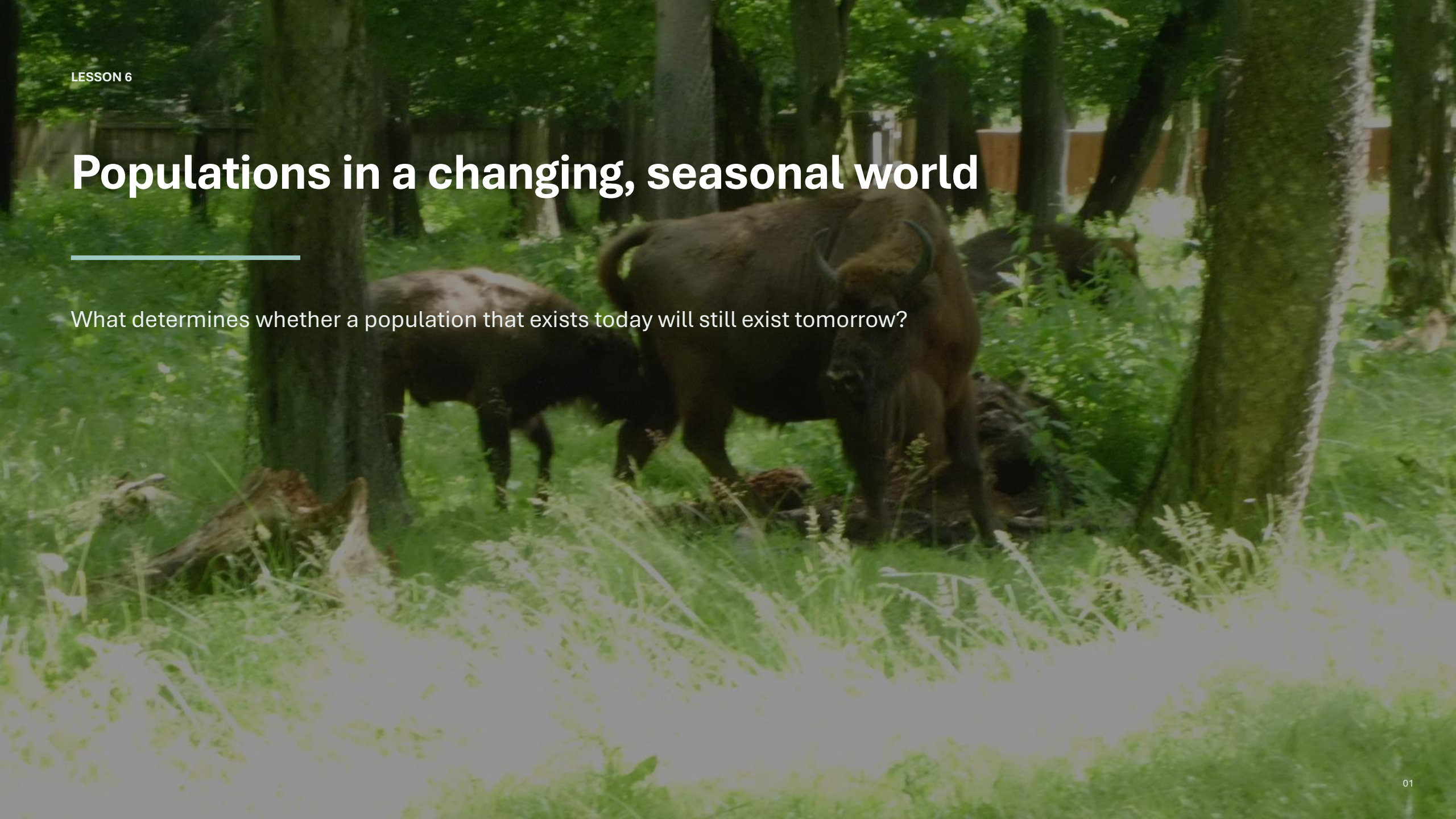


LESSON 6

Populations in a changing, seasonal world

What determines whether a population that exists today will still exist tomorrow?

From conservation choices to biological feasibility

The previous lessons defined the decision; today asks if the target can persist.

1. **What are we conserving?**
   objective
2. **What dimension matters?**
   biodiversity · function · benefit
3. **Compared with what?**
   baseline · reference
4. **What drives change?**
   pressure · mechanism
5. **Who gains or loses?**
   values · equity

LESSON 6

Even if we know what we want to conserve...

can the population actually persist?

New question today: biological feasibility.

Population growth is built from rates, not just counts



Core question: through which process does the pressure change the population?

Caswell 2001.

LESSON 6 · 4

Density dependence: individuals change as density changes

When many individuals share limited resources, vital rates can shift.



growth slows

smaller or slower-growing individuals

maturity shifts

later or smaller at maturity

fecundity changes

fewer offspring or more variable reproduction

mortality rises

higher risk when food, space or sites are limited

recruitment changes

fewer young enter the counted population

This is why “how many are there?” is less useful than “what are the rates doing?”

Individual condition is not population condition

A population can decline even if the surviving adults look “fine”.

DEMOGRAPHIC BOTTLENECK

Recruitment failure

Fewer young survive long enough to enter the adult population.



APPARENT PARADOX

Surviving adults may grow larger

If there are fewer individuals, competition among remaining adults can decrease.



“There are 300 individuals left.”

Is that enough to call the population viable?

300

individuals

Growing	Stable	Declining
+4% yr^{-1}	~0% yr^{-1}	−8% yr^{-1}

Same N. Different futures.

A census is a snapshot. Viability is a probability about the future.

Same population size, very different risk

What else do we need to know besides N?

Population A



- many juveniles
- high recruitment
- 3 connected sites
- increasing trend

lower risk?

Population B



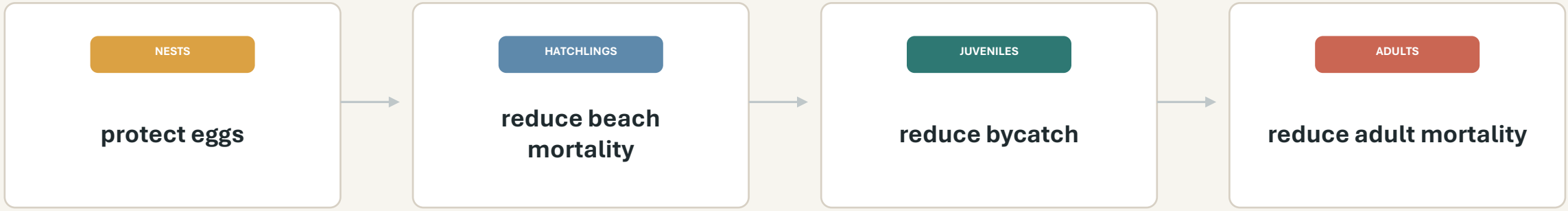
- mostly older adults
- almost no recruitment
- 1 isolated site
- declining trend

higher risk?

Case 1 — Loggerhead turtles: where would you spend the money?

The most visible mortality is not necessarily the strongest demographic lever.

You have €1 million to improve one stage.



Crouse et al. showed that improving egg survival was not necessarily the strongest lever;

later juvenile survival could matter much more for population growth.

Crouse, Crowder & Caswell 1987, Ecology.

Chance matters more when populations are small

The same kind of random event has a much larger proportional effect at low N.

LARGE POPULATION

N = 10,000

100 individuals fail to reproduce by chance

≈ 1% small proportional effect

SMALL POPULATION

N = 10

3 individuals fail to reproduce by chance

30% large proportional effect

Demographic stochasticity = random variation among individuals in survival and reproduction.

Lande 1993. Numbers are illustrative.

When rarity itself becomes a problem

At very low density, being rare can reduce population growth.

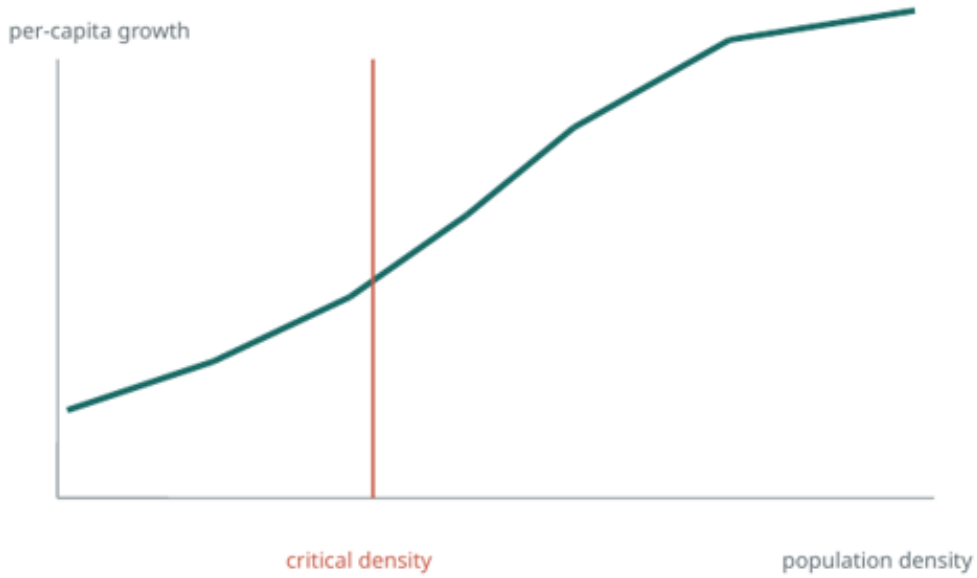
SIMPLE EXAMPLE

Can they still find a mate?

If individuals are very sparse, reproduction can fail even after the original pressure is removed.



STRONG ALLEE EFFECT

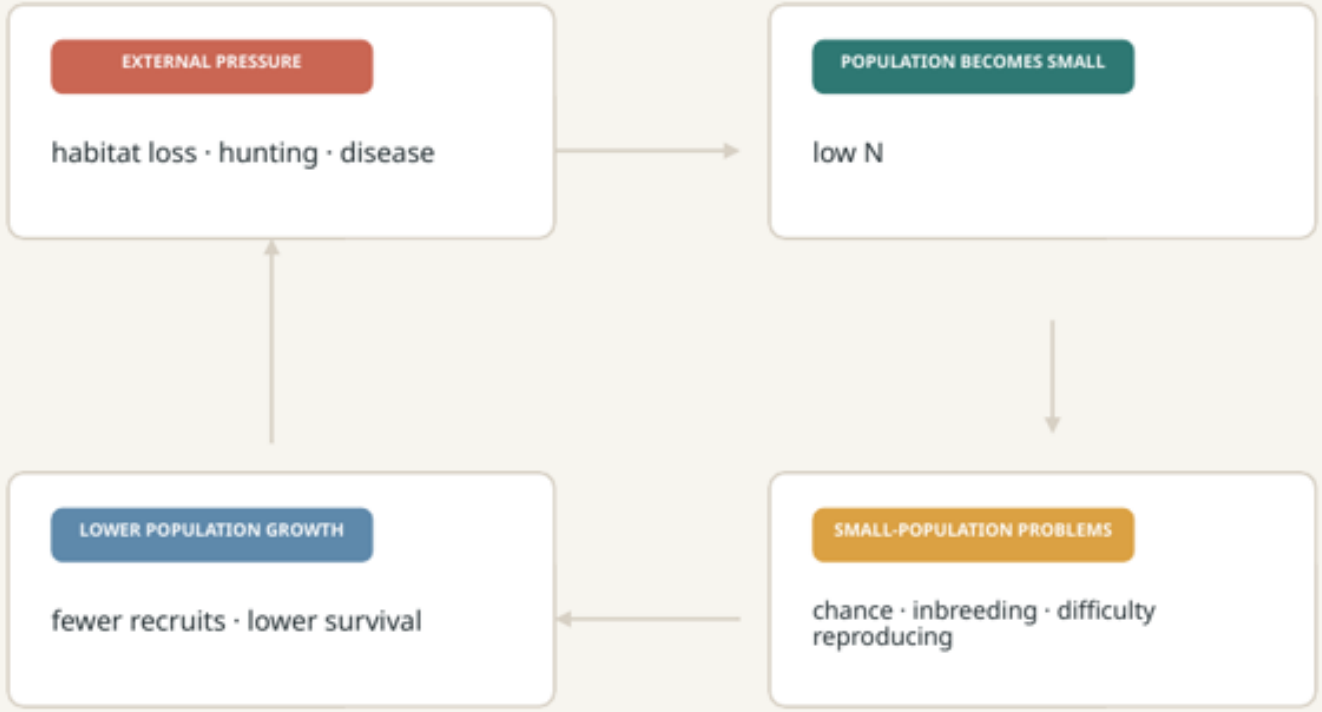


Below the threshold, growth is negative.

Courchamp, Clutton-Brock & Grenfell 1999. Graph conceptual.

Extinction vortex: a vicious circle

Small-population effects can accelerate decline, but they are usually not the original cause.



Key teaching point

The vortex is a feedback. Something usually pushes the population down first.

If habitat loss caused the decline, managing genetics alone will not solve continuing habitat loss.

Why there is no single safe population size

Different numbers answer different questions.

N

census size

How many individuals are counted?

Ne

effective population size

How fast do drift or inbreeding occur?

MVP

viability estimate

What population size gives a chosen persistence probability?

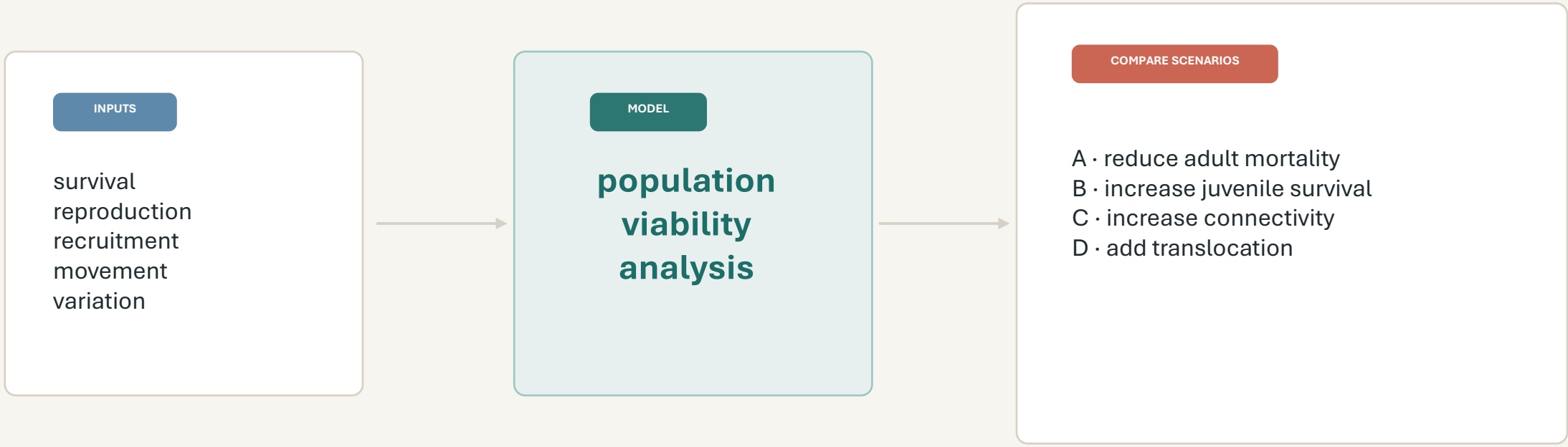
If a population contains 600 individuals, can we say it is safe?

No, not without trend, demography, Ne, environment, time horizon and acceptable risk.

Shaffer 1981; Franklin 1980; Frankham et al. 2014; Flather et al. 2011.

PVA is a structured “what if?”, not a prophecy

Population viability analysis



The result is conditional on the assumptions.

Under climate change, past rates may not remain valid which is exactly why assumptions must be explicit.

Brook et al. 2000; Coulson et al. 2001; Morris & Doak 2002.

Italian case — Trentino bears: biological success, social challenge

Reintroduction can restore numbers, but persistence also requires coexistence.

1990s

Alpine bear population near extinction
only a few animals remained

1999–2002

10 bears translocated from Slovenia to Trentino

afterwards

population recovered and expanded

today

coexistence, safety and management conflict remain

Question for conservation:

What did reintroduction solve biologically? What did it not solve socially or politically?

Link to Lesson 5:

ecological effectiveness ≠ social legitimacy.

LIFE Ursus / EU LIFE; Tosi et al. 2015; Berti et al. 2025. Numbers shown at lecture scale, not full demographic analysis.

Climate change is also changing the calendar

Organisms do not experience an annual mean; they experience seasons.

Mean

average conditions

Amplitude

strength of seasonal contrast

Timing

when events occur

Predictability

how reliable seasons are



A food peak, flood pulse, snowmelt or bloom can shift even if the annual mean looks similar.

Hernández-Carrasco et al. 2025, Science, “Ecological and evolutionary consequences of changing seasonality”.

Two ways changing seasons affect populations

A seasonal change can alter the conditions organisms experience or the cues they use.

PATHWAY 1

Experienced environment

seasonal water / temperature / food

↓

physiology and energy balance

↓

survival · reproduction · recruitment

PATHWAY 2

Synchronization

environmental cue

↓

migration · breeding · emergence

↓

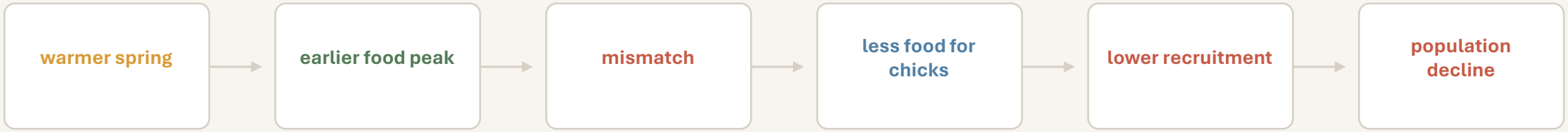
matched timing — or mismatch

This is the bridge from population growth to climate change.

Hernández-Carrasco et al. 2025, Science.

Case 3 — Phenological mismatch can become demographic decline

Climate can act through ecological interactions, not only direct physiological stress.



Dutch pied flycatcher populations with the strongest mismatch declined by about 90% over two decades.

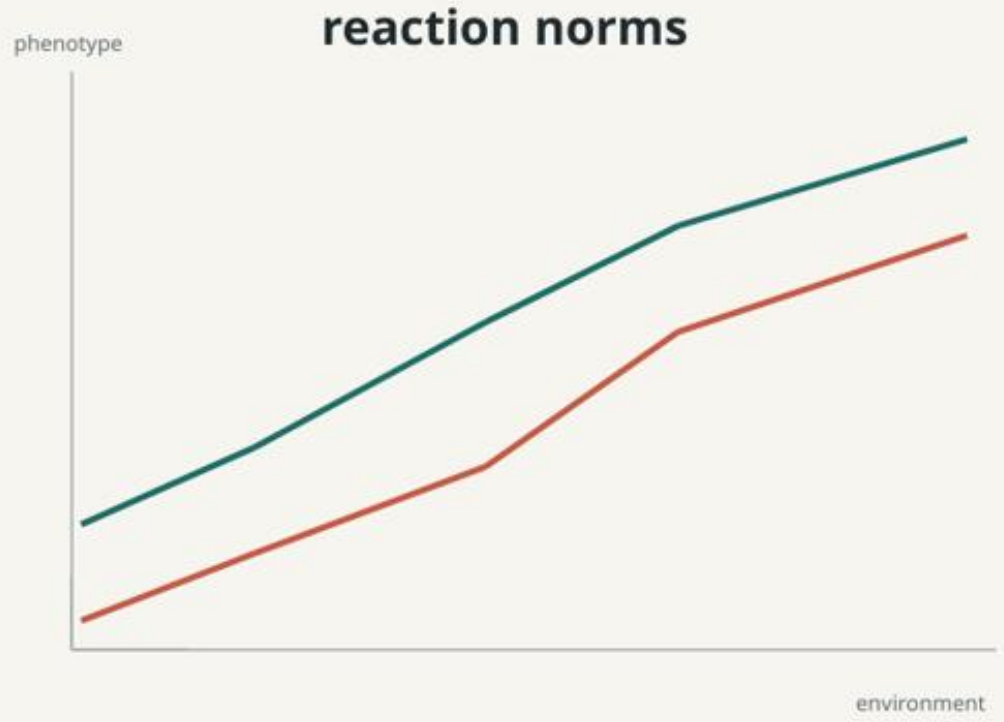
The mechanism is not “temperature → decline” but timing → food availability for chicks → recruitment → population trend.

Ask: where in this chain could management realistically intervene?

Both et al. 2006, Nature; Hernández-Carrasco et al. 2025.

Observed phenotypic change is not automatically evolution

A familiar evidence rule: observation is not the same as mechanism.



Birds breed earlier in warmer springs.

Possible explanations:

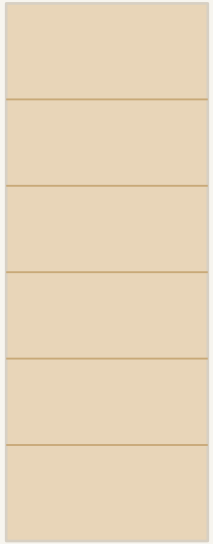
- phenotypic plasticity
- genetic evolution
- both processes
- confounding or sampling

Do not call every phenotypic shift “adaptation”.

Merilä & Hendry 2014; reaction-norm concept.

Can evolution be fast enough? Daphnia says: sometimes

Dormant eggs allow past genotypes to be tested under common conditions.



Evidence of rapid evolutionary response does not mean rescue is guaranteed.

Evolutionary rescue is a race: adaptive evolution must improve population growth before the population crashes.

More likely when heritable variation exists, generation time is short, selection is strong enough, and change is not too fast.



Geerts et al. 2015, Nature Climate Change; Bell 2017. Diagram conceptual.

If populations cannot persist in place, can they move or find refugia?

Movement and buffered microclimates are the bridge to fragmentation and connectivity.

Range shifts show tracking, but not every species can keep pace.

Observed median terrestrial shifts

≈ 16.9 km / decade poleward

≈ 11.0 m / decade upslope

Tracking can fail because of...

dispersal limits · fragmentation · missing habitat · missing mutualists · novel competitors



CLIMATE REFUGIA

Persistence without moving far

Next lesson: if persistence requires movement, connectivity becomes a conservation process.

Chen et al. 2011, Science; Morelli et al. 2016; Isaak et al. 2016. Photo: real course asset.

Return to the 300 individuals

Now build the answer yourselves.

300

individuals left

- trend
- age / stage structure
- survival and reproduction
- recruitment
- spatial distribution
- environmental variability
- Ne / genetic information
- density / Allee effects
- future seasonality
- capacity to tolerate, adapt or move
- time horizon and acceptable risk

Three messages to carry forward

Population biology constrains what conservation choices are biologically achievable.

1. **Population size alone does not tell us viability.**

2. **Viability depends on demography, chance, genetics, density and space.**

3. **Under climate change, timing and seasonality can change survival, recruitment and synchronization.**

Selected references: Caughley 1994; Lande 1993; Crouse et al. 1987; Shaffer 1981; Frankham et al. 2014; Both et al. 2006; Hernández-Carrasco et al. 2025; Chen et al. 2011; Morelli et al. 2016.