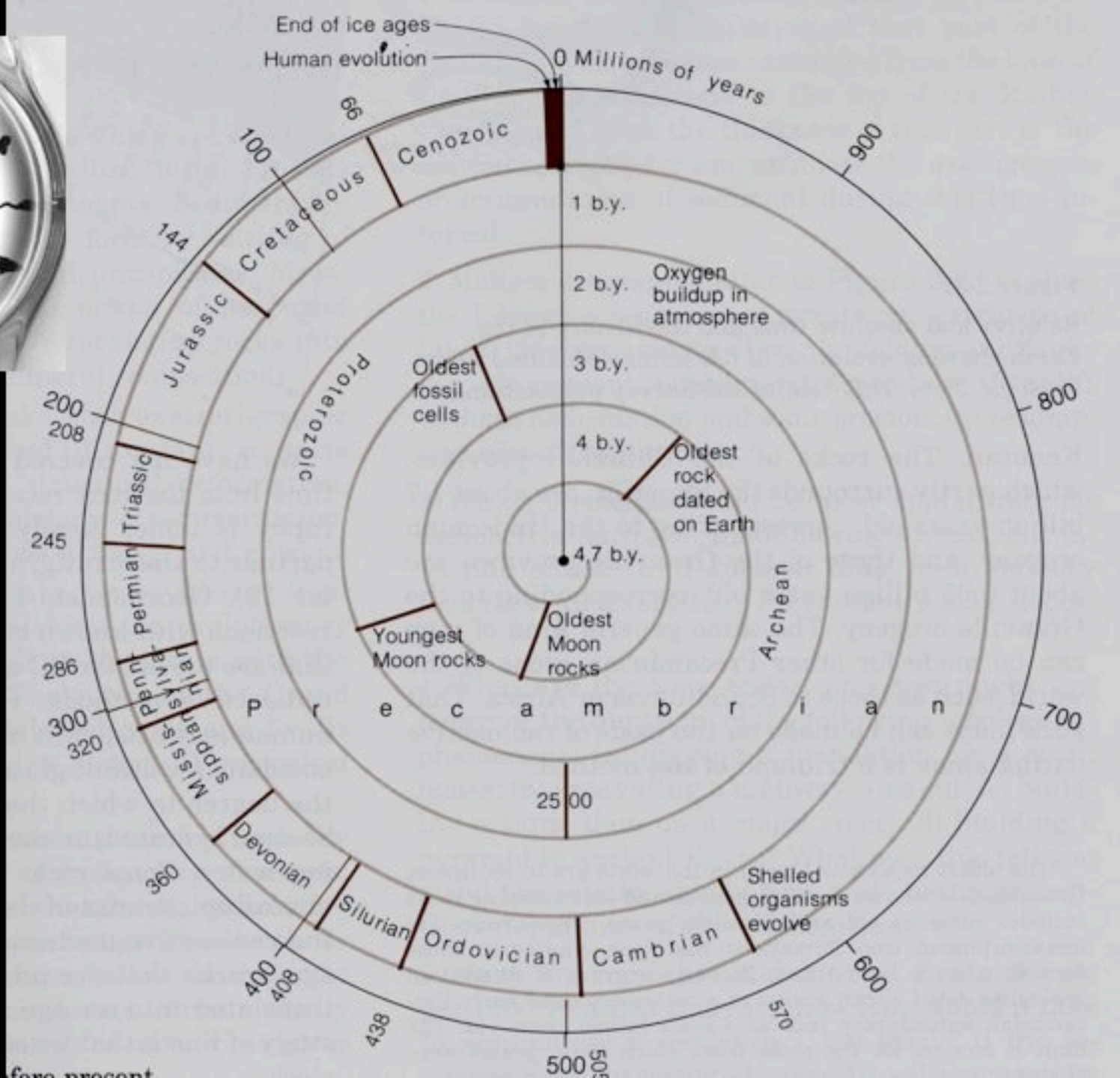
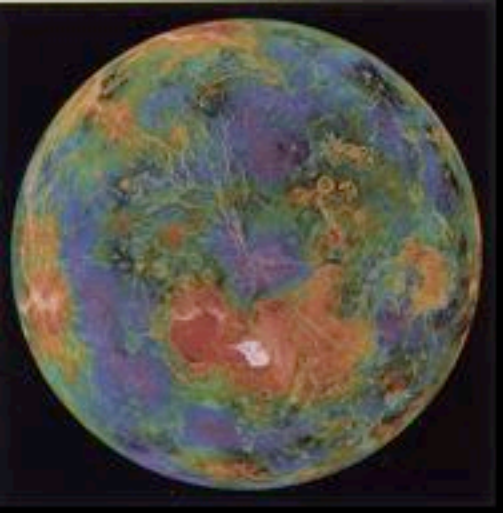
Biodiversity and Climate Change: Lessons from Swiss Clocks

Brian Moss
University of Liverpool, UK



fore present



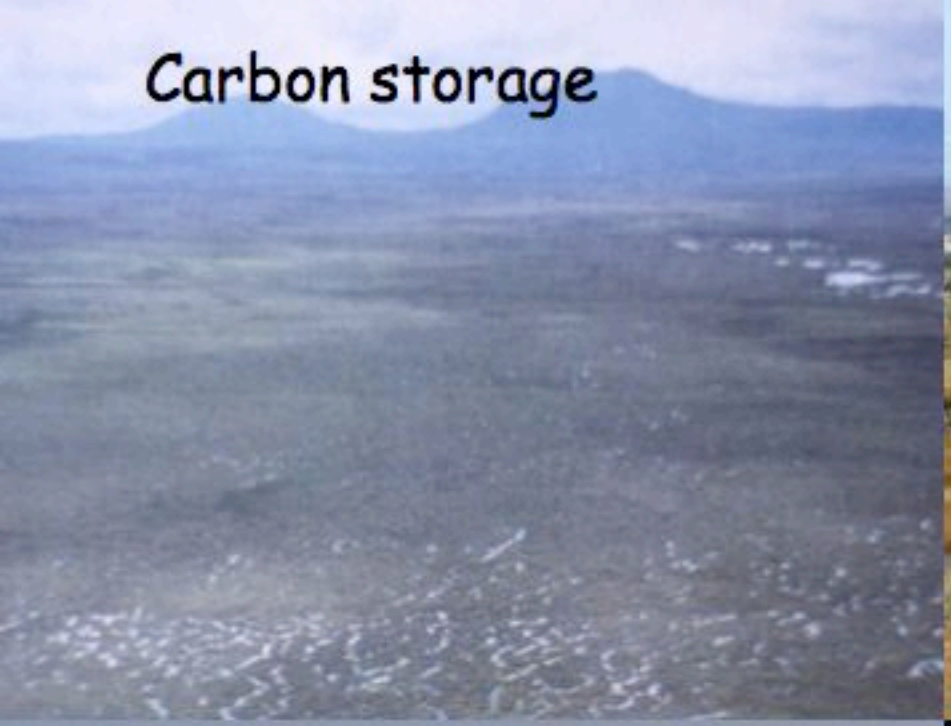
Old view: physics and chemistry of the Earth determine its nature at the surface; biosphere follows as a consequence

Modern view:living organisms use the raw materials of physics and chemistry to maintain the nature of the surface in an equable state for life

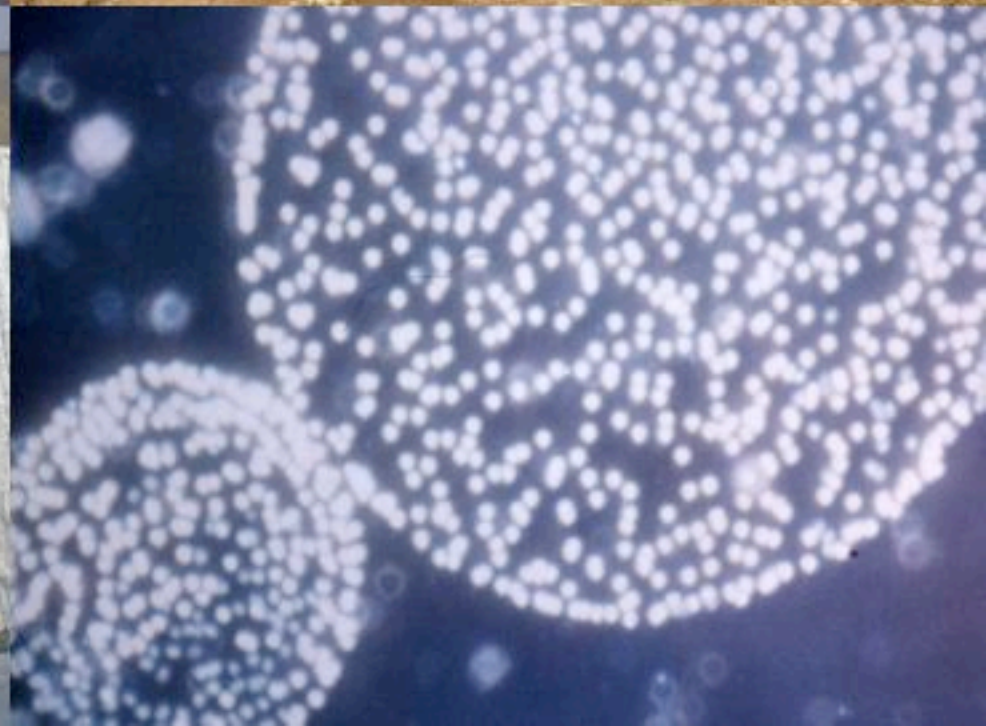
Atmospheric composition of planets

	Venus	Equilibrium Earth	Mars	Earth as it is
Carbon dioxide(%)	98	98	95	0.03
Nitrogen (%)	1.9	1.9	2.7	79
Oxygen (%)	Trace	Trace	0.13	21
Argon (%)	0.1	0.1	2	1
Surface temperature (C)	477	290	-53	13
Total pressure (bars)	90	60	0.0064	1


Photosynthesis
$6CO_2 + 6H_2O \longleftrightarrow C_6H_{12}O_6 + 6O_2$
Respiration


Carbon storage


Oxygen regulation



- Life has established and maintained: non-equilibrium, high O_2, low CO_2 state, within relatively narrow limits, despite major impacts of volcanic activity, plate tectonics, meteor collisions and the innovations that living organisms themselves have made, e.g colonisation of the land

- This has involved a continually changing cast of probably up to at least 2 or 3 million species, maybe ten times as many, at any one time

Species richness (biodiversity) is:

- often underestimated
- much higher than you think
- driven by natural selection in exploiting opportunities, coping with change, & minimising competition for resources among species

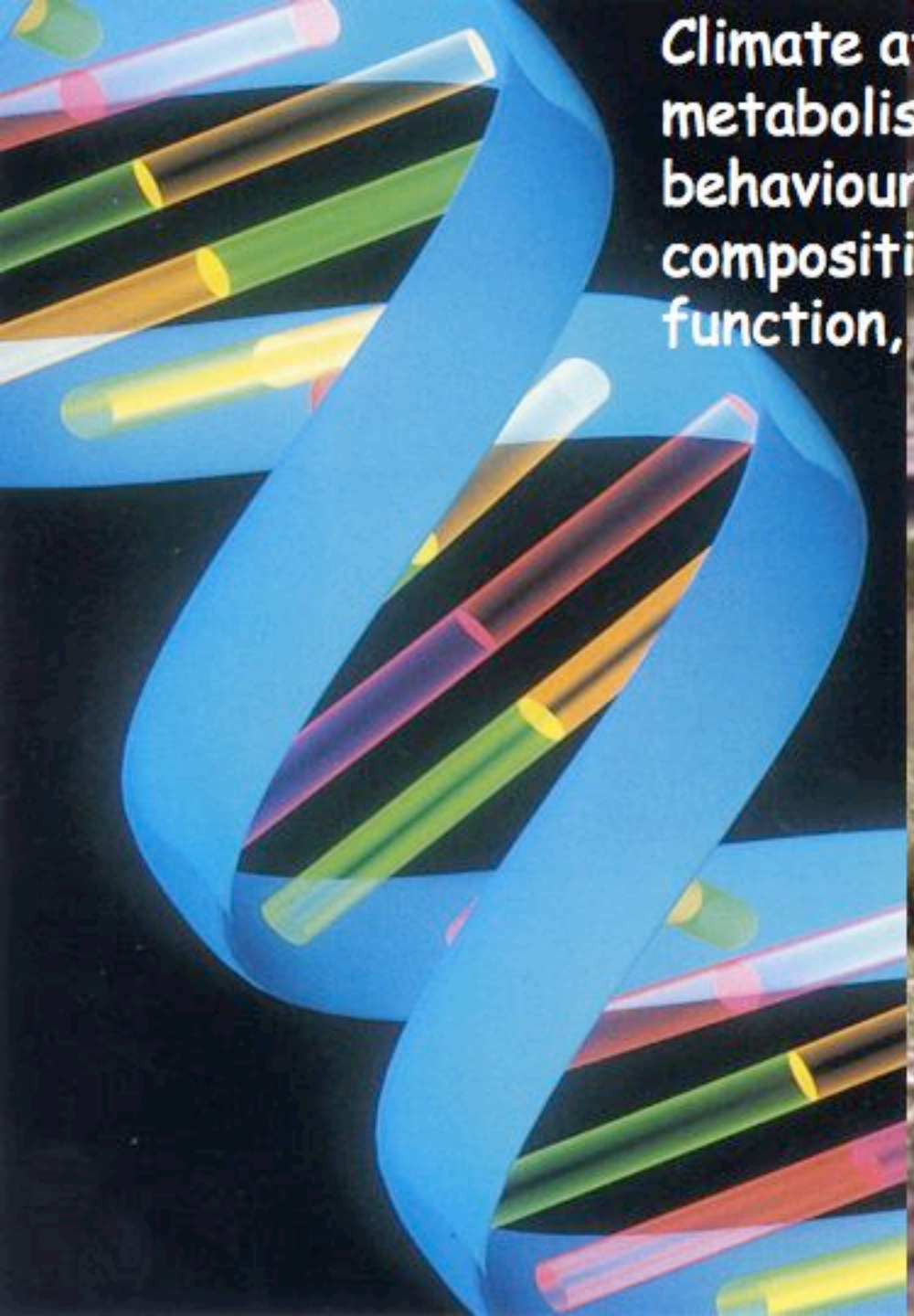
- And by subsequent species sorting

- Selection & sorting are:
- powerful,
- continuous
- ruthless

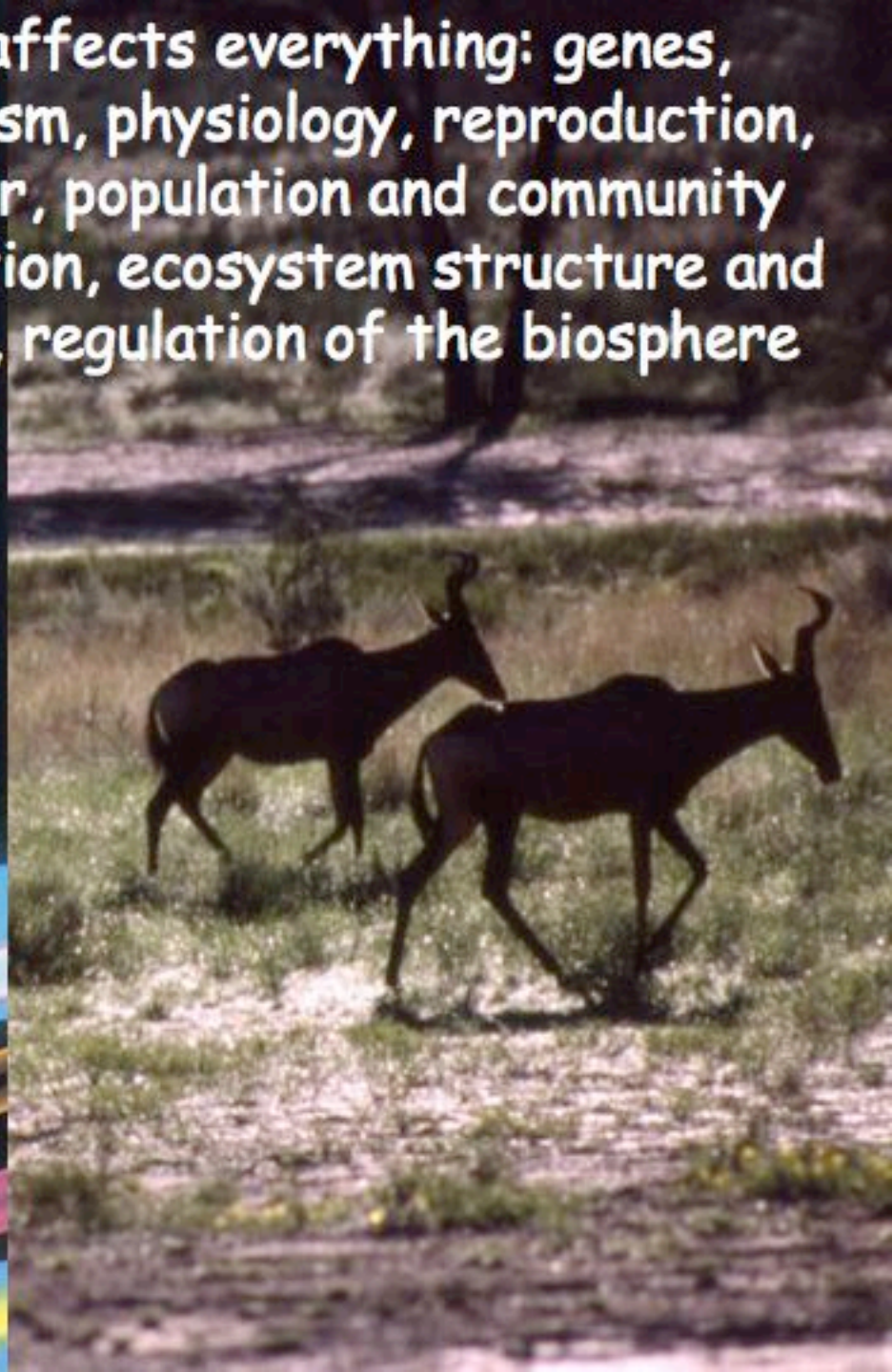
- High species richness therefore has significance.
- There is likely to be little redundancy
- Loss of some species may be accommodated in the short term
- But has consequences in the long term for resilience & ability to accommodate change

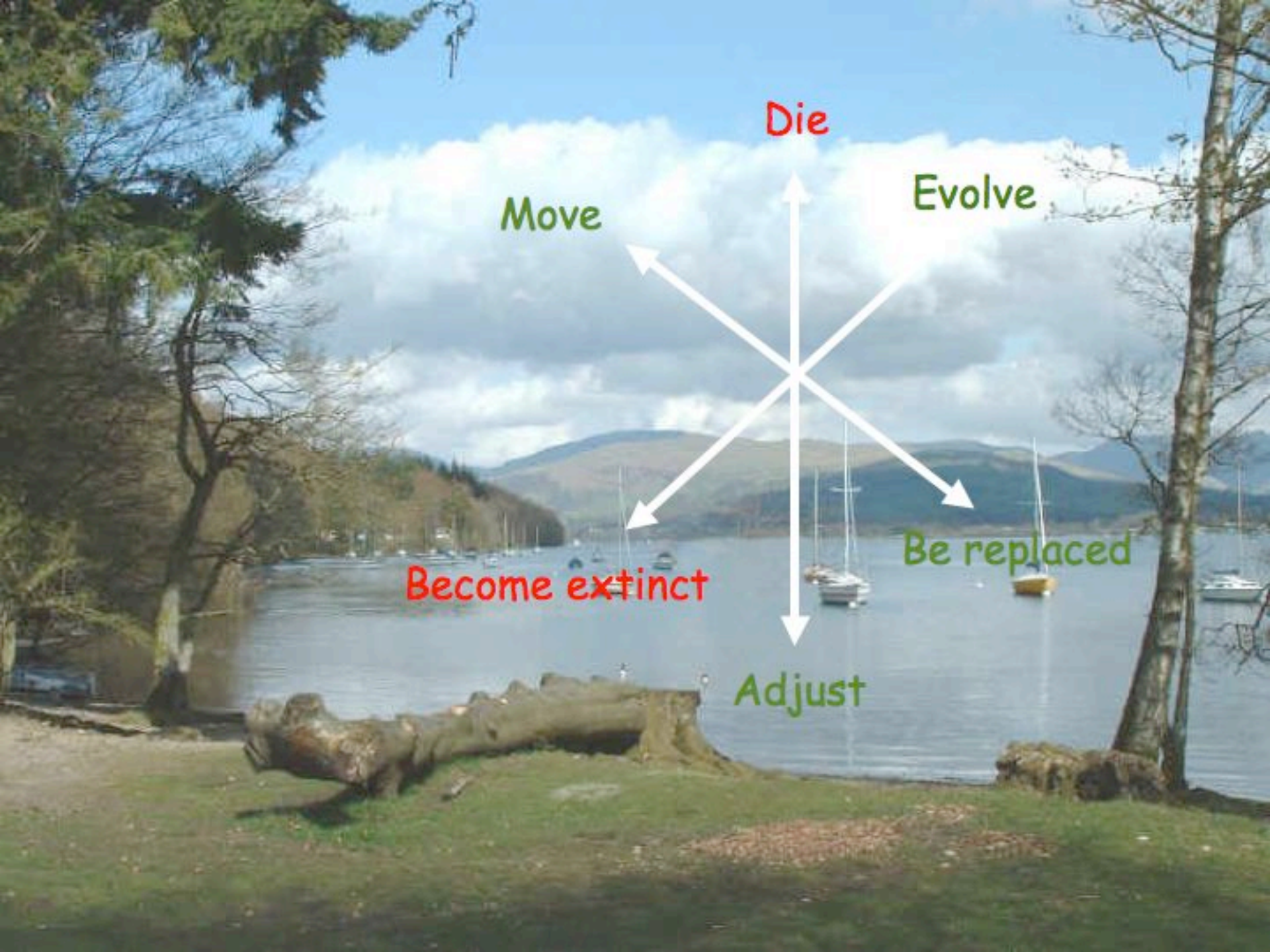
Aldo Leopold: forester,farmer, administrator & Professor of Wildlife Management (University of Wisconsin)

- *If the biota, in the course of aeons has built something that we like but do not understand, then who but a fool would discard seemingly useless parts? To keep every cog and wheel is the first principle of intelligent tinkering.* 1938

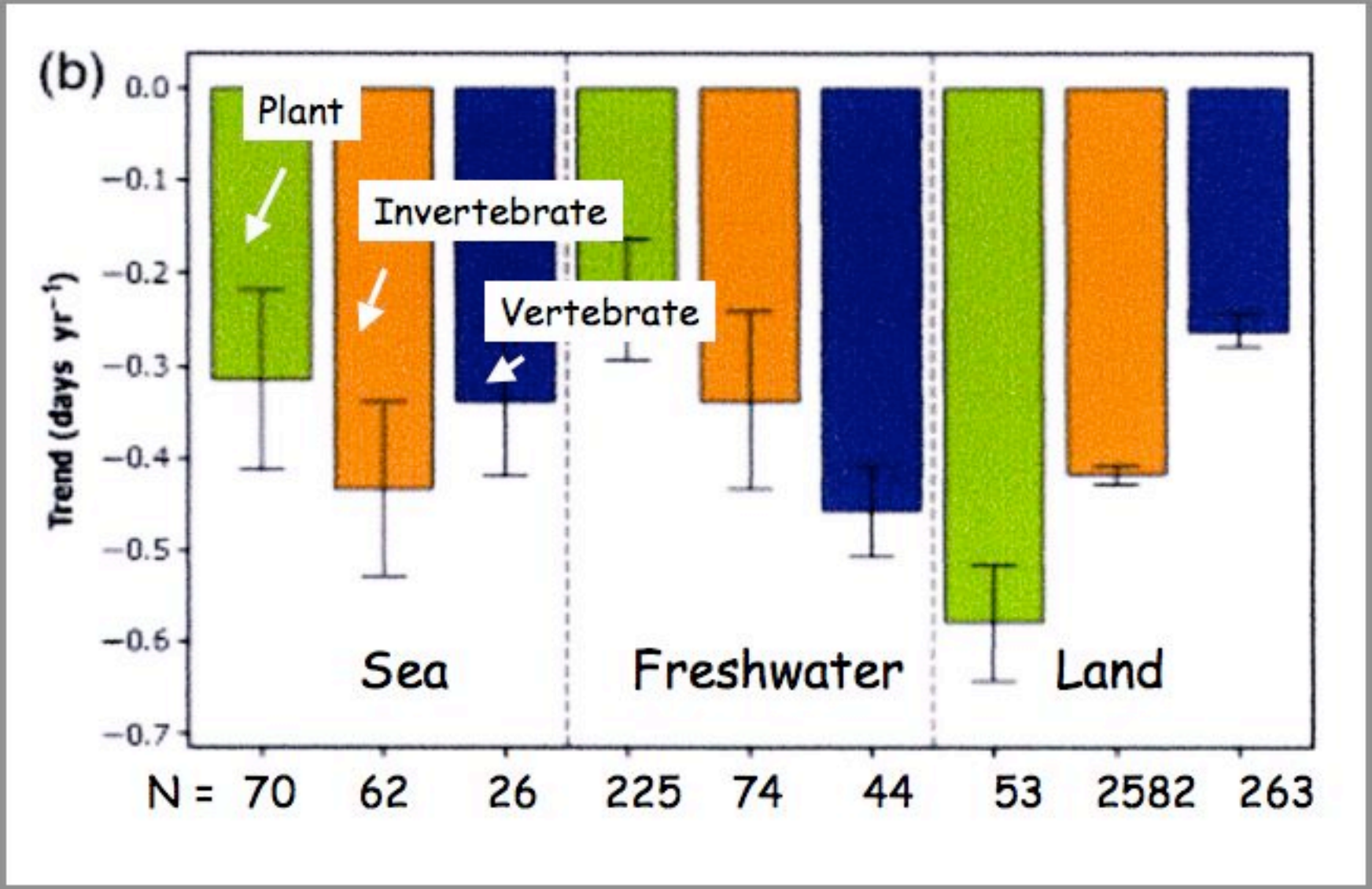


Climate affects everything: genes, metabolism, physiology, reproduction, behaviour, population and community composition, ecosystem structure and function, regulation of the biosphere

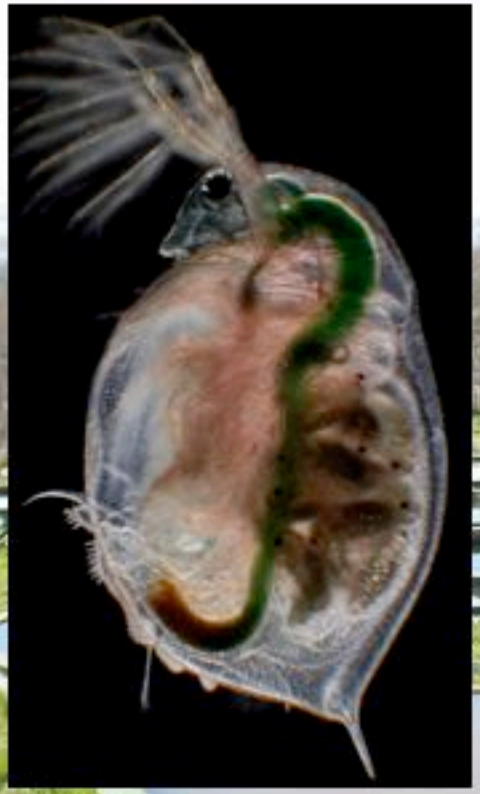



Die
Evolve
Move
Be replaced
Become extinct
Adjust

Change in phenology (days earlier per year) of UK organisms, 1976-2005

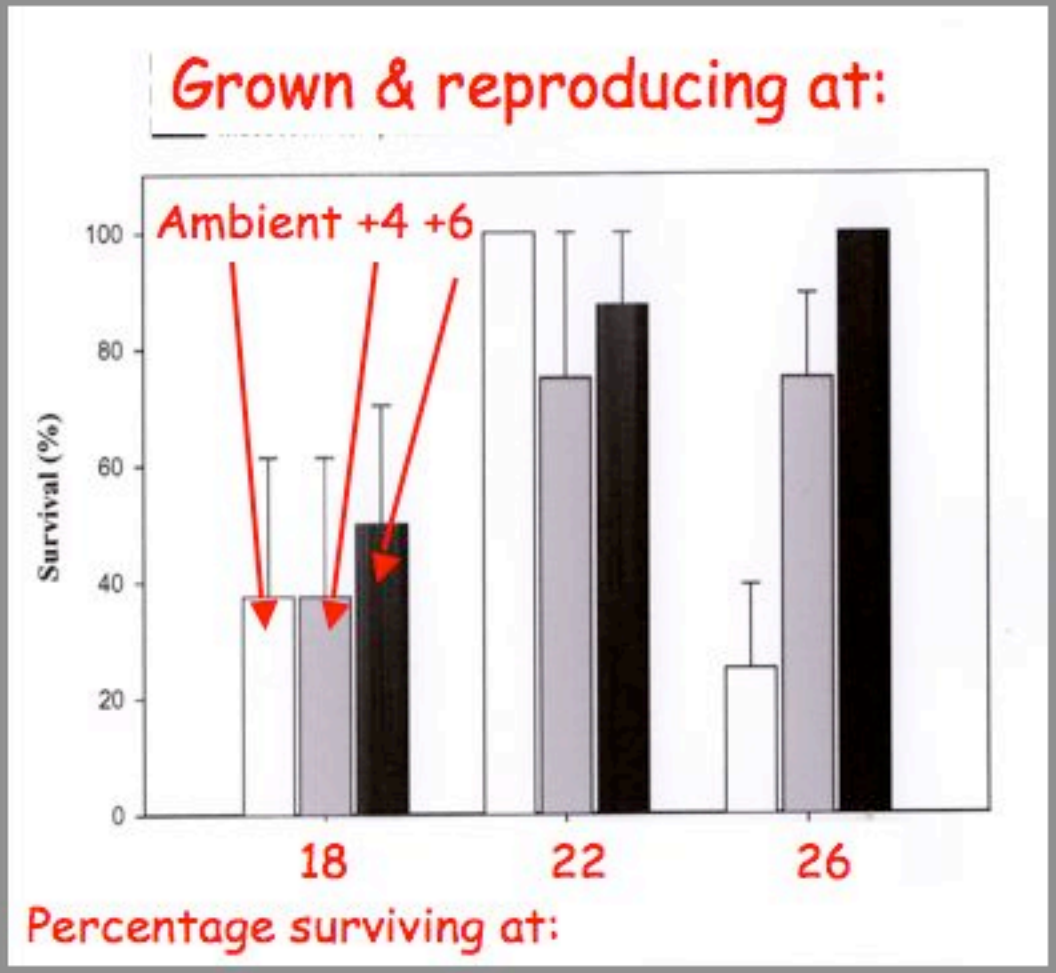


Experimental evolution in small animals
in temperature controlled mesocosm experiments
in Liverpool (UK) and Denmark



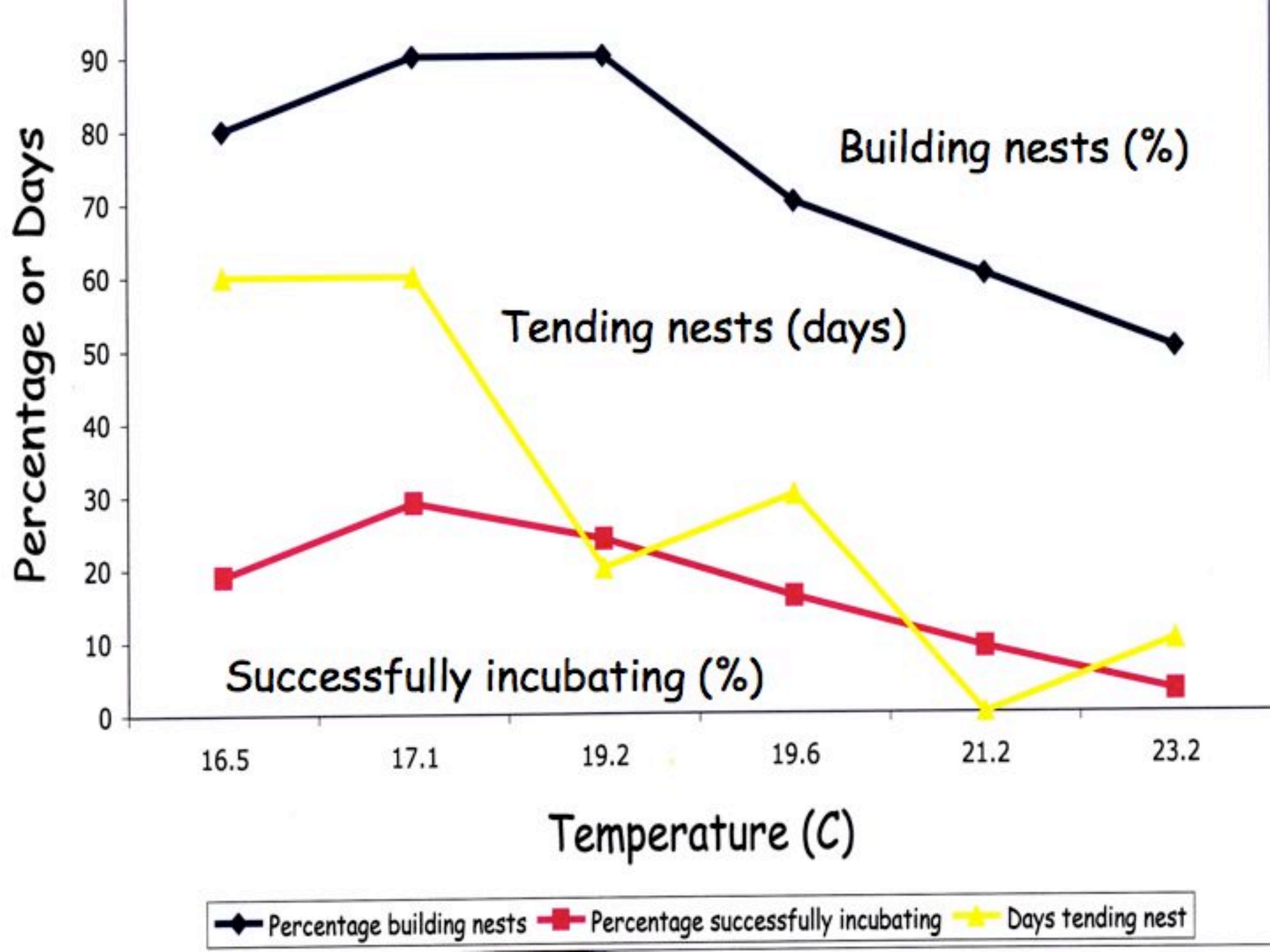
Clonal populations added then resampled several months later and tested for temperature characteristics

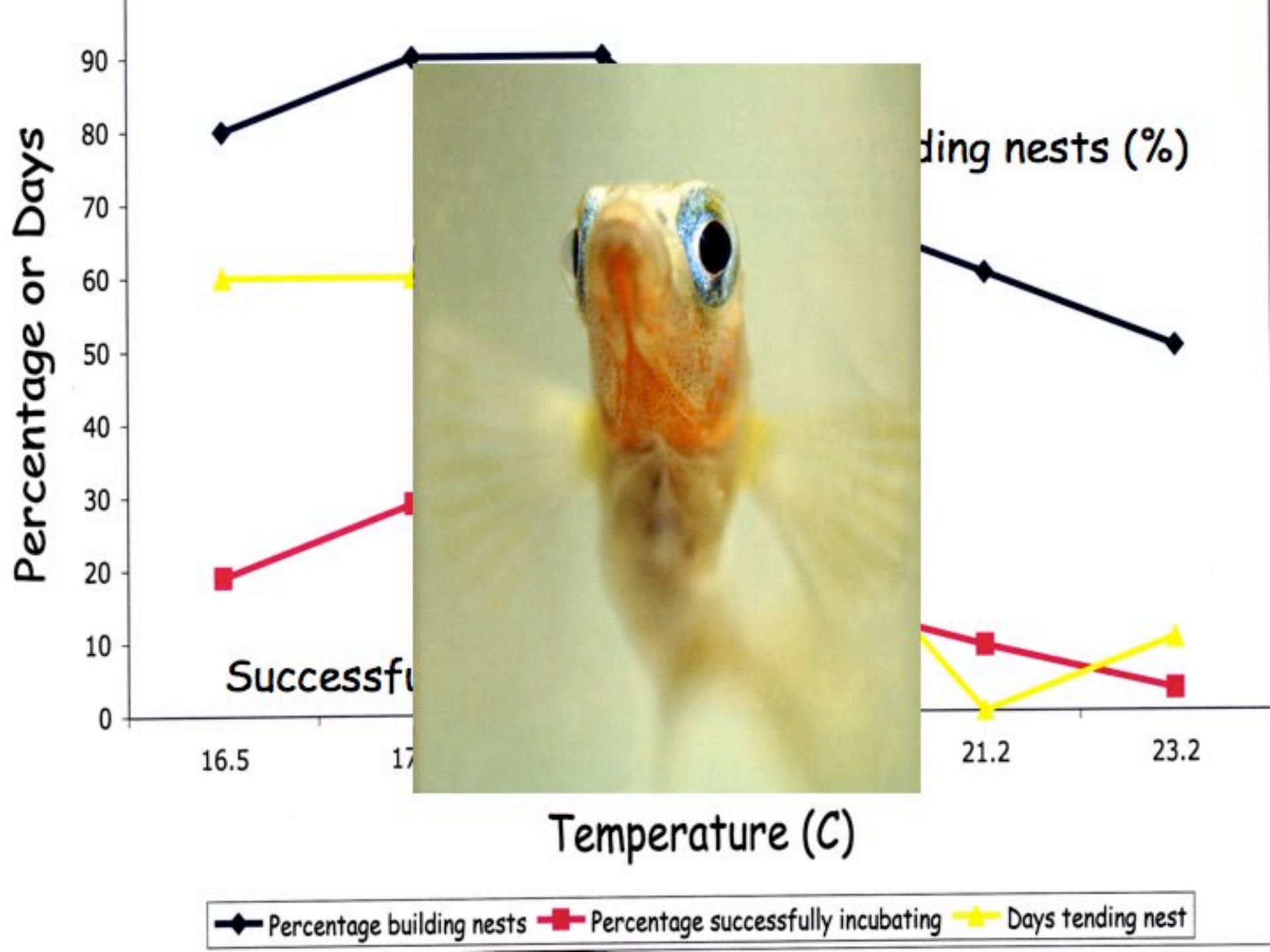
Rapid microevolutionary response after one-year natural selection

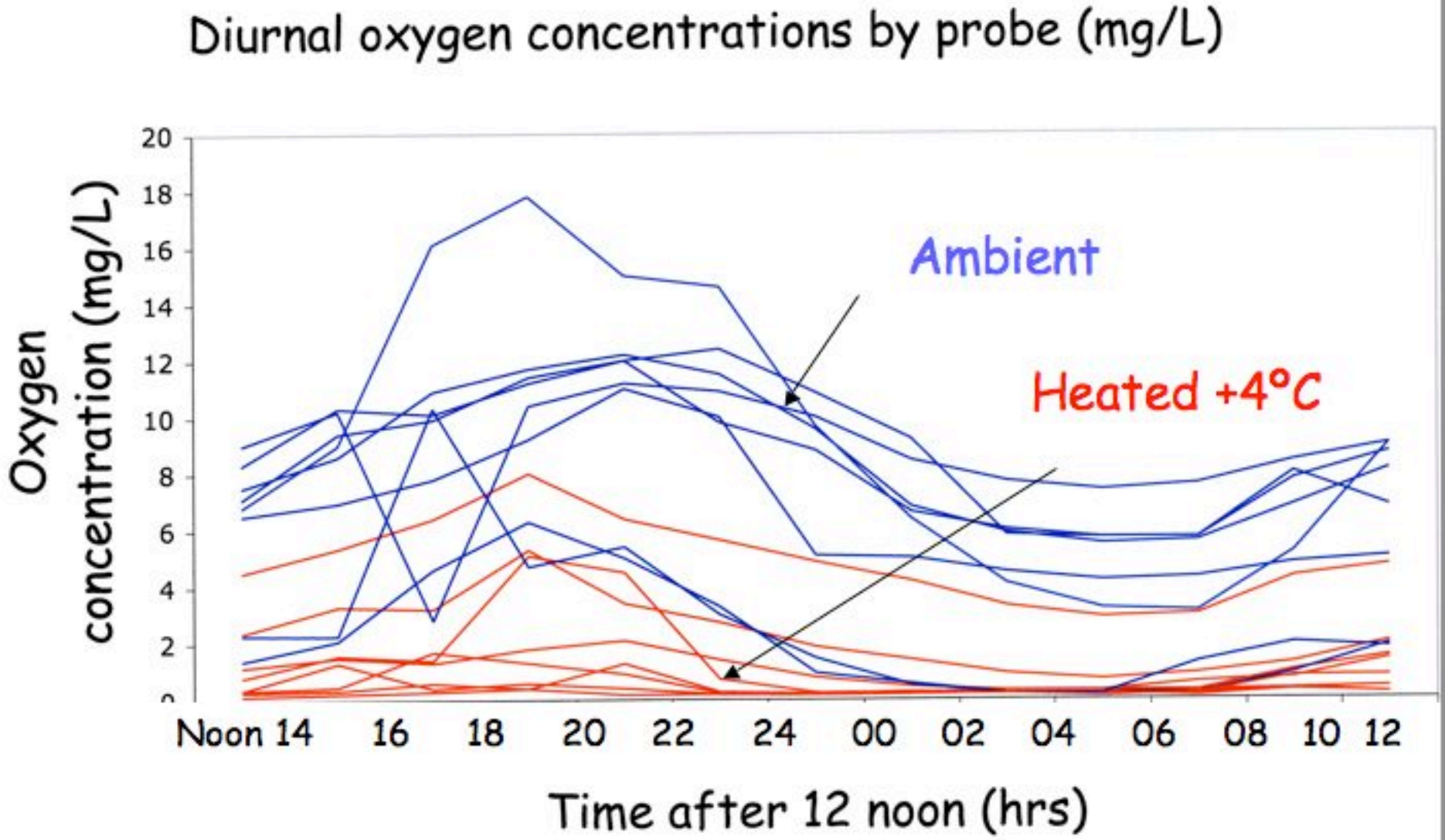


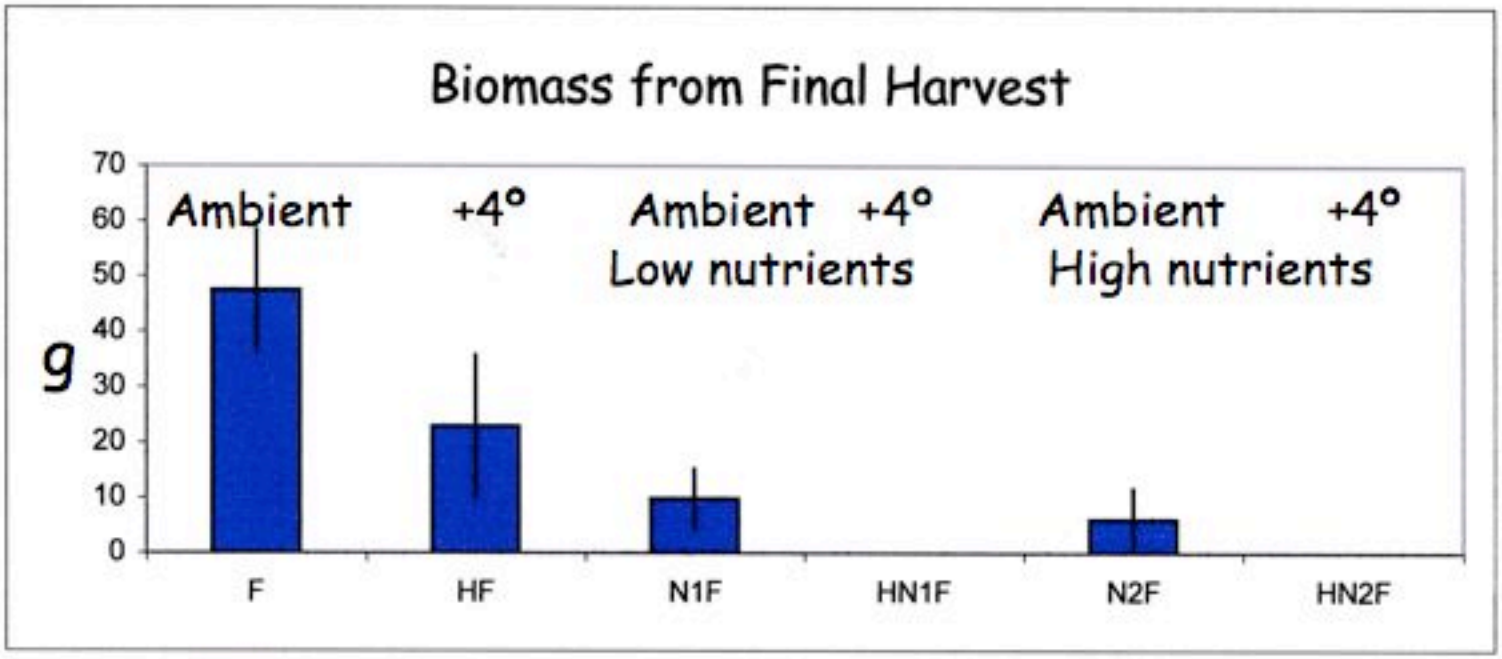
Simocephalus vetulus

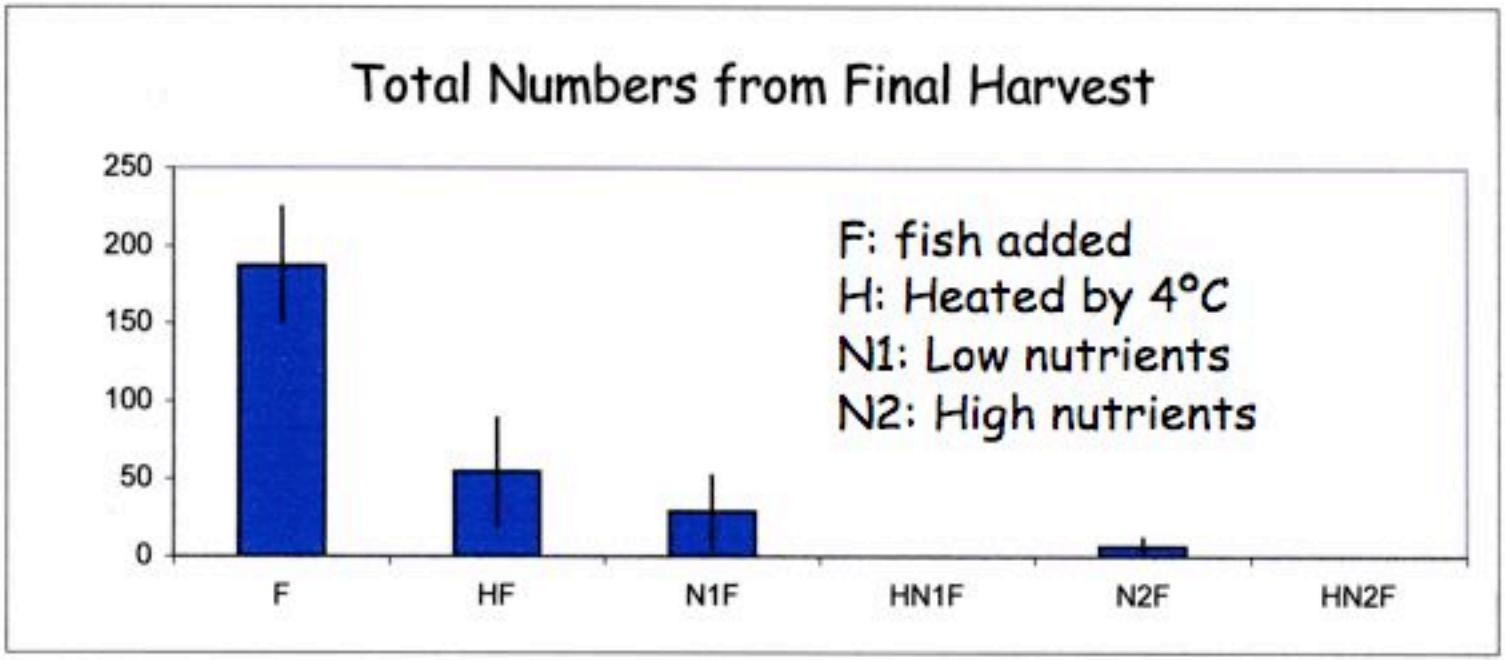
Three spined stickleback, *Gasterosteus aculeatus*


Percentage or Days
90
80
70
60
50
40
30
20
10
0
Building nests (%)
Tending nests (days)
Successfully incubating (%)
16.5
17.1
19.2
19.6
21.2
23.2
Temperature (C)
Percentage building nests
Percentage successfully incubating
Days tending nest


Percentage or Days
90
80
70
60
50
40
30
20
10
0
ding nests (%)
Successfu
16.5
17
21.2
23.2
Temperature (C)
Percentage building nests
Percentage successfully incubating
Days tending nest

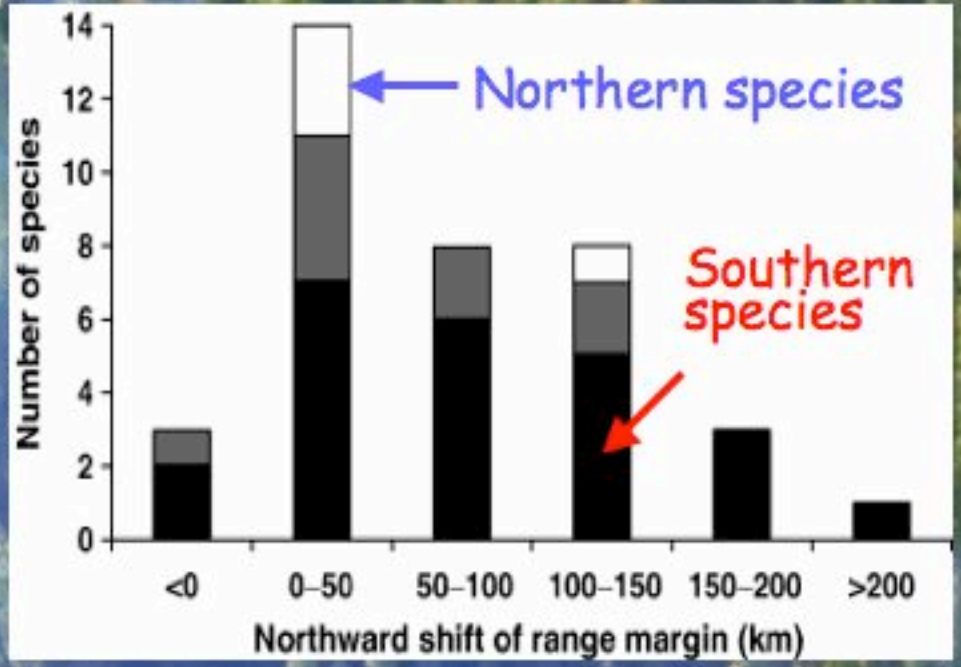

Diurnal oxygen concentrations by probe (mg/L)
Oxygen concentration (mg/L)
20
18
16
14
12
10
8
6
4
2
Ambient
Heated +4°C
Noon 14 16 18 20 22 24 00 02 04 06 08 10 12
Time after 12 noon (hrs)

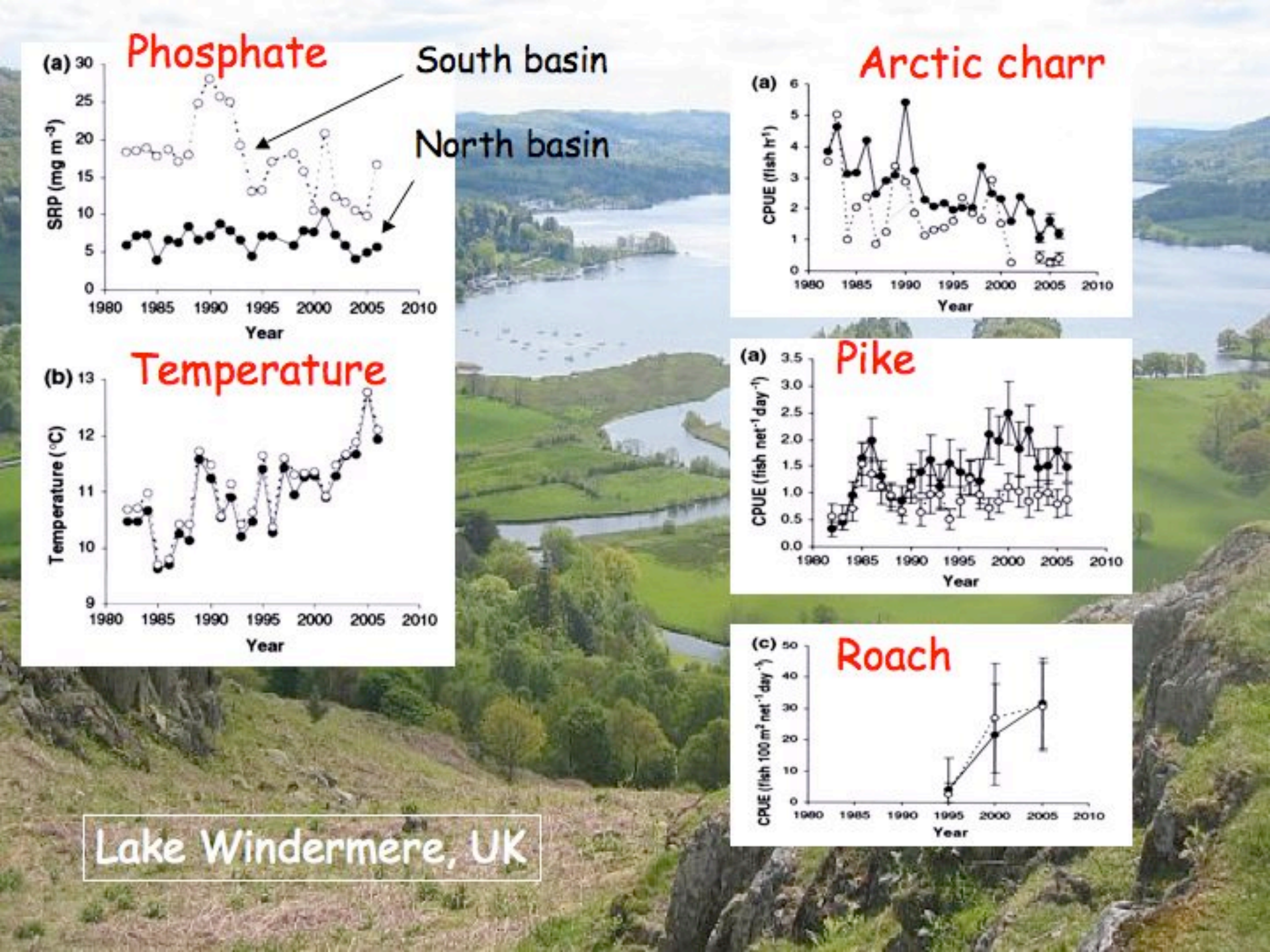

Biomass from Final Harvest
g
70
60
50
40
30
20
10
0
Ambient
+4°
Ambient
+4°
Low nutrients
Ambient
+4°
High nutrients
F
HF
N1F
HN1F
N2F
HN2F


Total Numbers from Final Harvest
250
200
150
100
50
0
F: fish added
H: Heated by 4°C
N1: Low nutrients
N2: High nutrients
F
HF
N1F
HN1F
N2F
HN2F

Lagarosiphon vulgare (South African exotic) came to dominate mixed native plant community in mesocosm experiments with 3°C rise

Dragonfly movements 1960-2005

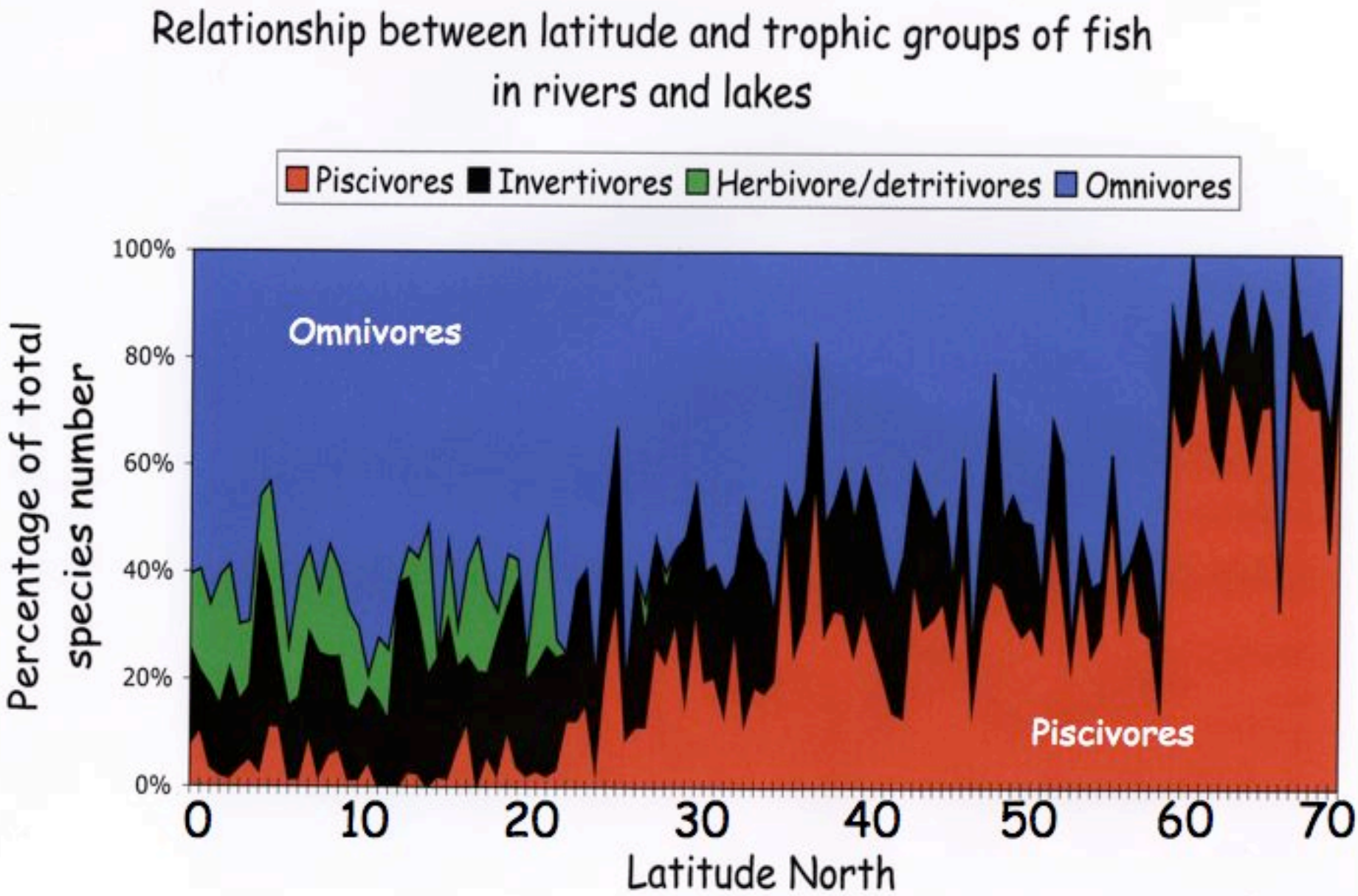


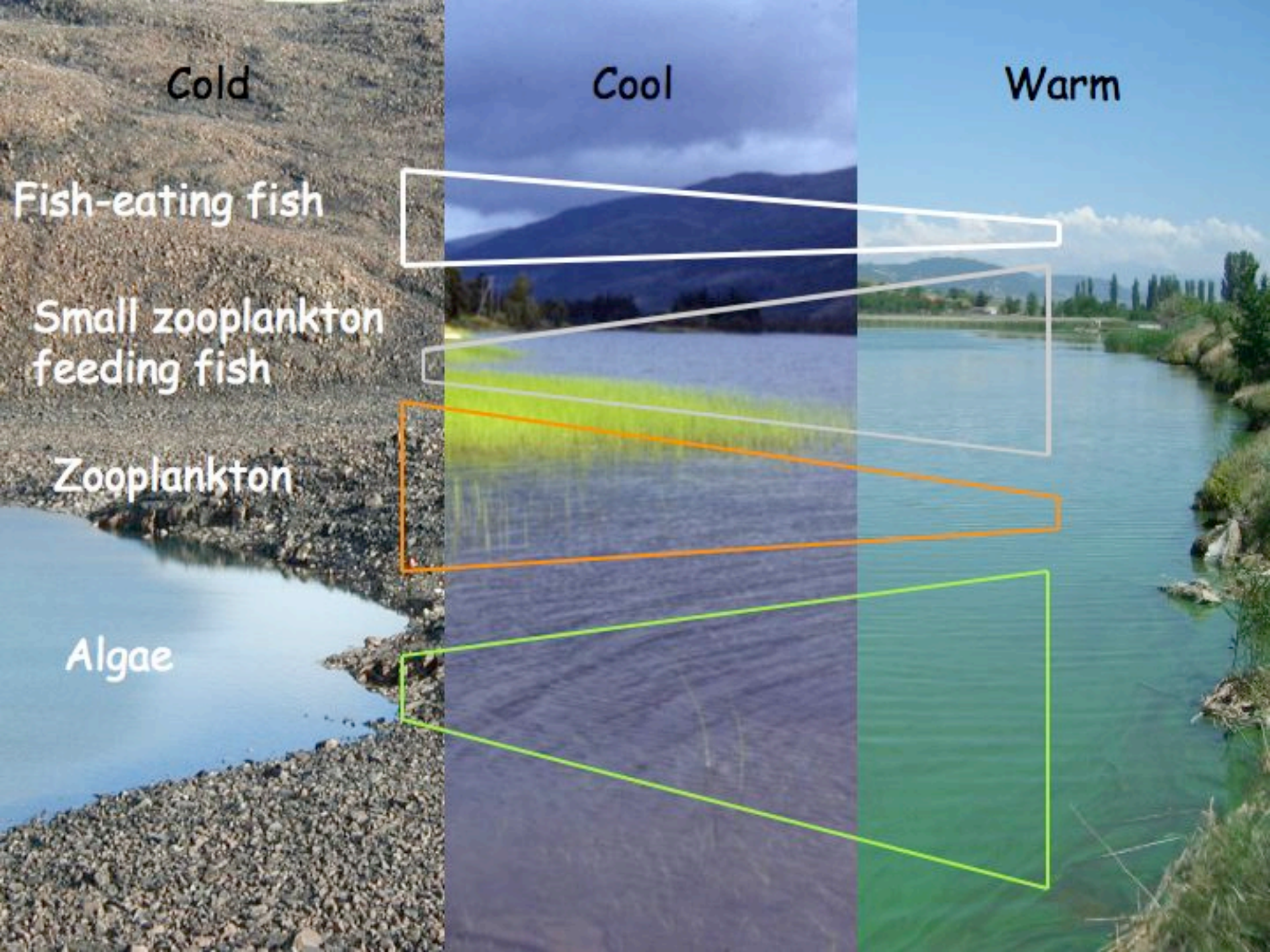

Phosphate
South basin
North basin
(a)
SRP (mg m-3)
Year
Temperature
(b)
Temperature (°C)
Year
Arctic charr
(a)
CPUE (fish h-1)
Year
Pike
(a)
CPUE (fish net-1 day-1)
Year
Roach
(c)
CPUE (fish 100 m2 net-1 day-1)
Year
Lake Windermere, UK

Among natural communities there are predictable patterns with latitude

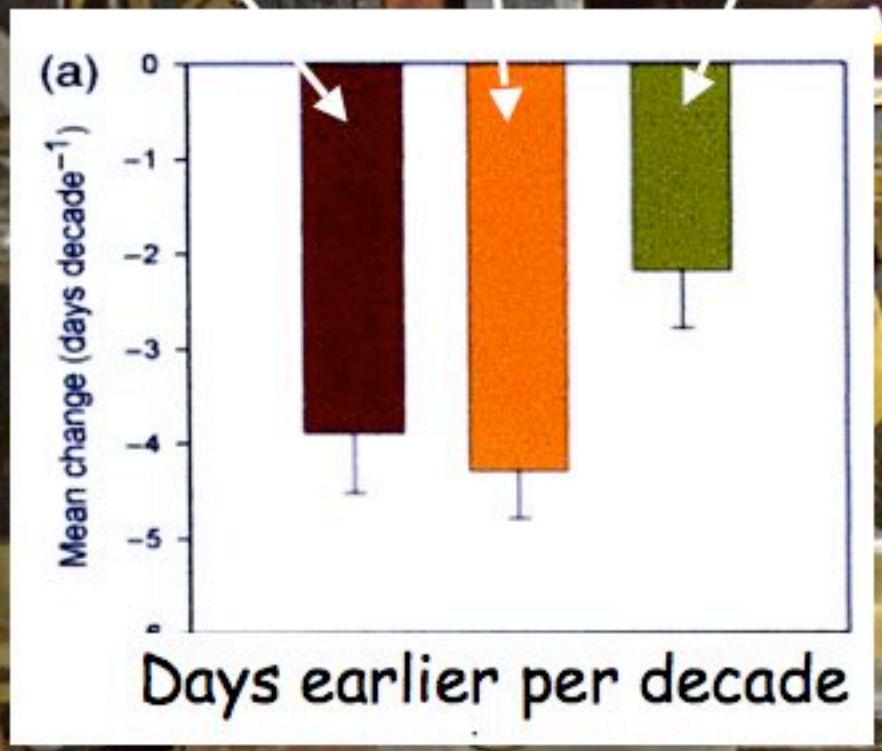
The Americas

60 lakes, 60 rivers, stratified random sampling in 10° latitude blocks.


Relationship between latitude and trophic groups of fish in rivers and lakes
Piscivores
Invertivores
Herbivore/detritivores
Omnivores
100%
80%
60%
40%
20%
0%
Percentage of total species number
Omnivores
Piscivores
0
10
20
30
40
50
60
70
Latitude North

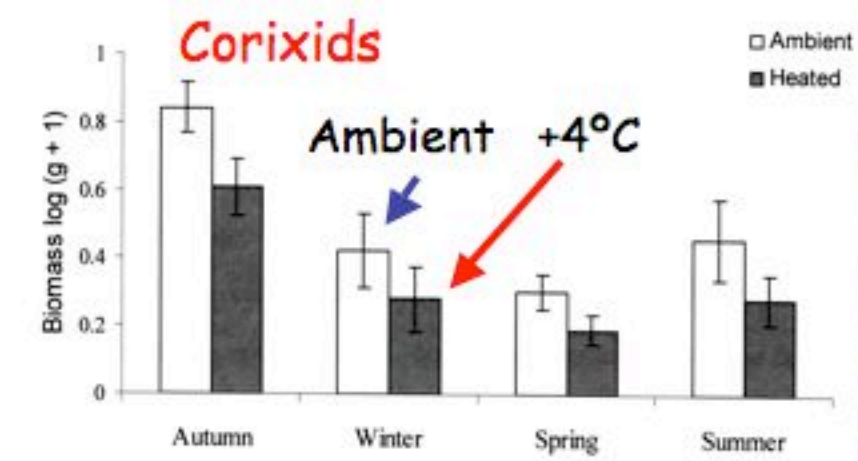

Cold
Cool
Warm
Fish-eating fish
Small zooplankton feeding fish
Zooplankton
Algae

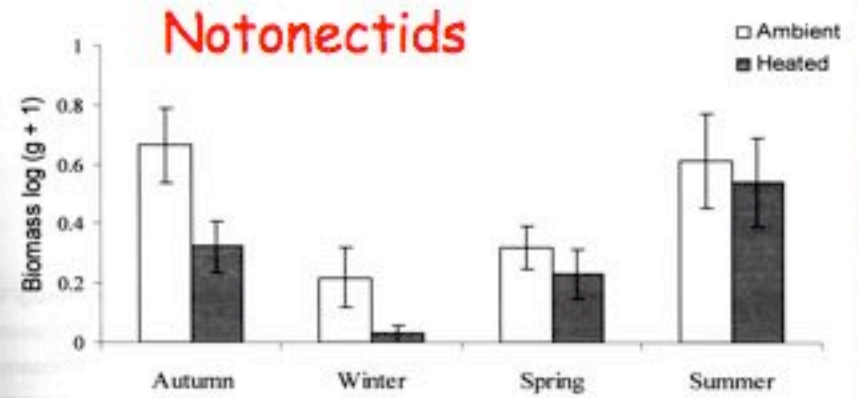
Plants Grazers Predators

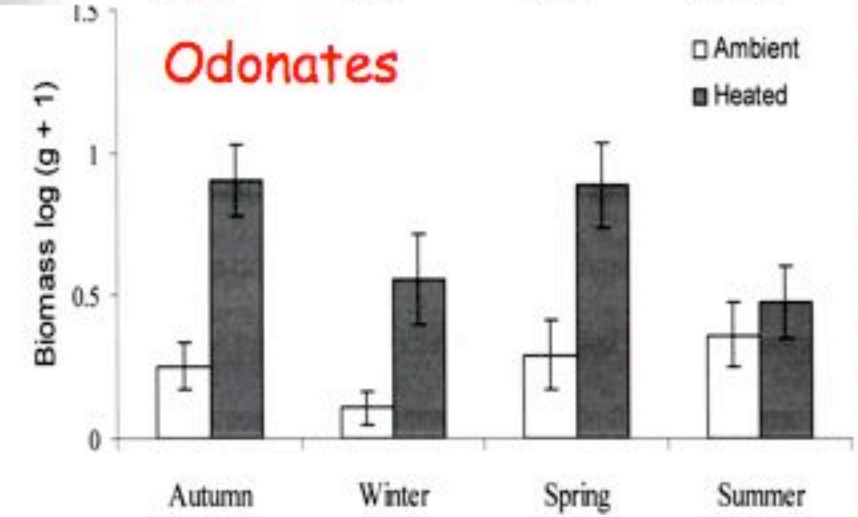


Days earlier per decade

- The parts are differently temperature-compensated


Corixids
Ambient
Heated
Ambient
+4°C
Biomass log (g + 1)
0
0.2
0.4
0.6
0.8
1
Autumn
Winter
Spring
Summer

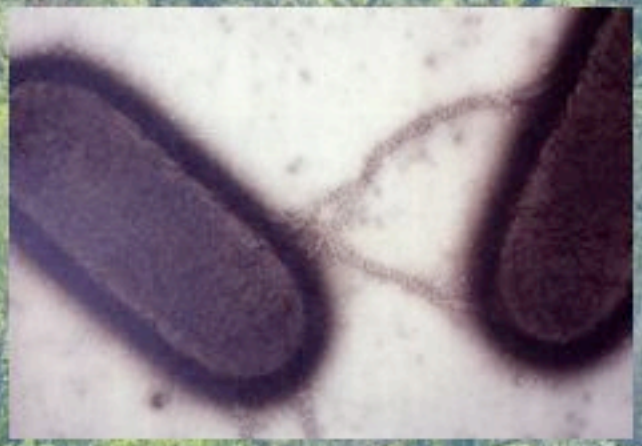

Notonectids
Ambient
Heated
Biomass log (g + 1)
0
0.2
0.4
0.6
0.8
1
Autumn
Winter
Spring
Summer


Odonates
Ambient
Heated
Biomass log (g + 1)
0
0.5
1
1.5
Autumn
Winter
Spring
Summer


Notonectids (water boatmen)

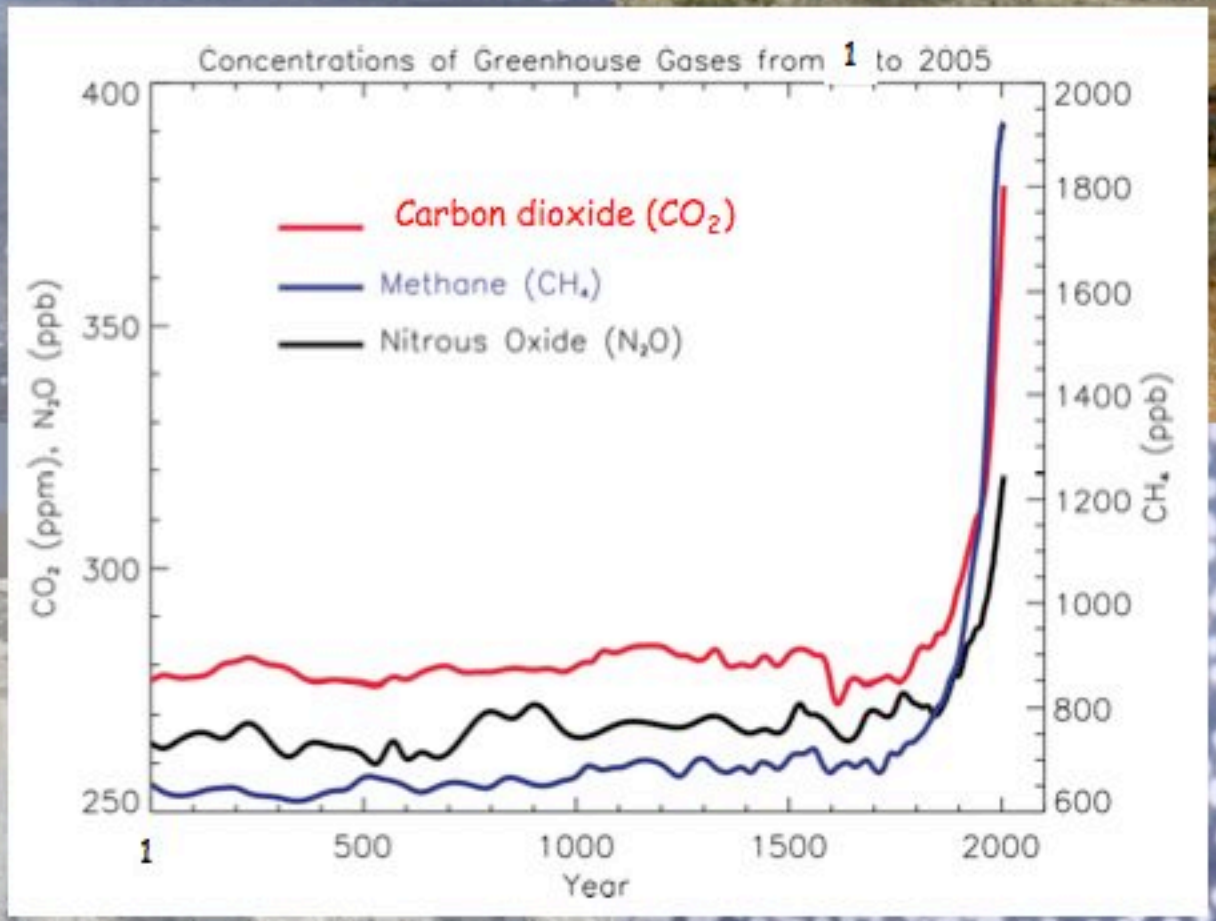

Odonatids
(damselflies & dragonflies)

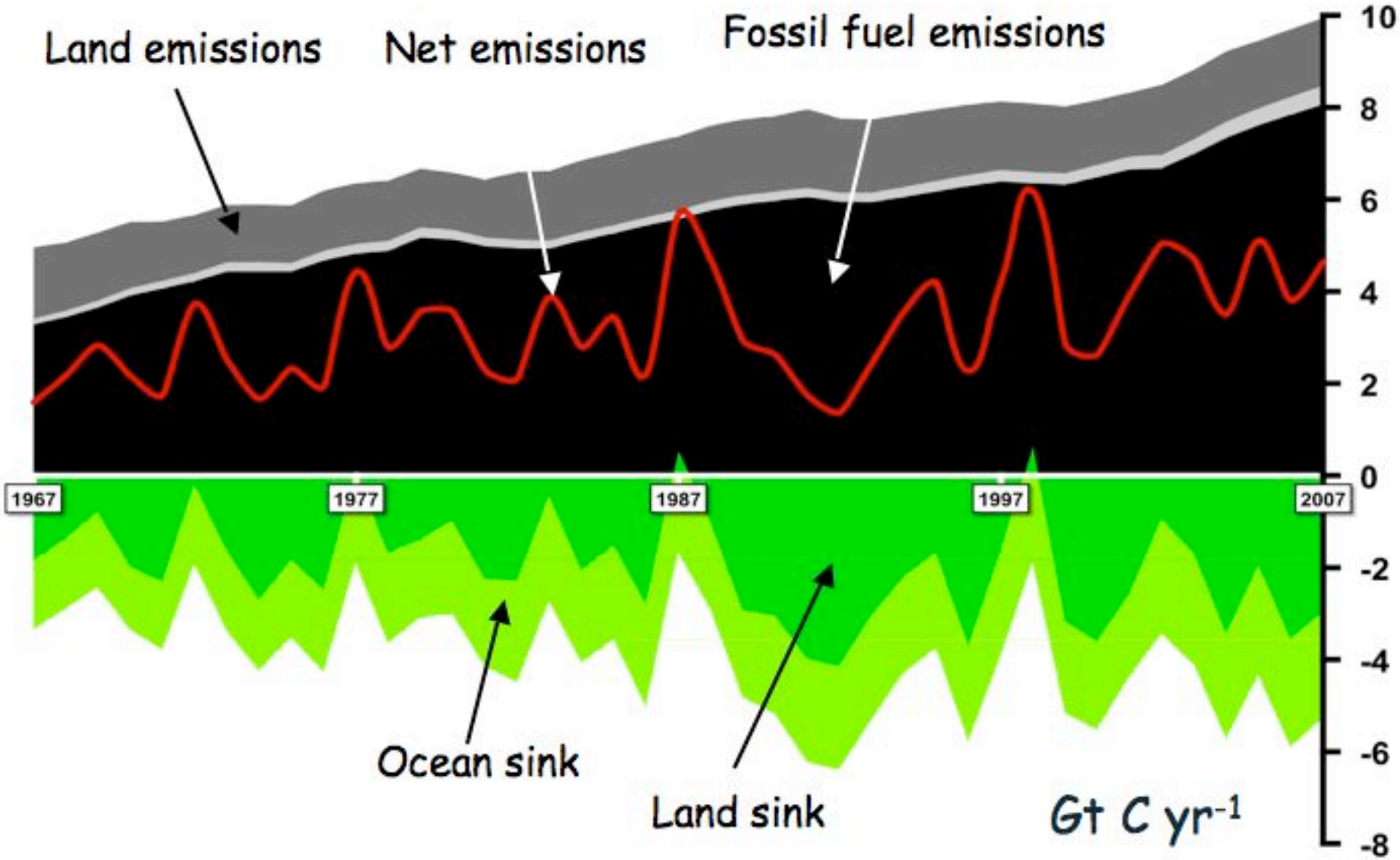

•Movement is not free
•Mobility varies
•Simple community replacement is highly unlikely



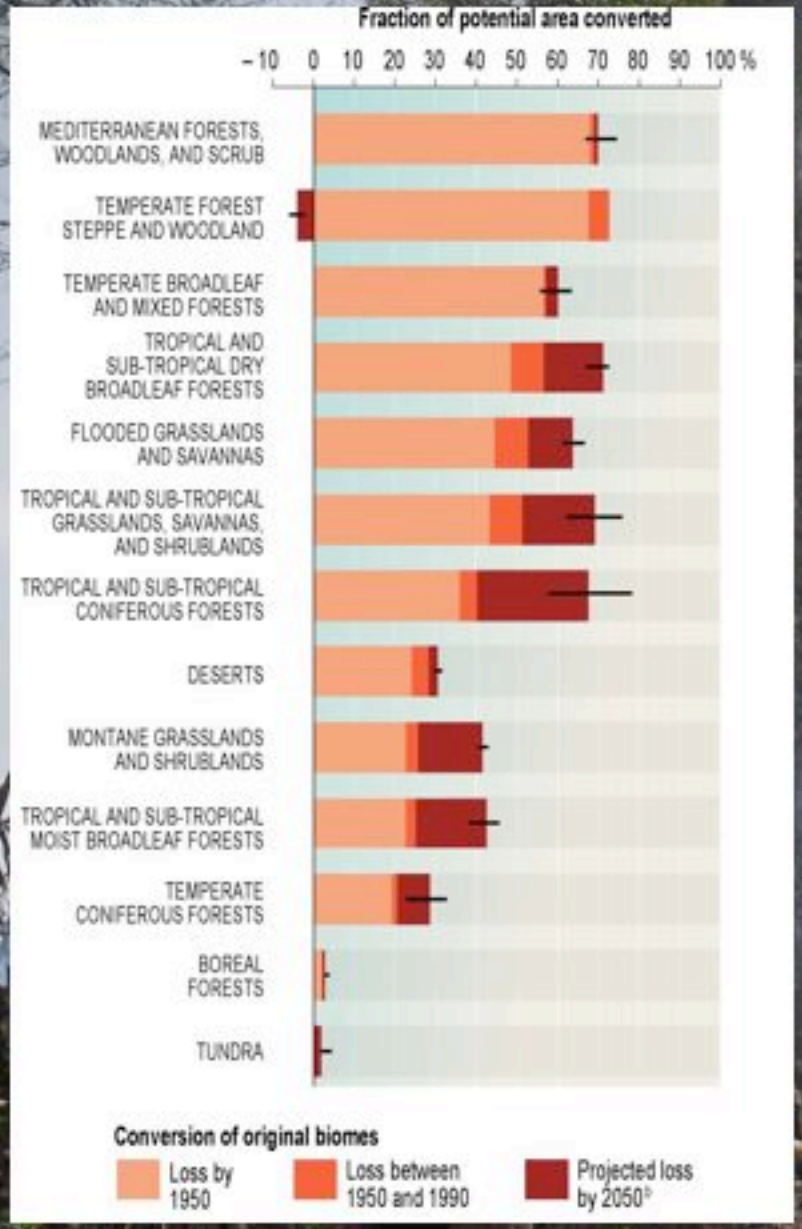
- Too many species, all idiosyncratic, too many unknowns to predict details of future communities
- But given **<u>time and opportunity</u>**, through natural selection and species sorting, functional communities would assemble

Processes rather than biodiversity



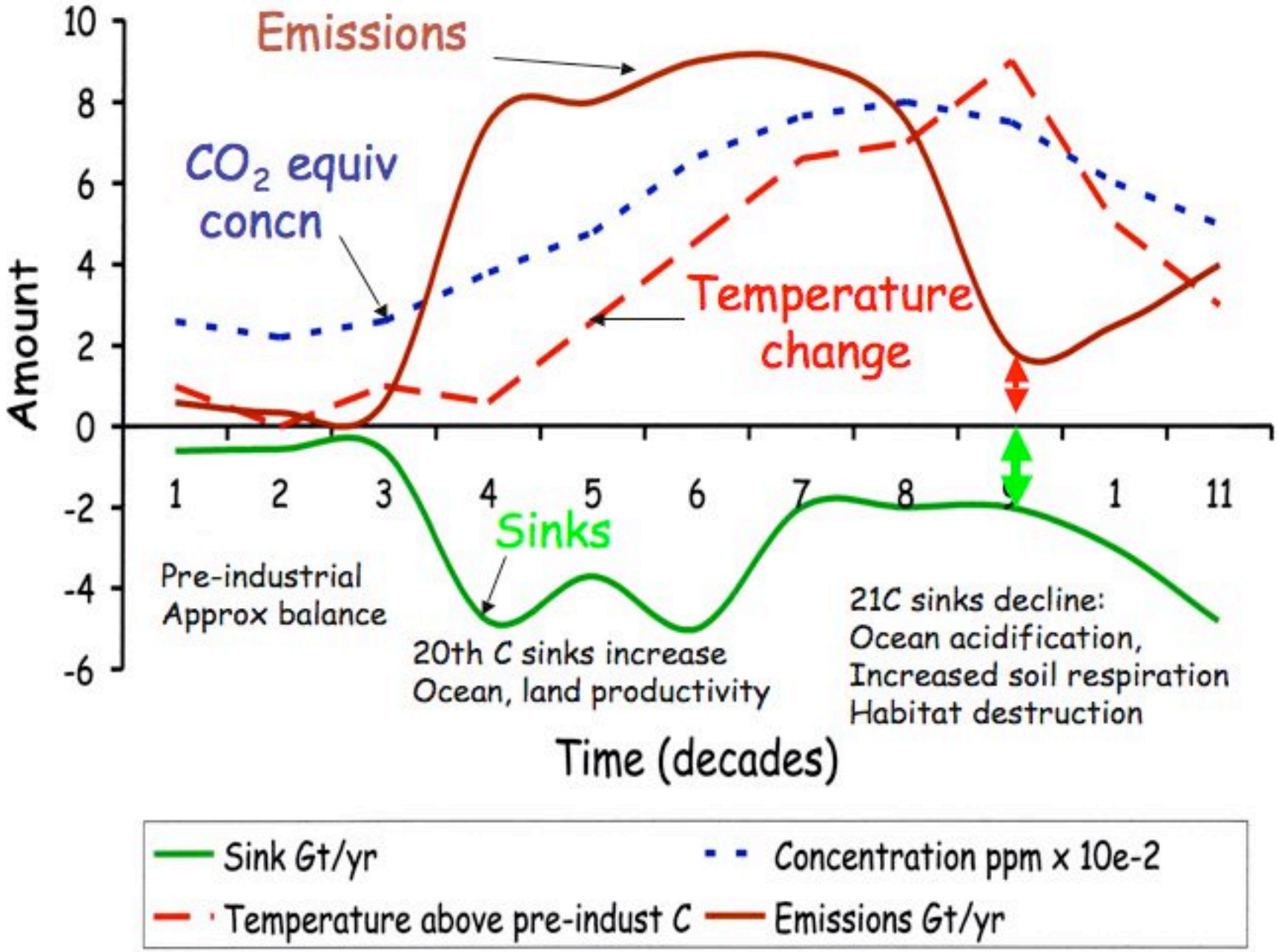

Land emissions
Net emissions
Fossil fuel emissions
10
8
6
4
2
0
-2
-4
-6
-8
1967
1977
1987
1997
2007
Ocean sink
Land sink
Gt C yr-1

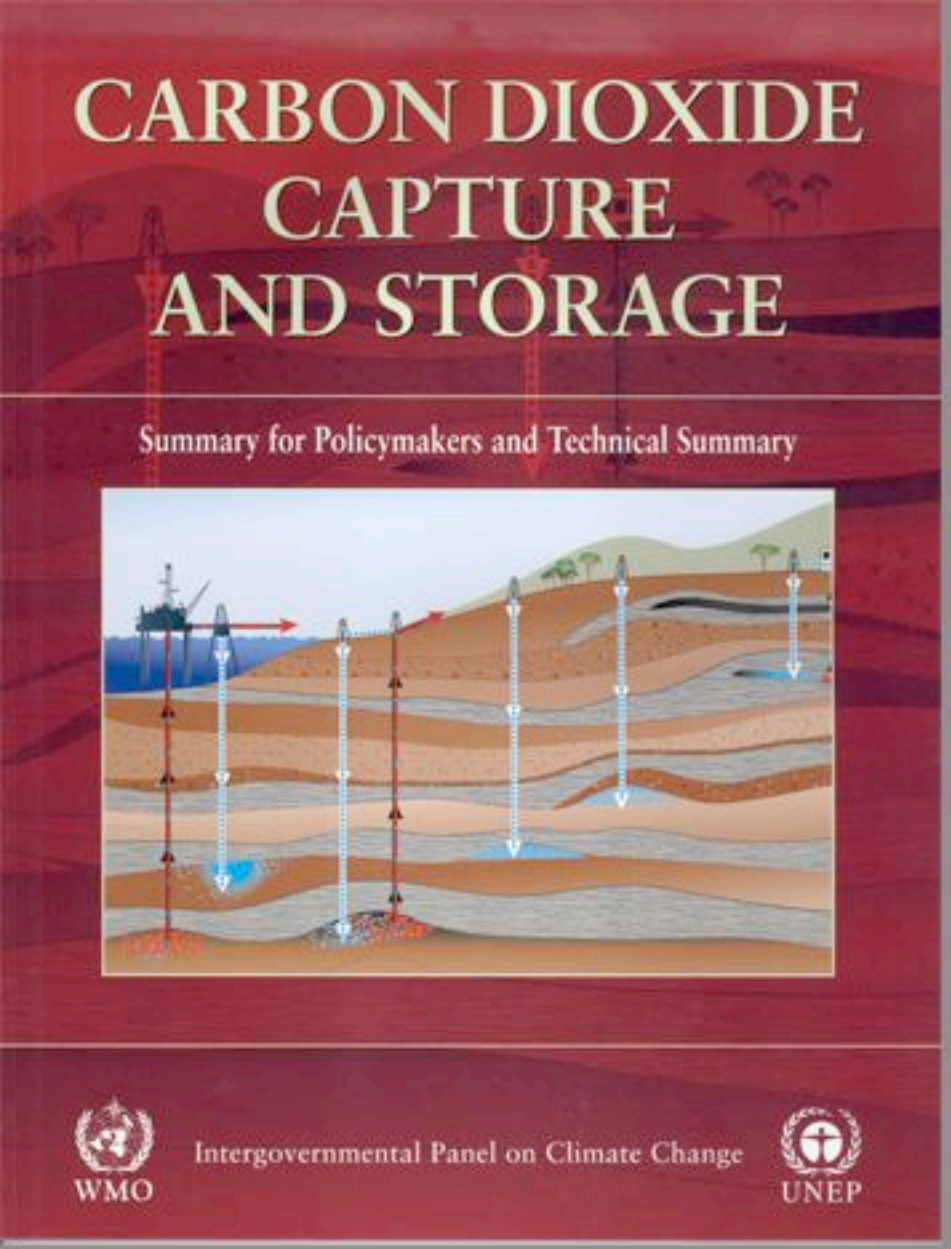
Lost sinks



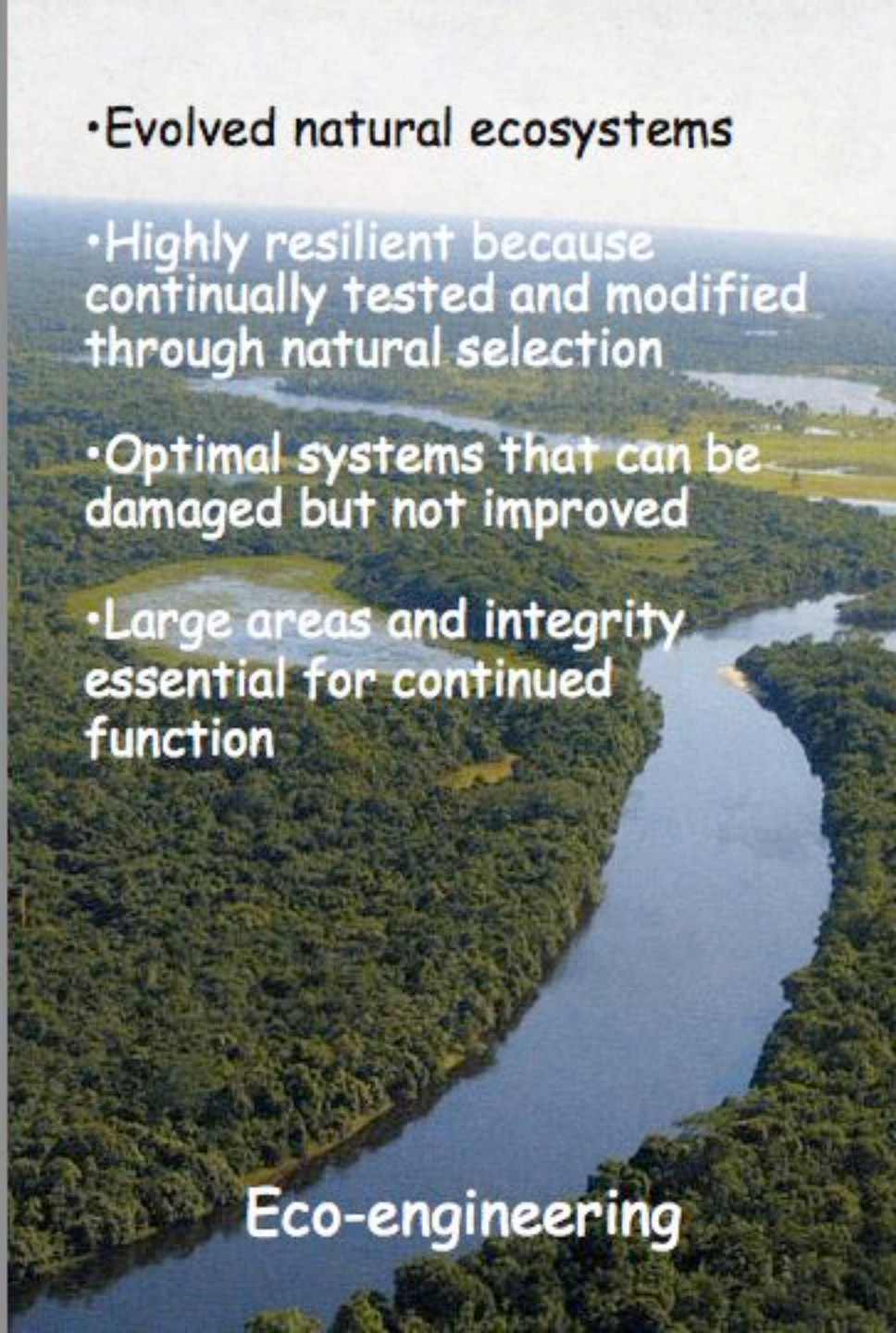
Millennium Ecosystem Assessment 2004

Loss of habitat
Ocean acidification
Increased soil respiration


Emissions
CO_2 equiv concn
Temperature change
Sinks
Amount
10
8
6
4
2
0
-2
-4
-6
1
2
3
4
5
6
7
8
9
1
11
Pre-industrial Approx balance
20th C sinks increase Ocean, land productivity
21C sinks decline: Ocean acidification, Increased soil respiration Habitat destruction
Time (decades)
Sink Gt/yr
Concentration ppm x 10e-2
Temperature above pre-indust C
Emissions Gt/yr

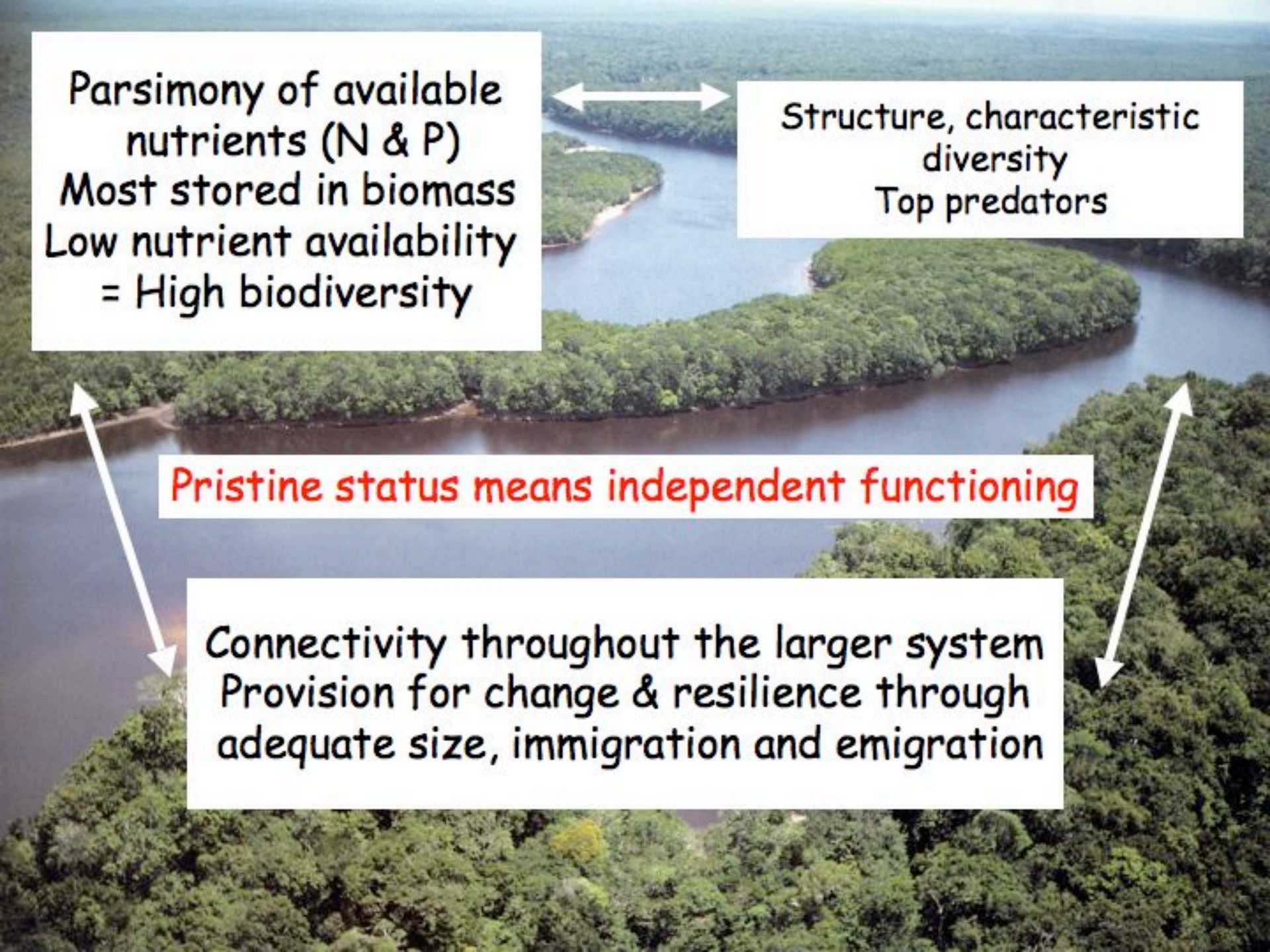


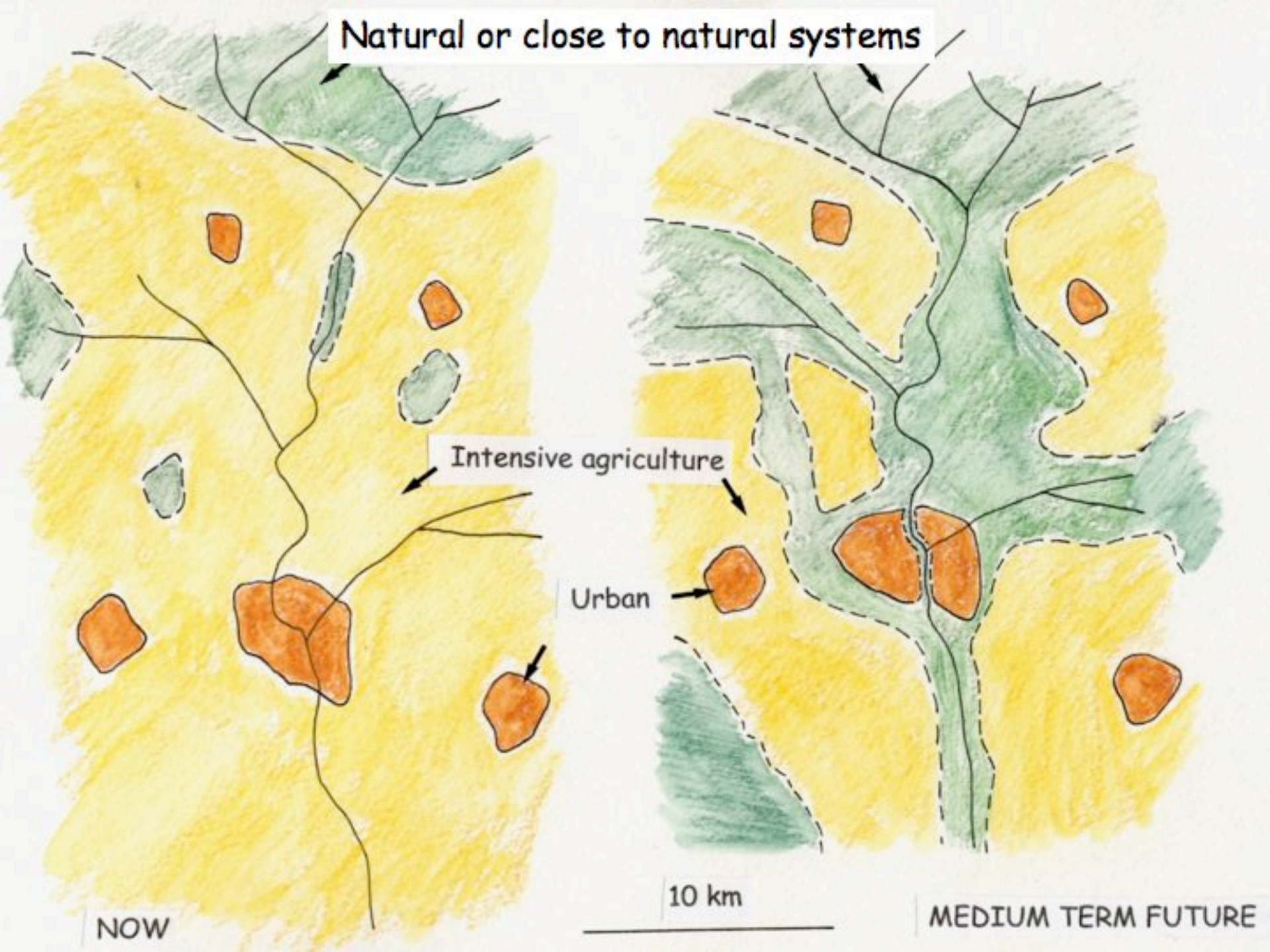
Geoengineering



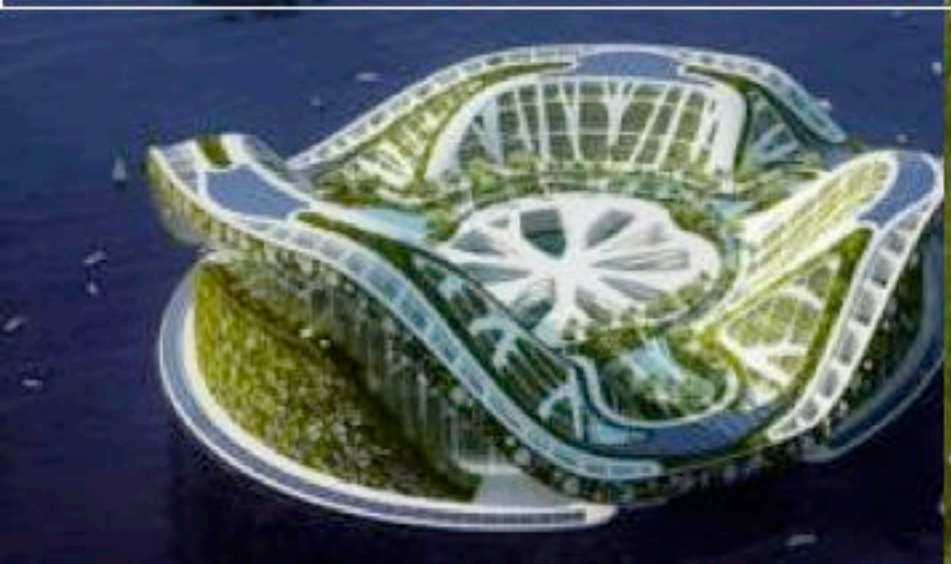
- Evolved natural ecosystems
- Highly resilient because continually tested and modified through natural selection
- Optimal systems that can be damaged but not improved
- Large areas and integrity essential for continued function

Eco-engineering


Parsimony of available nutrients (N & P)
Most stored in biomass
Low nutrient availability
= High biodiversity
Structure, characteristic diversity
Top predators
Pristine status means independent functioning
Connectivity throughout the larger system
Provision for change & resilience through adequate size, immigration and emigration


Natural or close to natural systems
Intensive agriculture
Urban
10 km
NOW
MEDIUM TERM FUTURE

Need for a long-term strategy



1. Reduce emissions
2. Rebuild the carbon sinks
3. New sorts of attractive cities to free land for regenerated ecosystems
4. More intensive, high-technology, ethical, farming on much reduced areas
5. New arrangements to use less food more efficiently
6. Population reduction &
7. Steady-state economies