral bleaching, lake eutrophication, forest dieback
- Stability debt: delayed decline after habitat loss or biodiversity erosion



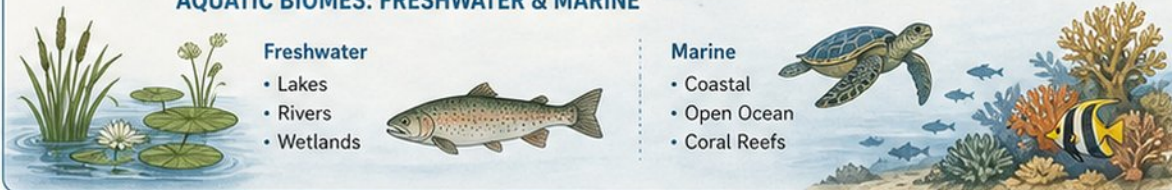
Global Biomes: Climate, Life, and Adaptations



BIOME LEGEND

Tropical Rainforest	Taiga (Boreal Forest)	Freshwater Marine } Aquatic Biomes
Savanna (Tropical Grassland)	Tundra	
Temperate Grassland	Desert	
Temperate Forest	Mediterranean Shrubland	

AQUATIC BIOMES: FRESHWATER & MARINE



- **Climate** shapes biomes via temperature and precipitation



- **Tropical rainforests:** high biodiversity, warm, wet year-round



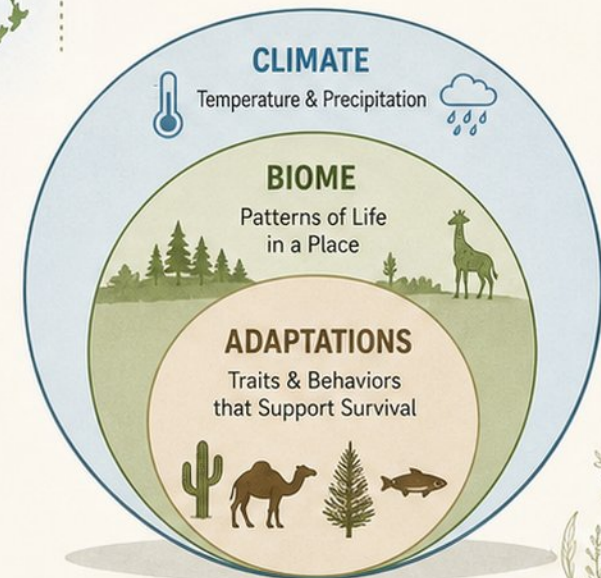
- **Deserts:** arid, extreme temps, water-storing adaptations



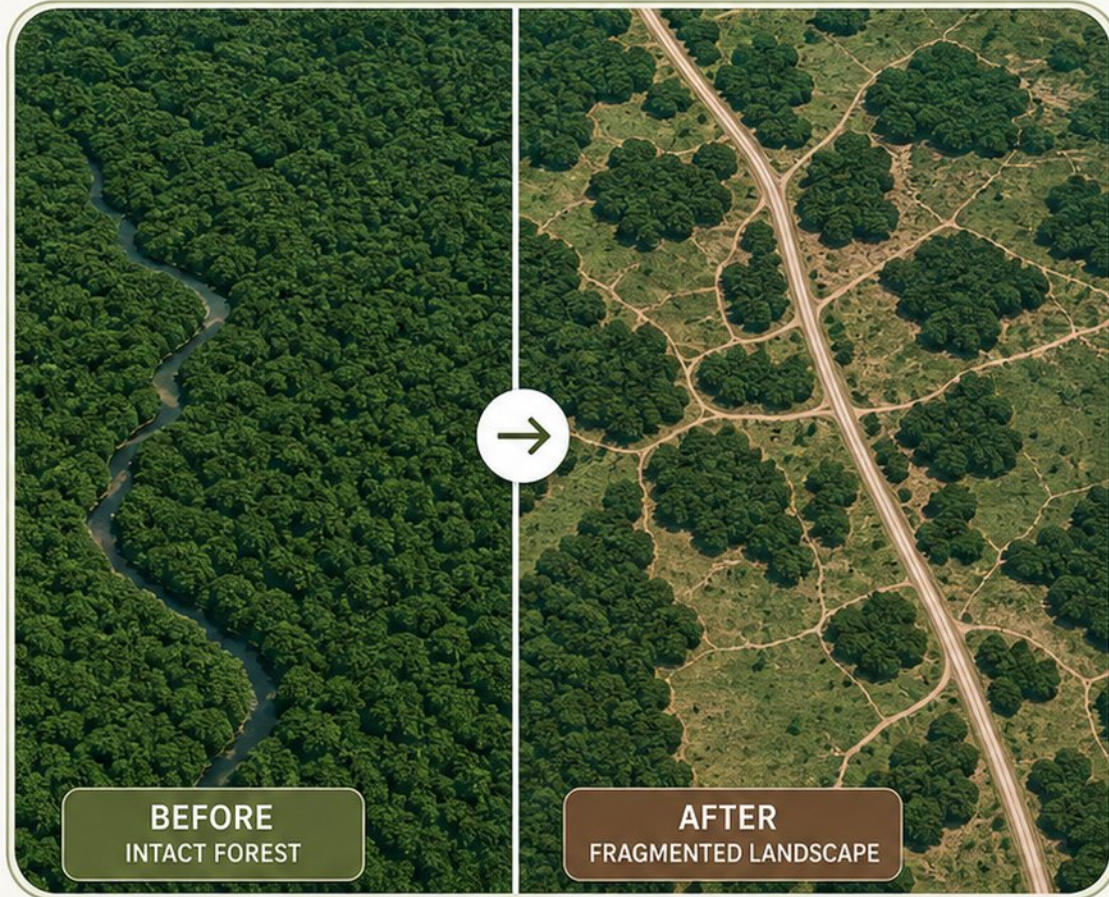
- **Taiga & tundra:** cold, permafrost, conifers, low diversity



- **Aquatic biomes** span freshwater and marine zones



Human Impacts: Habitat Loss, Fragmentation, and Degradation



- “Tropical primary forest loss hit 4.3 million ha in 2025, led by agriculture.”



- “Fragmentation shrinks habitat, amplifies edge effects, and blocks gene flow.”



- “Vertebrate populations have declined 73% on average since 1970.”



- “Ecosystem decay: biodiversity loss continues in fragments long after disturbance.”

Human Impacts:

Climate Change, Pollution, and Invasive Species



- Climate change shifts phenology, ranges, and acidifies oceans, increasing fire risks



- Pollution and toxins cascade through food webs, biomagnifying in top predators



- Invasive species harm native biodiversity via competition, predation, and novel diseases



- Multi-threat strategies are more effective than single-threat interventions



Conservation Strategies: Protected Areas, Restoration, and Sustainable Practices

Protected area networks, ecological corridors, and ecosystem restoration form evidence-based conservation strategies.



- Ecological corridors reconnect fragmented habitats, reducing operational risks and boosting resilience.



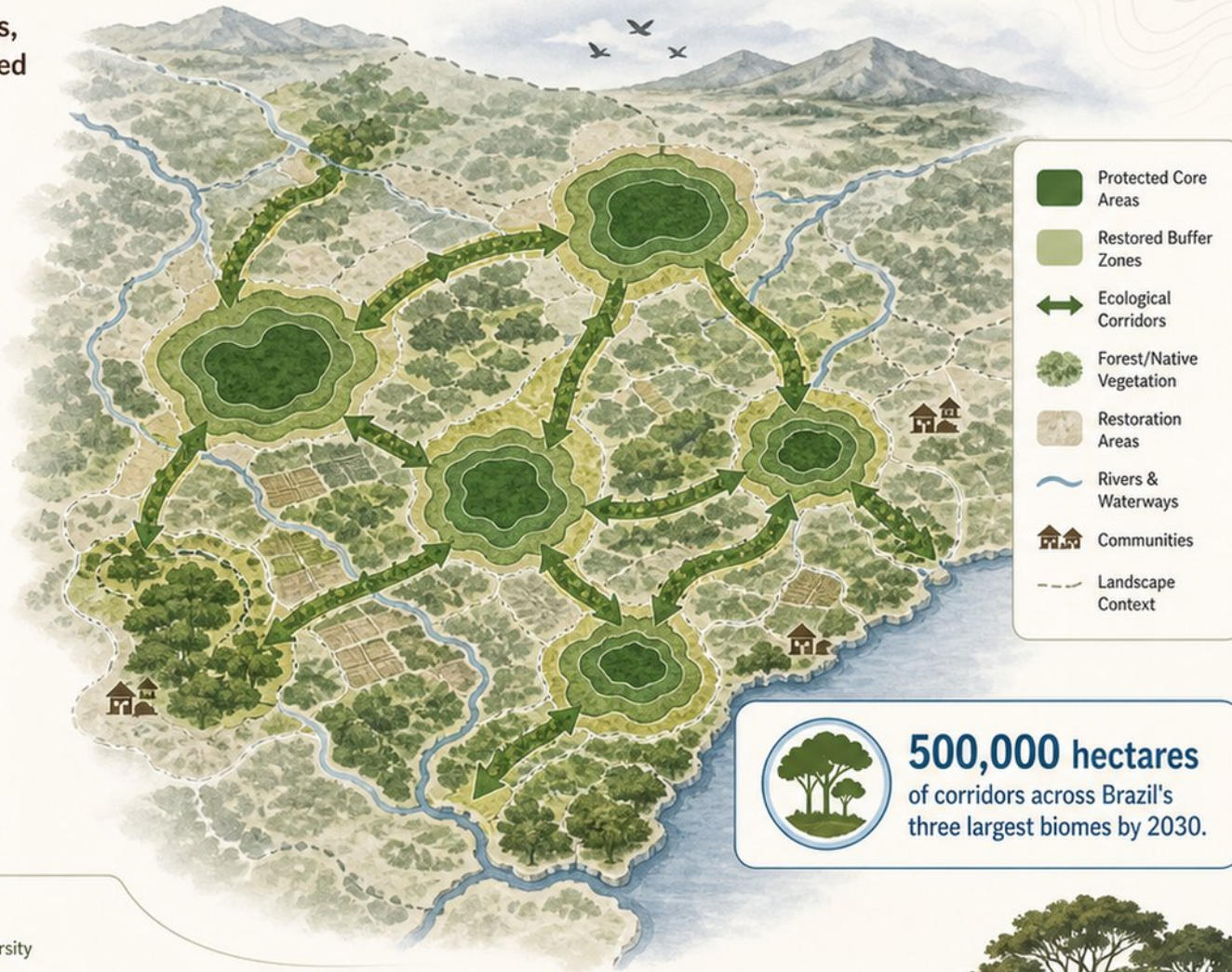
- Suzano commits to 500,000 hectares of corridors across Brazil's three largest biomes by 2030.



- Nature-based Solutions deliver carbon sequestration, flood mitigation, water quality, and biodiversity co-benefits.

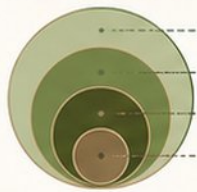


- Community-based conservation and indigenous land rights are essential for durable, long-term outcomes.



500,000 hectares
of corridors across Brazil's
three largest biomes by 2030.

NESTED SCALES: THINKING AND ACTING



- | | |
|-----------|---|
| Global | Climate stability, biodiversity |
| National | Biome-level conservation, policy alignment |
| Landscape | Protected area networks, corridors, stewardship |
| Local | Restoration, communities, sustainable practices |

Applied Ecology:

Ecosystem Services and Natural Capital in Business



- Define ecosystem services: provisioning, regulating, supporting, cultural



- Arup: £1M invested in nature-based carbon credits with biodiversity co-benefits



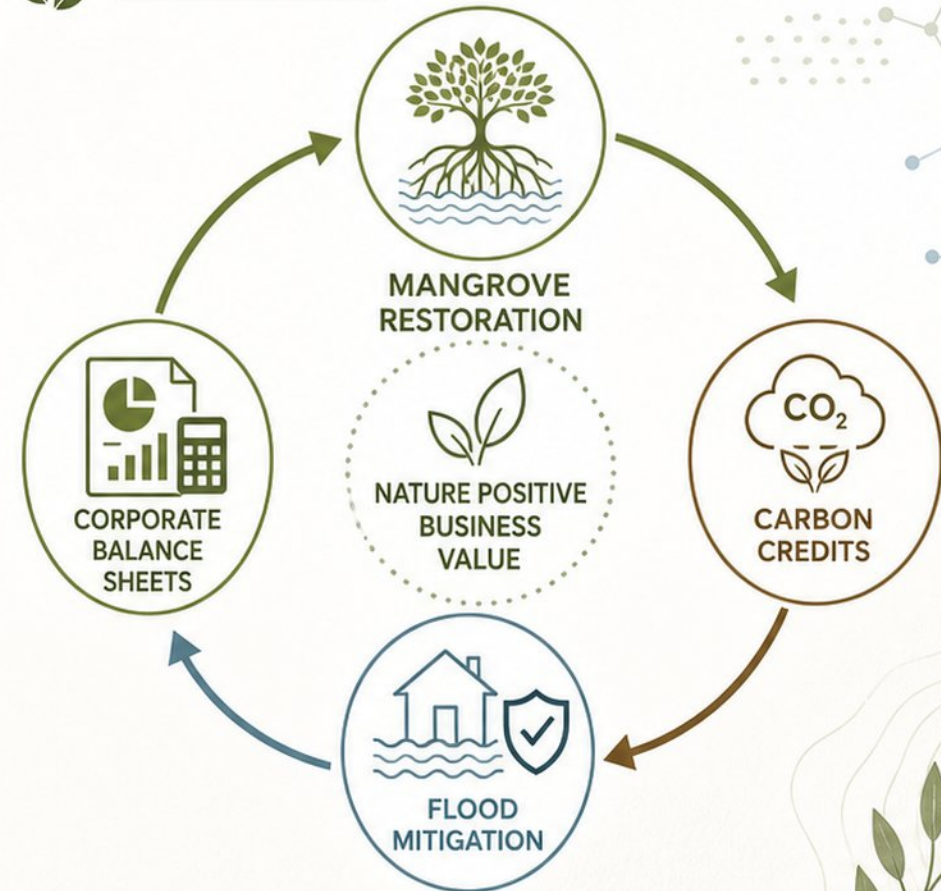
- Julius Baer: mangrove restoration partnership generating 300,000 tCO₂ removal



- Use frameworks (planetary boundaries, circular economy) to integrate ecology into strategy



- Business case: risk reduction, supply chain resilience, green finance, social license



RISK
REDUCTION



SUPPLY CHAIN
RESILIENCE

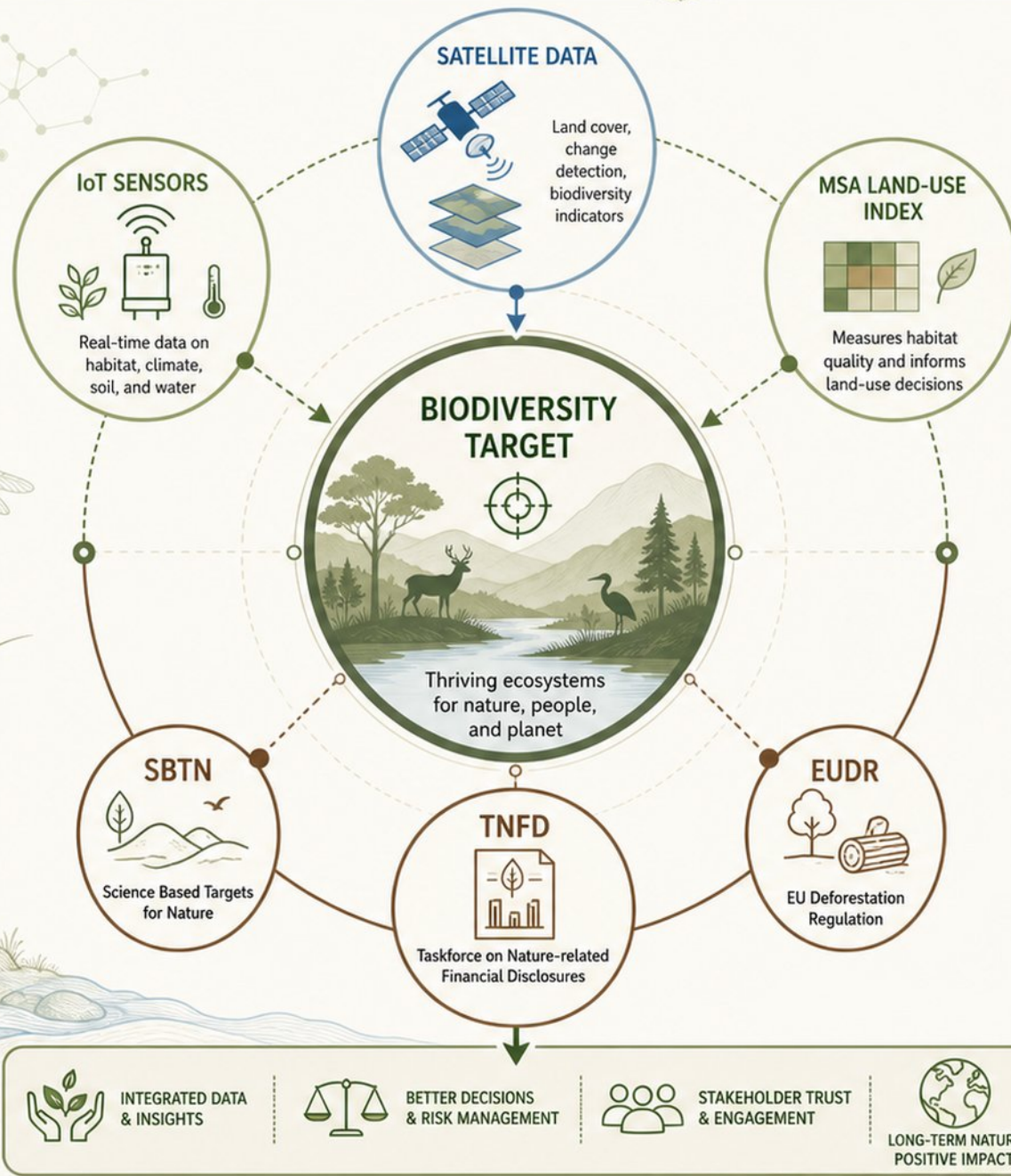


GREEN
FINANCE



SOCIAL
LICENSE

Applied Ecology: Tools, Frameworks, and Certifications



- Biodiversity monitoring with IoT sensors, satellite data, and MSA land-use index
- Key frameworks: SBTN, TNFD, and EU Deforestation Regulation (EUDR)
- High-integrity carbon credits (Verra, CCB Gold Seal) fund long-term conservation
- Robust accounting and transparency prevent greenwashing and ensure ecological integrity

Synthesis: Connecting Ecology to Personal and Organizational Action



- Energy flows, matter cycles, and populations shift in interconnected ways



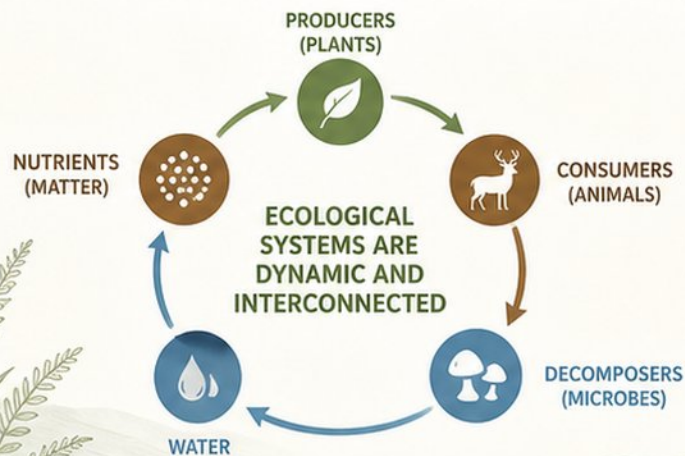
- Species interactions and biodiversity underpin resilient, stable ecosystems



- Ecological literacy strengthens risk assessment and resource decisions



- Monitor biodiversity, value ecosystem services, and set science-based targets



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