# Stability and change

D4.2 · SL and HL

# An ecosystem can persist while its organisms change

## Follow boundaries, feedback, resource balances and community change

Shared D4.2 covers stability requirements, Amazon feedback, mesocosms, keystone species, harvesting, agriculture, pollution and rewilding.

AHL: succession causes, primary development, community cycles, climax models and arrested succession.

All numerical records are invented teaching data. Named studies and conservation examples have separate source links in the handout.

# Name what persists and how it responds to disturbance

| **Property** | **Meaning and limitation** |
|---|---|
| Stability | Persistence of important properties/processes on a stated timescale |
| Resistance | Limited change during a disturbance |
| Resilience | Capacity to recover after disturbance |
| Measurement | Composition, productivity and canopy cover need not recover together |

# Deep-time evidence supports persistence without identical communities

## Use fossils carefully

Cerrejón fossils from Colombia show rainforest organization about 58 million years ago, including plant families important in modern Neotropical forest.

This supports a long history of rainforest organization. It does not establish unchanged species or uninterrupted occupancy at every location.

Tree turnover, population fluctuations and substantial material/energy flows can coexist with persistent ecosystem function.

# Connect a requirement to the process it maintains

1. **Energy.** Continuing light input replaces energy eventually dissipated as heat; it is not recycled like nutrients.
2. **Nutrients.** Decomposition returns mineral nutrients to the non-living environment for producer uptake.
3. **Response capacity.** Genetic variants and partly overlapping functions can support resilience, provided conditions remain within tolerances. More species do not guarantee resistance to every pressure.

# Population density regulation is only one part of ecosystem behaviour

## Use the logistic model within its boundary

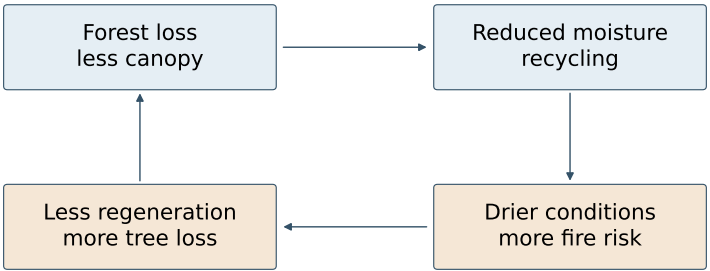
The logistic model predicts slowing growth as density-dependent constraints increase. Carrying capacity depends on the stated conditions.

A fitted curve for one population does not establish stability of the entire food web, nutrient balance or climate interactions.

Extreme or sustained change can exceed tolerances; a community can be stable under ordinary variation and vulnerable beyond it.

# Follow a reinforcing forest–moisture feedback

A reinforcing feedback, not a measured threshold




Climate, spatial pattern and other moisture sources also matter

A conceptual feedback does not supply a universal tipping threshold.

# Explain the water link and the uncertainty

1. **Water and cooling.** Transpiration returns soil water to the atmosphere; evaporation/transpiration cool surfaces. Atmospheric transport connects regions.
2. **Reinforcement.** Forest loss can reduce recycling, increase dryness/fire and hinder regeneration, promoting further loss.
3. **Boundaries.** Ocean moisture, circulation, climate and spatial pattern also matter. The minimum forest area is uncertain; transitions need not occur everywhere simultaneously.

# State the forest-area baseline before calculating loss

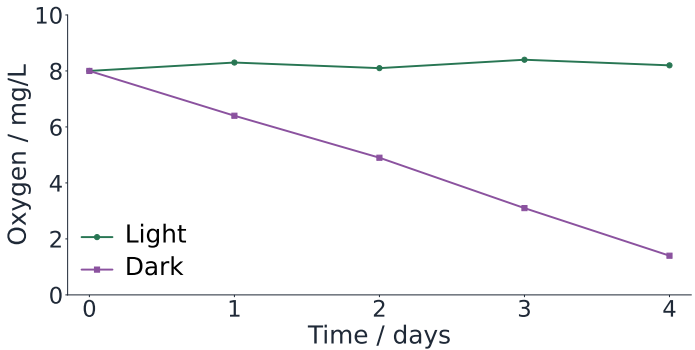
1. **First loss.** 12,000 $\rightarrow$ 9,000 square kilometres: $3{,}000/12{,}000 \times 100 = 25\%$.
2. **Second loss.** 9,000 $\rightarrow$ 8,400: $600/9{,}000 \times 100 \approx 6.67\%$ of the later start; five percentage points of original area.
3. **Total.** $3{,}600/12{,}000 \times 100 = 30\%$ lost relative to original. These invented areas do not locate an Amazon tipping point.

# Control a contained plant–microbial ecosystem comparison

1. **Boundary.** A sealed vessel can exclude matter exchange while allowing light and heat: closed, not isolated.
2. **Design.** Randomly allocate independent replicated vessels to light treatments; match water volume, starting community, nutrients, temperature and headspace.
3. **Measurement and care.** Use suitable non-disruptive observations and agreed maintenance/welfare criteria. Do not seal animals into an oxygen-depletion treatment.

# Interpret a net oxygen change before assigning a mechanism

Invented mesocosm means; uncertainty not supplied




Stable concentration can coexist with production and consumption.

# Do not turn a mean trace into a significance test

1. **Invented dark treatment.** $8.0 \rightarrow 1.4$ mg/L in four days: net fall 6.6 mg/L; mean net rate $6.6/4 = 1.65$ mg/L per day.
2. **Mechanism.** Light permits photosynthetic oxygen production; respiration can continue in darkness. Net change does not separately measure each rate.
3. **Evaluation.** Independent vessel replication matters. No uncertainty test is supplied; sensor drift or unequal biomass can confound. Short persistence does not establish indefinite stability.

# Trace the intermediate grazer rather than jumping to the endpoint

1. **Direct interaction.** Sea otters consume sea urchins in nearshore North Pacific systems.
2. **Indirect consequence.** Reduced grazing can support kelp and the habitat it provides. A keystone effect is disproportionate to abundance, not simply being most numerous.
3. **Evaluation.** Measure grazers and kelp with appropriate controls and replicated sites. Other predators, storms and temperature can alter the outcome.

# Renewable means capable of regeneration, not impossible to exhaust

## Sustainability preserves continuing capacity

Removal faster than replacement reduces a resource stock. Precautionary harvest below uncertain replacement leaves a margin for recovery and error.

Equal current replacement and harvest is a simple balance. Replacement can change with stock size, age structure, food, climate and mortality.

Catch is a removal, not a stock measure. More effort can maintain catch while abundance falls; a protective quota can reduce catch without proving stock collapse.

# Use a stated net-replacement stock model

1. **Relation.** Next stock = current stock + net replacement − harvest; other gains/losses are included in net replacement.
2. **Decline.** 1,000 tonnes; replacement 100, harvest 150 tonnes/year. Net −50/year; two years leave 900 tonnes if rates stay constant.
3. **Recovery.** From 900, replacement 120 and harvest 80 gives +40 tonnes/year; three years leave 1,020 tonnes. Constant rates are assumptions.

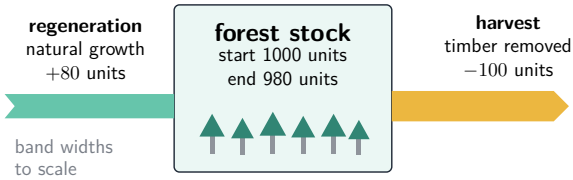
# Assess a terrestrial plant and a marine fish through recruitment

| Resource | Evidence needed |
|---|---|
| Brazil nut tree | Seeds harvested from Bertholletia excelsa; monitor seedling, juvenile and reproductive-adult replacement |
| Published comparison | Peres and colleagues: persistent intensive harvest associated with poor juvenile representation |
| Atlantic cod | Gadus morhua: spawning biomass, recruitment, age/size structure, landings and discards |
| Sampling | Research surveys help separate abundance from fishing effort; do not pool distinct stocks uncritically |

# Scale a representative quadrat estimate with consistent units

1. **Invented mean.** Four juveniles per 0.25-square-metre quadrat.
2. **Estimate.** Density $= 4/0.25 = 16$ per square metre; 100-square-metre area gives 1,600.
3. **Sampling.** Use preselected random coordinates or appropriate strata. Patchiness, replication and counting rules determine uncertainty; convenient dense patches bias extrapolation.

# Is the harvest sustainable?




$1000 + 80 - 100 = 980$ units

harvest exceeds regeneration by 20

if these flows continue, the stock falls by 20 each period

the yield is sustainable only if harvest $\leq$ regeneration

> The stock falls from 1,000 to 980

# Connect a pressure to a management mechanism

| Pressure | Process and possible response |
|---|---|
| Erosion | Physical soil loss; ground cover/contour management can reduce removal |
| Leaching | Dissolved nutrient loss; match fertilizer timing and supply to uptake |
| Agrochemicals | Non-target effects, nutrient pollution and resistance need assessment |
| Carbon footprint | Include manufacture, machinery, land-use and soil processes within a stated boundary |

# A single yield or carbon total does not settle sustainability

## Compare equal output and long-term system effects

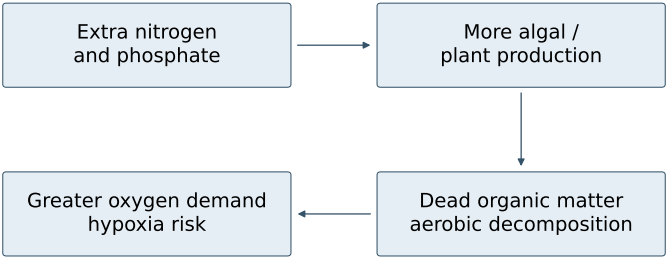
Harvest exports nutrients. Fertilizers, nitrogen fixation and organic inputs can replenish supply but have different costs and effects.

Runoff crosses the surface; leaching moves dissolved material downward. Soil, slope, rain and cultivation influence losses.

Compare equal-output footprints alongside soil condition, biodiversity, water quality and future input supply. Total emissions and emissions per kilogram answer different questions.

# Follow nutrients through production, death and decomposition

Eutrophication: connect nutrients to oxygen demand




Nutrient limitation, light and respiration affect the outcome

> Biochemical oxygen demand and dissolved oxygen are different quantities.

# Explain both an oxygen increase and a later oxygen shortage

1. **Enrichment.** Nitrogen/phosphate input can increase production where that nutrient limits growth; dense growth may shade submerged producers.
2. **Demand.** Respiration and aerobic decomposition consume oxygen, especially as organic matter dies; hypoxia can harm sensitive animals.
3. **Timing.** Photosynthesis can raise daytime oxygen. Day/night change, bloom decline, mixing and other conditions affect the record.

# A five-day oxygen-demand result is not automatically a daily rate

1. **Simplified matched tests.** Undiluted dark incubation for five days at 20 degrees Celsius; formal methods may need dilution/seed corrections.
2. **Interval differences.** $8 \rightarrow 3$ mg/L gives 5 mg/L consumed; $8 \rightarrow 6$ gives 2 mg/L. Compare same temperature, initial oxygen and duration.
3. **Management.** Reduce nutrient input through suitable fertilizer management, buffer strips or treatment. Recovery can lag because nutrients and altered interactions remain.

# Compare concentrations using equivalent tissue mass

1. **Definitions.** Bioaccumulation: build-up within an organism. Biomagnification: rising concentration between trophic levels.
2. **Invented food-chain record.** $0.02 \rightarrow 0.10 \rightarrow 0.50 \rightarrow 2.00$ mg/kg wet tissue. Ratios 5, 5, 4; overall 100.
3. **Boundary.** Not a universal tenfold rule. Compare trophic position, age, tissue and exposure. No new pollutant atoms or extra energy are created.

# Persistence and chemical form matter

## DDT/DDE and methylmercury illustrate different effects

DDT and persistent products can pass through webs. DDE is associated with eggshell thinning and reproductive impairment in susceptible birds.

Microbial conversion of mercury to methylmercury matters in aquatic systems; slow elimination and feeding can produce high tissue concentrations and neurotoxic effects.

Different chemical forms and organisms behave differently. A larger animal's greater total burden does not alone establish a higher concentration.

# Separate an observed pathway from an unsupported population claim

| Material/evidence | Mechanism and limitation |
|---|---|
| Large items | Nets/lines entangle; ingestion can obstruct or damage digestion |
| Microplastics | Commonly below 5 mm; fragments/fibres can be ingested and enter webs |
| Persistence | Slow breakdown; fragmentation is not complete mineralization |
| Communication | Striking images show possible harm, not prevalence; standardized surveys test frequency and change |

# Name the process that management aims to recover

1. **Interactions.** Reintroducing appropriate apex predators or other keystone species can restore ecological effects.
2. **Connectivity.** Reconnect habitats for dispersal/recolonization; consider invasives, disease, neighbouring uses and human–wildlife conflict.
3. **Pressures.** Reduce barriers to regeneration; set measurable goals and monitor against suitable comparisons rather than assuming immediate recovery.

# Hinewai shows context-dependent selective management

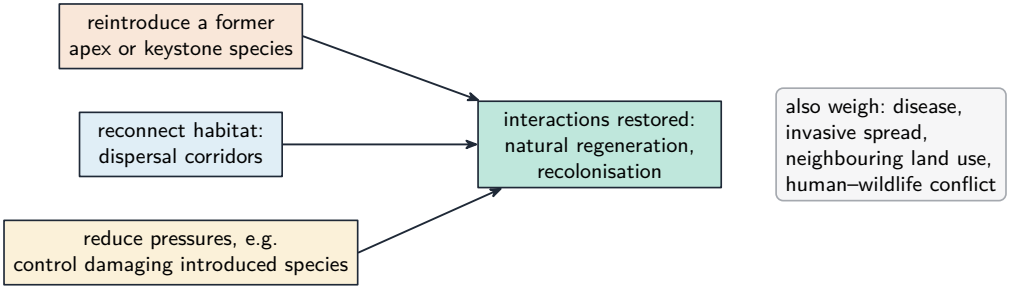
## Minimal interference is not zero management

At Hinewai Reserve on Banks Peninsula, New Zealand, managers foster natural regeneration of native vegetation.

Selected damaging introduced organisms are controlled, while introduced gorse can remain temporarily as a nurse canopy for native seedlings.

This does not justify keeping every introduced species everywhere. Evaluate native recruitment, connectivity and restored interactions over the appropriate timescale.

# Rewilding



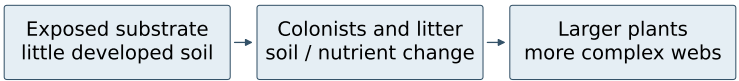

Restored interactions, with risks to weigh

# Identify the starting conditions and the driver

| Case | Distinction |
| --- | --- |
| Primary succession | New substrate with little or no developed soil |
| Secondary succession | Soil and biological legacies remain after disturbance |
| Abiotic causes | Exposed substrate, water-level change or physical disturbance |
| Biotic causes | Colonization, litter, shading, competition and altered nutrient supply |

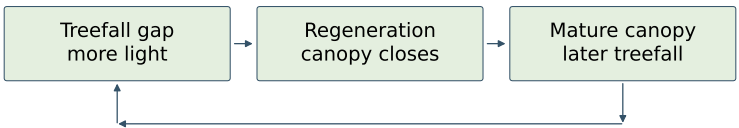
# Compare a representative sequence with a repeating patch cycle

Representative primary succession




Early trends need not continue rising indefinitely

A forest-gap cycle: soil and biological legacies remain




Community change has multiple pathways rather than one universal timetable.

# Explain early trends and their limits

1. **Development.** Tolerant colonists establish; weathering and organic inputs build soil. Alder–Frankia associations can increase nitrogen supply.
2. **Consequences.** Larger plants, greater early production/diversity, richer webs and nutrient cycling can develop. Later shade, competition and nutrient limits alter trends.
3. **Evidence.** Fastie's Glacier Bay reconstruction found multiple pathways related to context and seed arrival. Different-aged sites are not automatically one comparable chronosequence.

# A forest-gap cycle is a community cycle, not one tree's life history

1. **Opening.** Treefall in a temperate beech forest increases light and changes regeneration and ground vegetation.
2. **Closure.** Growing trees close the canopy, restoring shaded conditions; later disturbance can reopen a gap.
3. **Scale.** Different patches occupy different states while the forest persists. Duration is variable; severe disturbances can redirect the pathway.

# Explain arrested or redirected succession through its mechanism

1. **Climax model.** Relative later-successional persistence under stated environmental conditions; not a permanently fixed species list.
2. **Grazing.** Livestock remove seedlings and can maintain openness where woodland could establish. Not every natural grassland is destined to be forest.
3. **Drainage.** Lowering wetland water levels changes oxygen, decomposition and establishment. Restoring hydrology or reducing grazing permits change, but seed supply, soils and remaining pressures constrain recovery.

# Attempt the handout questions using complete causal chains

## Define a boundary, calculate a comparison and evaluate evidence

Explain feedback, controlled mesocosms, keystone effects, resource recruitment, agricultural costs, oxygen demand, pollution and rewilding.

Practice stock: 1,200 tonnes, replacement 90 and harvest 130 tonnes yearly. Quadrat: six juveniles per 0.50 square metre across 200 square metres.

AHL: distinguish succession causes, primary development, patch cycles and grazing/drainage that arrest or redirect change.

# Check the shared numerical results

1. **Stock.** Net $90 - 130 = -40$ tonnes/year; three years: $1{,}200 - 120 = 1{,}080$ tonnes if rates remain constant.
2. **Sampling.** $6/0.50 = 12$ per square metre; $12 \times 200 = 2{,}400$ estimated juveniles, conditional on representative sampling.
3. **BOD.** $9 \to 4$ and $9 \to 7$ give 5 and 2 mg/L over the defined five-day test. They are not automatically daily rates.

# Check yourself

## Name the measured property, timescale and denominator

Keep energy flow distinct from nutrient recycling, catch from stock, and oxygen demand from oxygen concentration.

Trace each indirect interaction and distinguish a model prediction from a uniquely established cause. State the percentage baseline.

AHL: organisms alter their conditions; conditions alter the community. Separate a primary sequence, a patch cycle and management that prevents a later state.