Fundamentals in Ecology

practical part

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organization

- Group work: groups with individual research questions
- terrestrial / aquatic themes
- Field and laboratory work, (obligate) opportunity for every student to participate in activities
- Introduction, visualization and statistics using R
- Evaluation: written report (special sessions by David);

    40% of final grade in Fundamentals in Ecology

schedule

- Experimental design in Ecology
- Introduction to practical (guidelines, experimental design)
- Setting up experiments
- Report writing
- Introduction to R
- Measurements 1
- Visualization of data in R
- Measurements 2
- Statistical analyses in R
- Measurements 3
- Easter Holidays / Semaine ENAC
- Measurements 4
- Data Analysis / Interpretation
- Questions / Discussion

Experimental design in Ecology

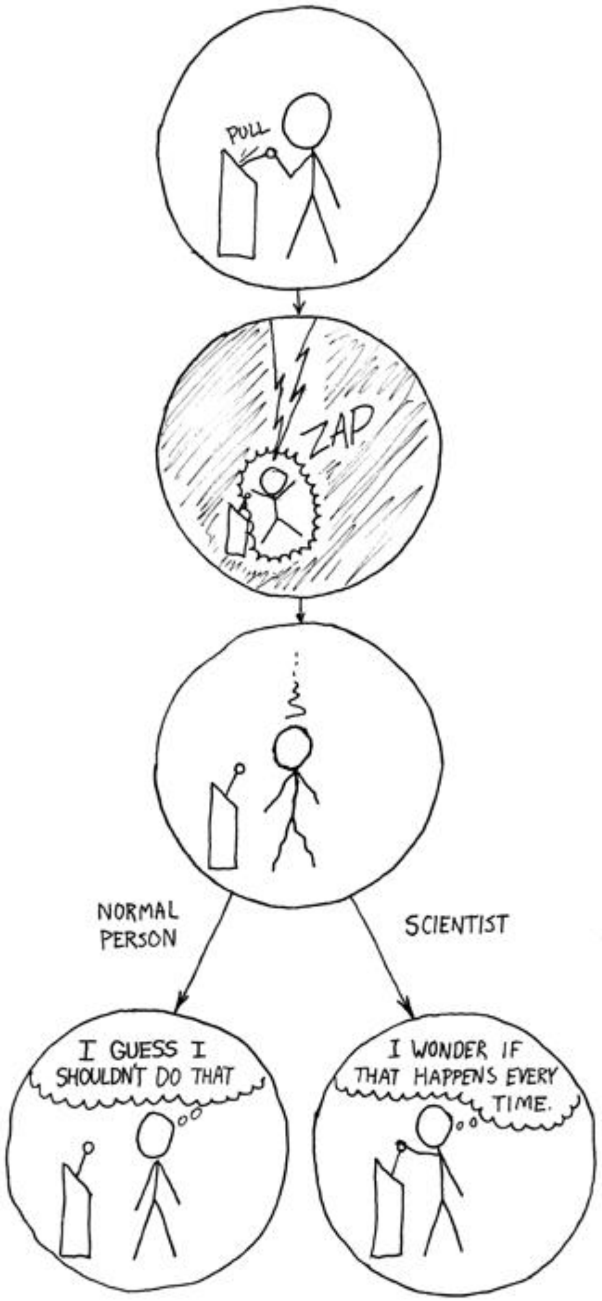
- The scientific method – hypotheses, critical tests, theory
- Tools: Observations, Experiments, Monitoring
- Importance of scale
- Iconic examples in Ecology

Experimental Design in Ecology

Experimental design and hypothesis testing is central to the **scientific process.**

Knowledge builds gradually on previously established knowledge, but without the formulation of **hypotheses** and **critical tests** of these hypotheses it is virtually impossible to know which knowledge to build on and which knowledge should be rejected.

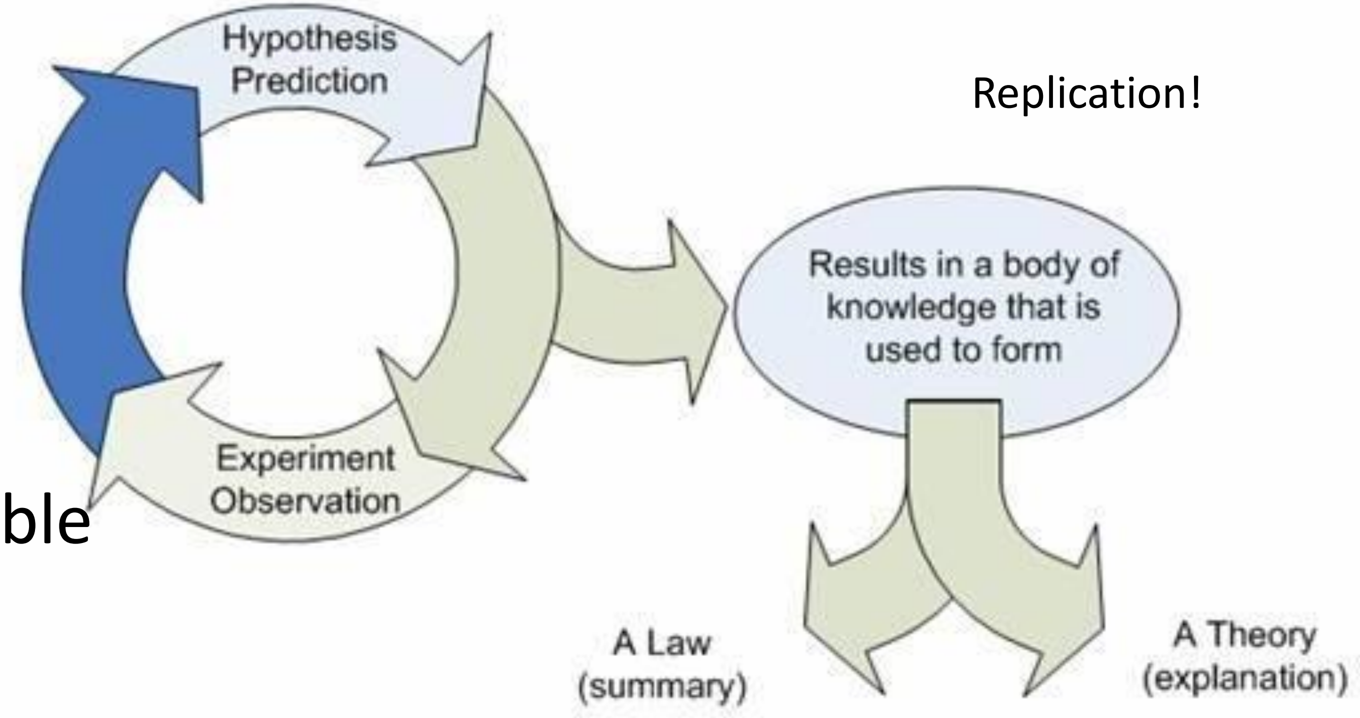
Experimental design: creating a set of procedures to test a hypothesis.



Scientific method

A problem-solving approach:

- Make an observation.
- Ask a question.
- Formulate a **hypothesis**, or testable explanation.
- Make a prediction based on the hypothesis.
- Test the prediction (experiment).
- Iterate: use the results to make new hypotheses or predictions.

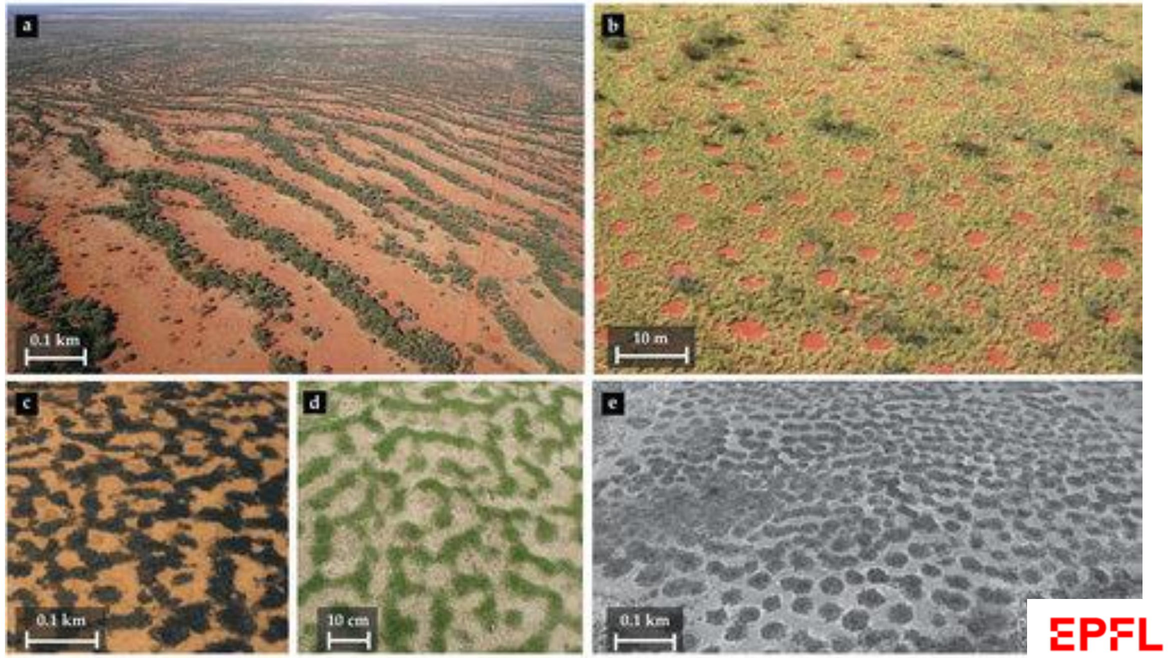


Replication!

Pattern description

The scientific process often starts with observations of patterns (also called puzzles, problems).

Quantitative and robust discription of patterns is a cruical part of the scientific process.



Field observations

Collect or sample species, species distribution, environmental parameter

Which parameter to collect? Prior knowledge!

Spatial and temporal scale important.

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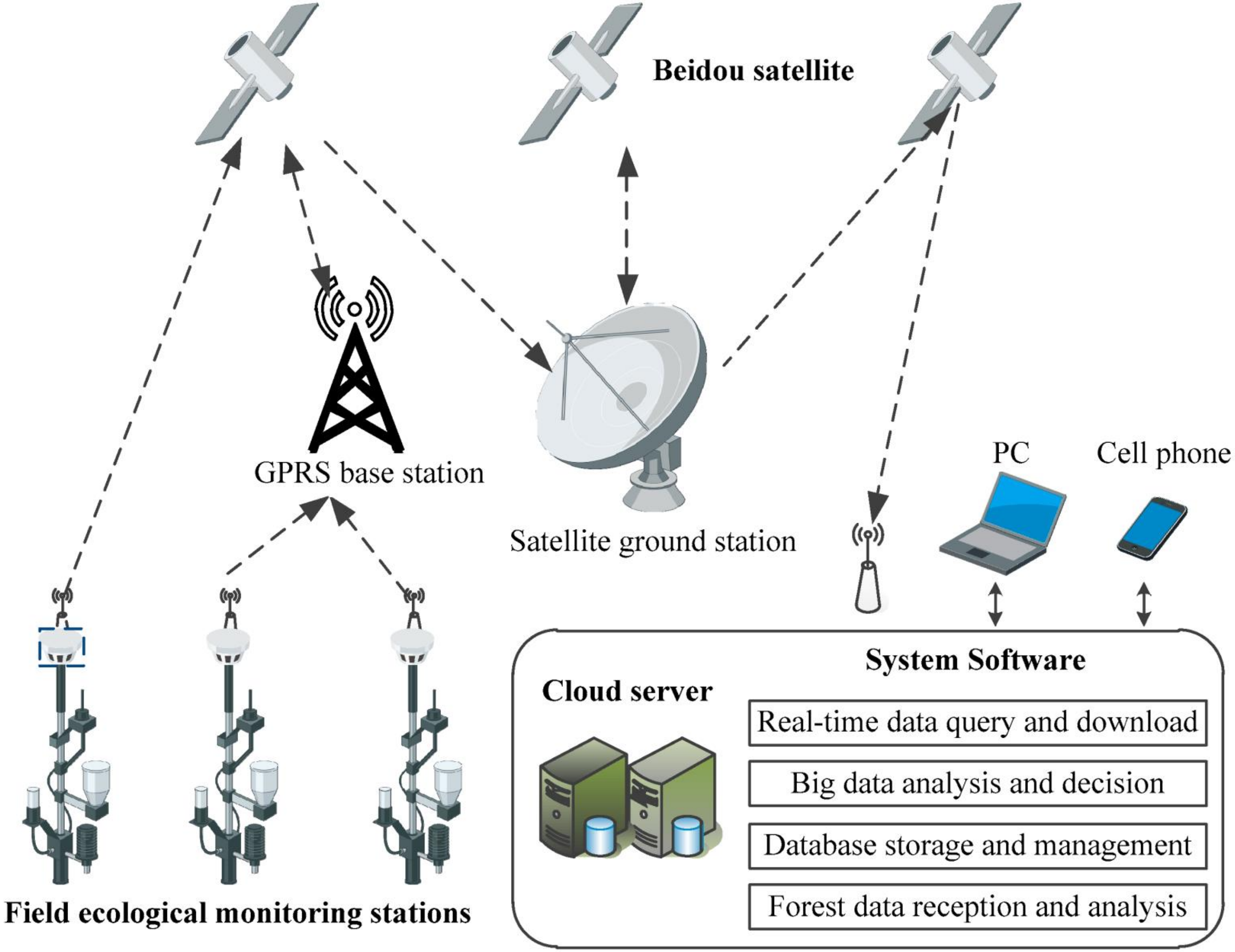
Remote Sensing/monitoring

Systems for regular and long-term observations in space and time, informing about environmental conditions with the purpose to estimate the past, the present and the future forecast of environmental parameters.



Experiments

An experiment is a research method in which scientists manipulate one or more **independent variables** and measure their effect on one or more **dependent variables**.

- statistical design and power
- replication
- relevant scale (spatial and temporal)

Basic experimental designs

- Completely randomized design
- Randomized block designs
- Matched pairs design
- BACI

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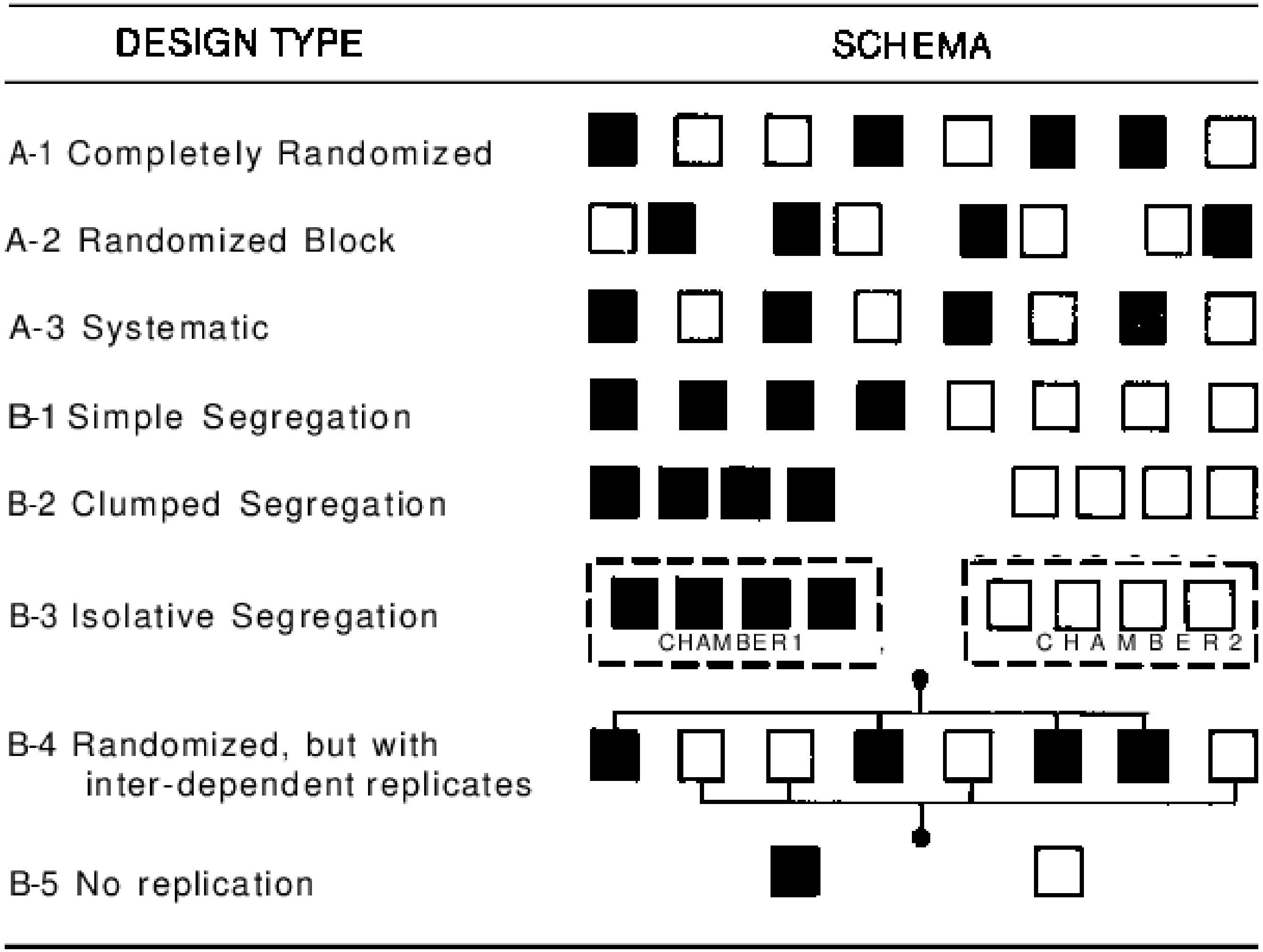
=> replication and pseudoreplication



Models

The explanation of an observed pattern is referred to as a model or theory.

Empirical models:

statistical descriptions of relationships resulting from ecological processes.

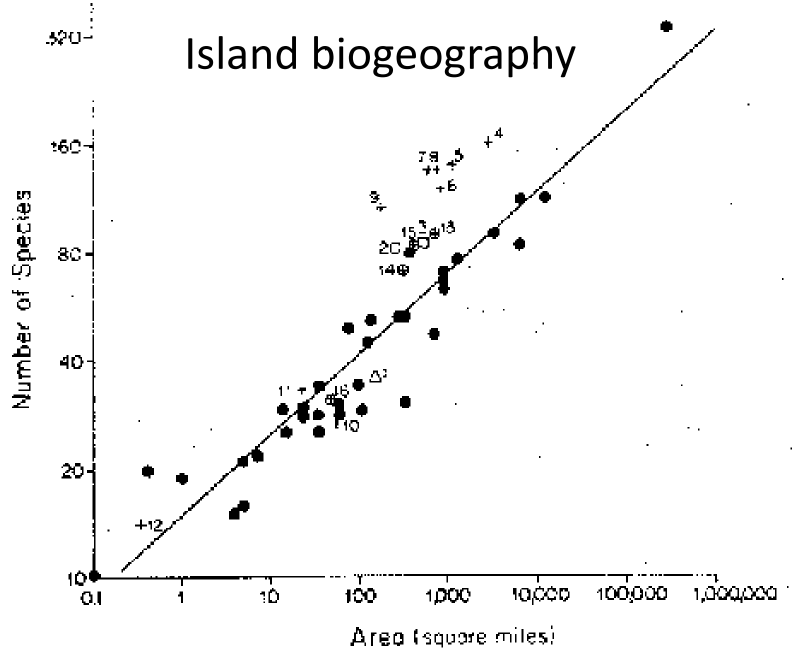
- the relationship between metabolism (response) and body mass (predictor), or species number and island area -> many statistical tools.

Theoretical models:

used to study processes, such as population growth or trophic interactions.

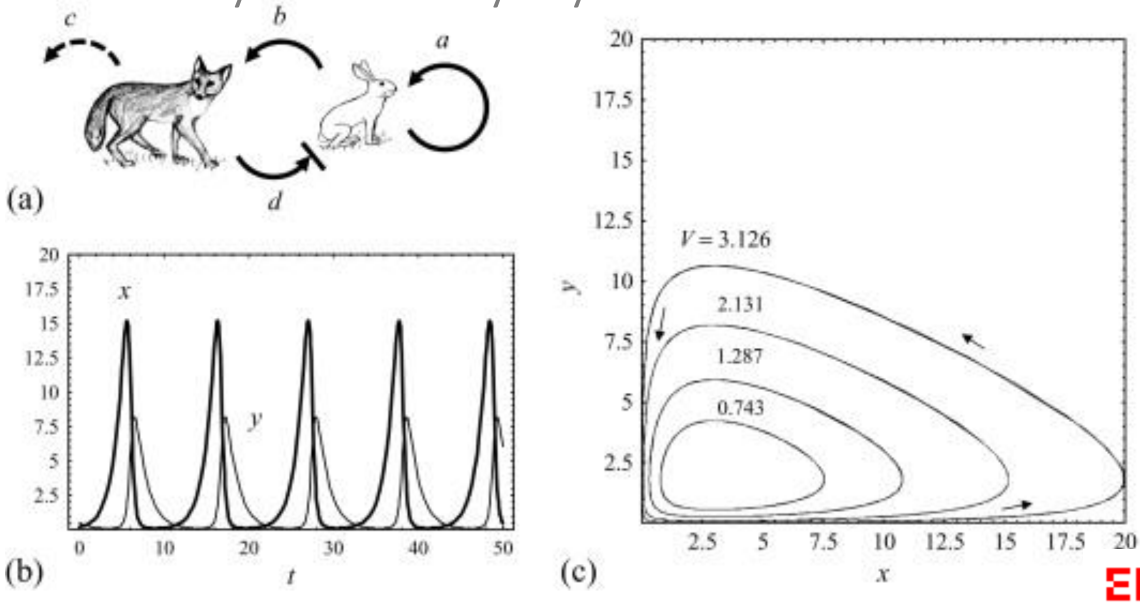
Both empirical and theoretical models can be used to make predictions, although the generality of predictions will be greater for theoretical models.

Island biogeography



Lotka-Voltera predator-prey cycles

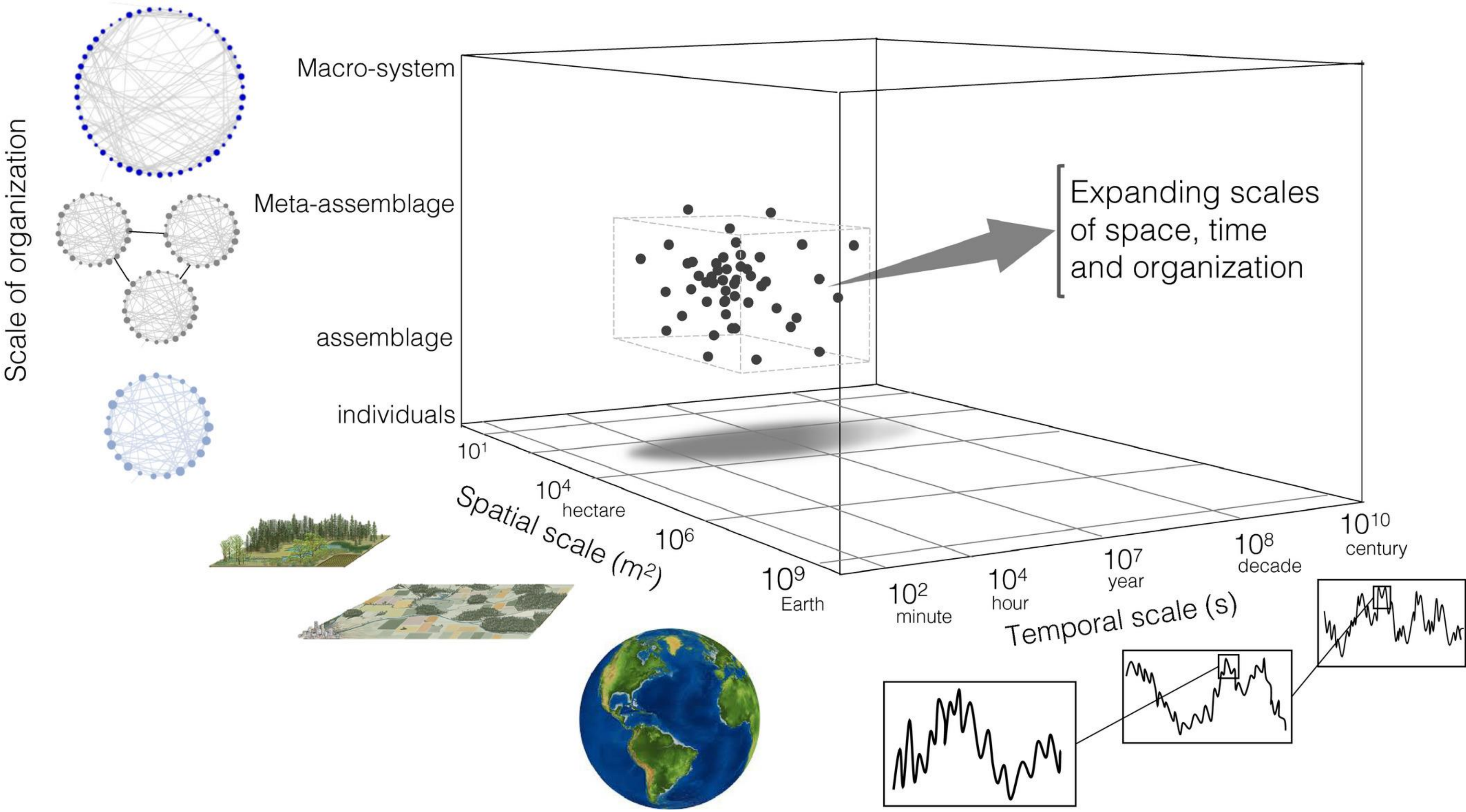
$\dot{x}=xa-by$ $\dot{y}=-yc-dx$



Scale

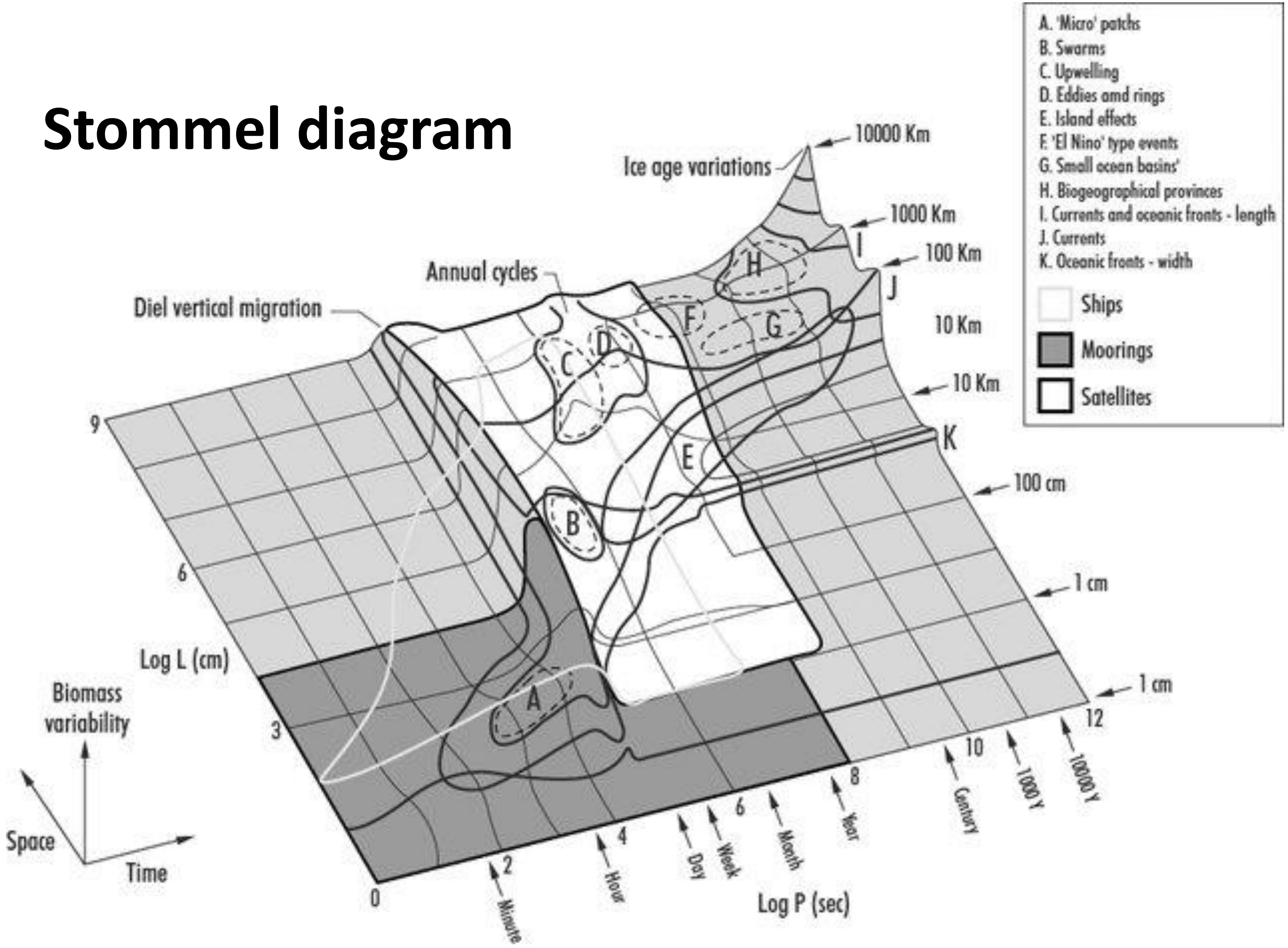
- most ecological questions are scale-dependent.

- technological advances allow us to cover increasingly **larger** and **smaller** scales



Scale

Stommel diagram



Physical oceanographer Henry Stommel created this diagram to emphasize the cross-scale dynamics of the ocean

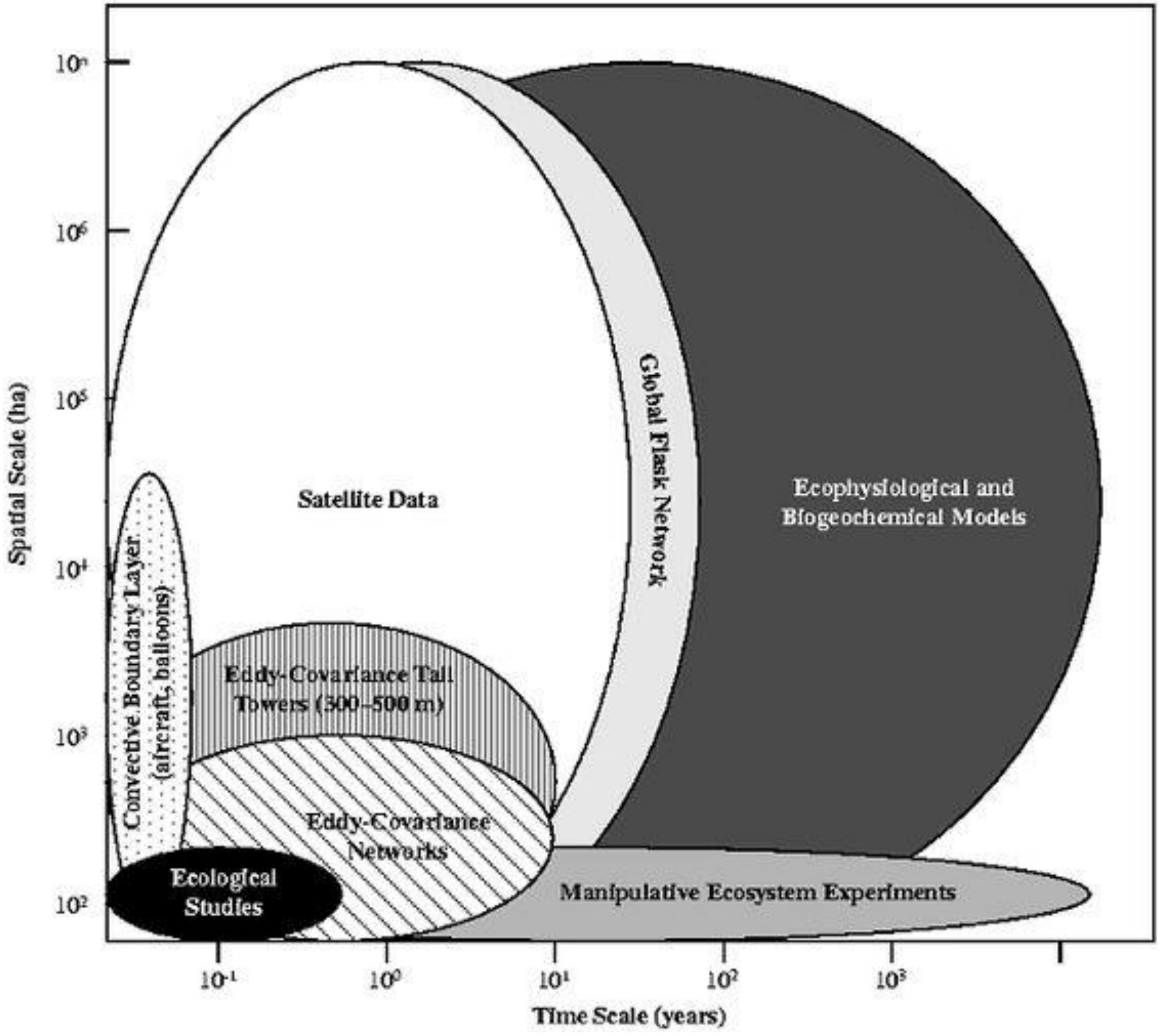
- adapted by biological oceanographers

monitoring & scales

LTER (Long Term Ecological Research)

- In 1980, the NSF (US) funded the first Long-Term Ecological Research (LTER) sites.
- Provide long-term context and knowledge for researchers working on shorter-term projects
- Open access to long-term data
- Develop and maintain large-scale experiments
- Interdisciplinary research
- Training for graduate students in interdisciplinary and collaborative team science

https://lternet.edu/



Some iconic examples...

- **Microcosm experiment** with *Paramecium* spp., testing the competitive exclusion principle
- **Transplant experiment** with barnacles showing how competition affects the distribution of species in the rocky intertidal zone
- Biodiversity-ecosystem functioning experiments
- Whole-lake nutrient enrichment experiments at the Experimental Lakes Area

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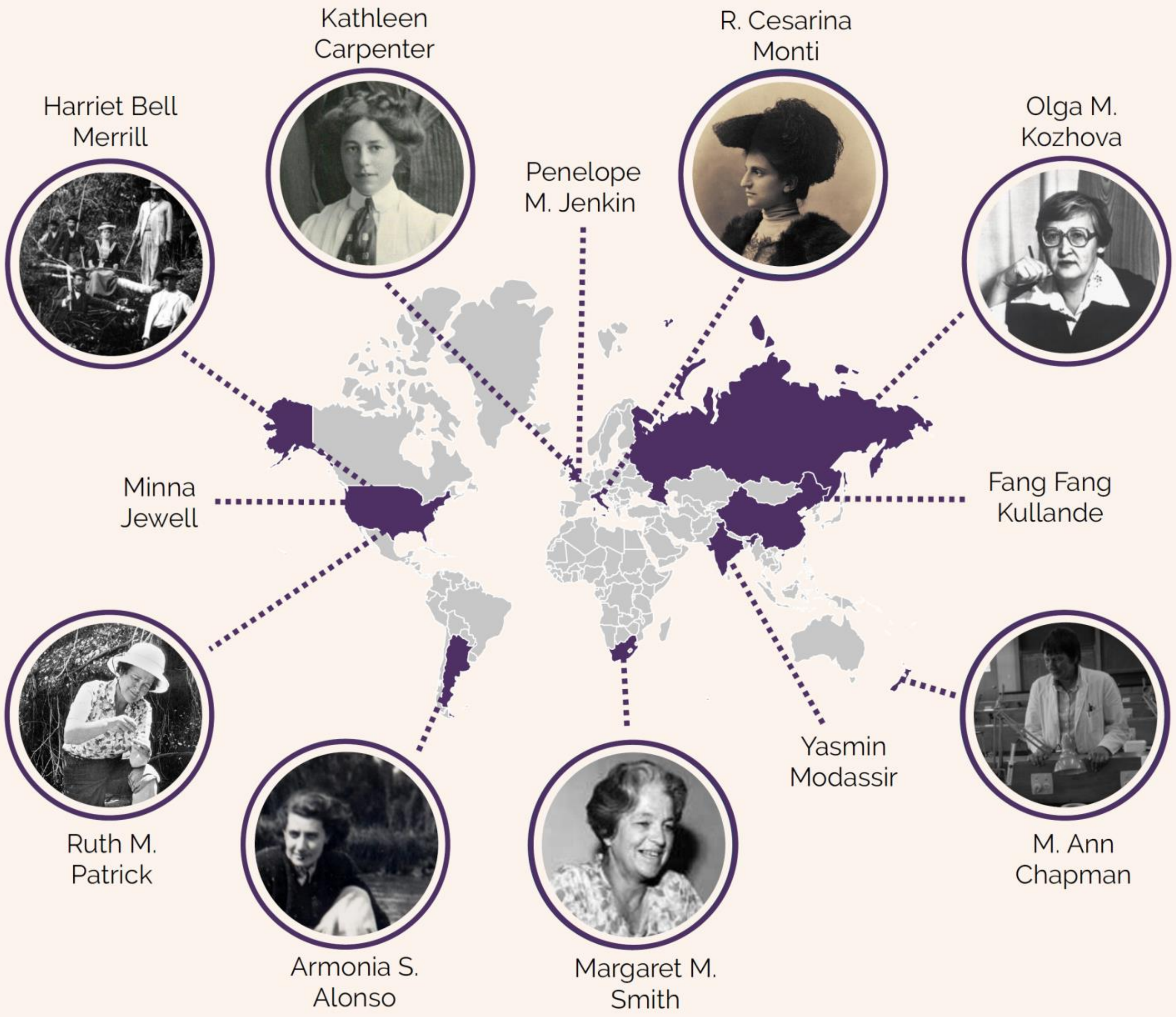
Women in Limnology

www.genderlimno.org



Catalan et al. 2022 WIREs

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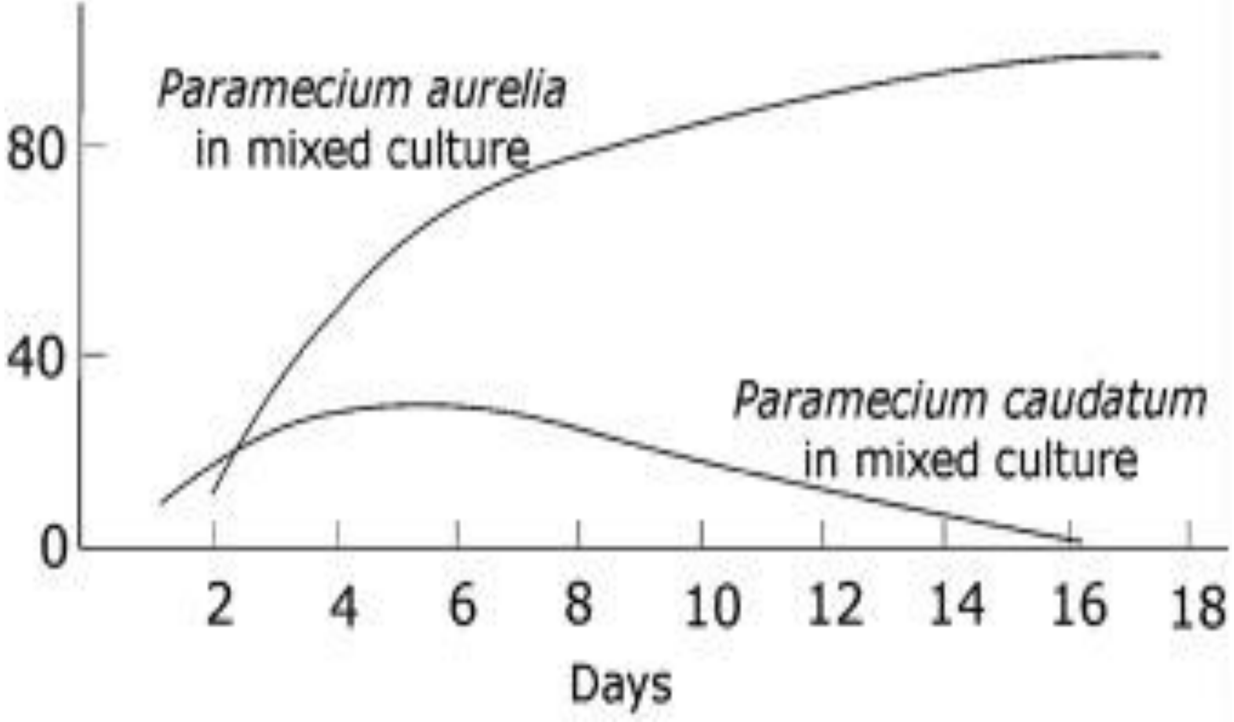
Microcosm experiments

Georgii Gause
1934

Two species of *Paramecium* were placed into flasks with a bacterial culture as food source. Both species were thus forced to share the same niche in this microcosm.

One Paramecium species went extinct, as apparently it was unable to compete with the other species for the single food resource.

Dynamics predicted by Lotka-Volterra model



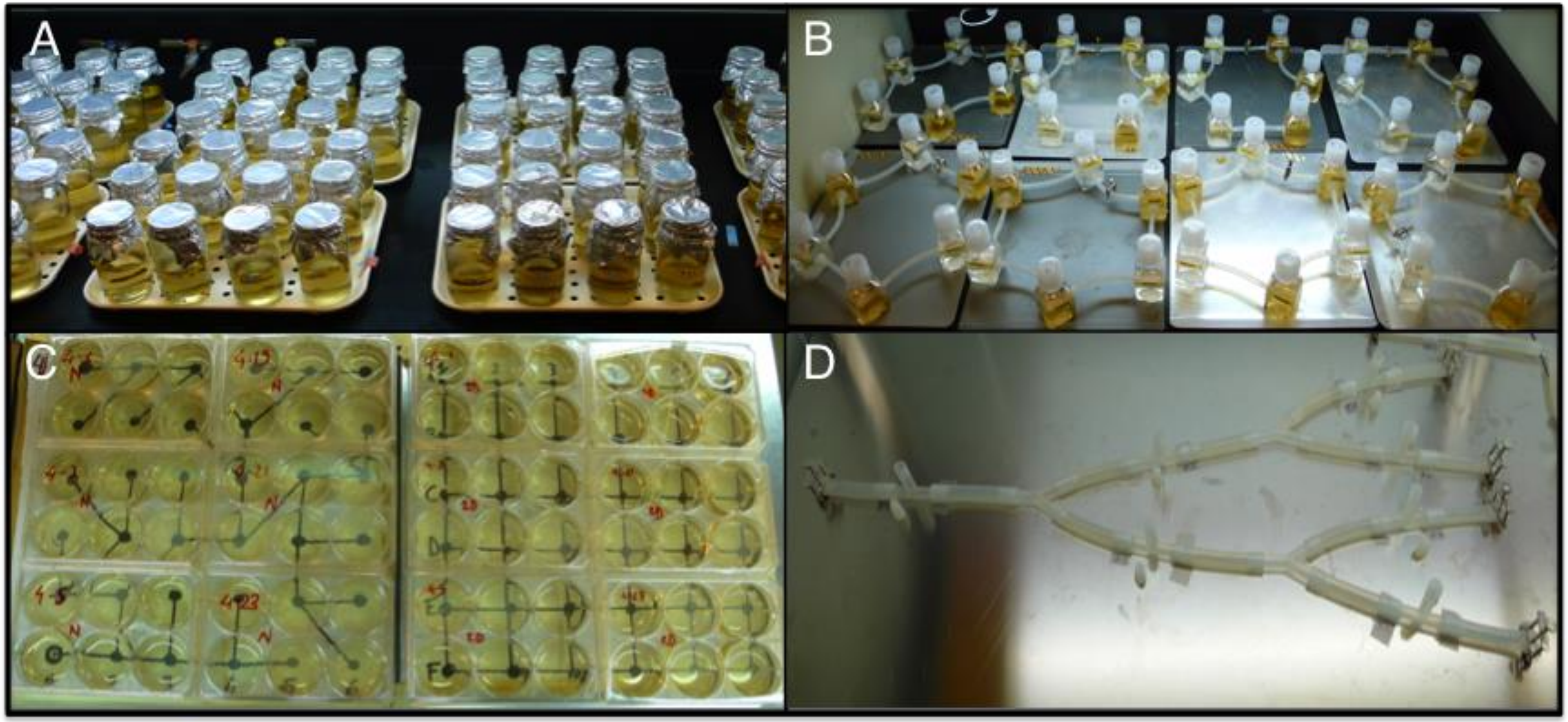
Microcosm experiments

Methods in Ecology and Evolution

Methods in Ecology and Evolution 2015, **6**, 218–231 doi: 10.1111/2041-210X.12312

Big answers from small worlds: a user's guide for protist microcosms as a model system in ecology and evolution

Florian Altermatt[1,2]*, Emanuel A. Fronhofer[1], Aurélie Garnier[2], Andrea Giometto[1,3], Frederik Hammes[4], Jan Klecka[5,6], Delphine Legrand[7], Elvira Mächler[1], Thomas M. Massie[2], Frank Pennekamp[2], Marco Plebani[2], Mikael Pontarp[2], Nicolas Schtickzelle[7], Virginie Thuillier[7] and Owen L. Petchey[1,2]



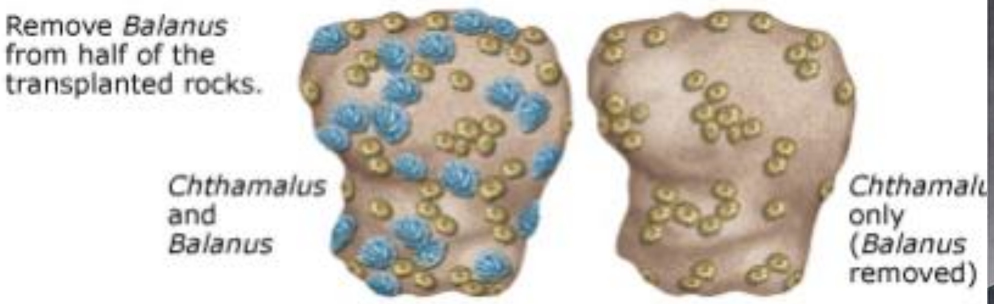
Transplant experiments

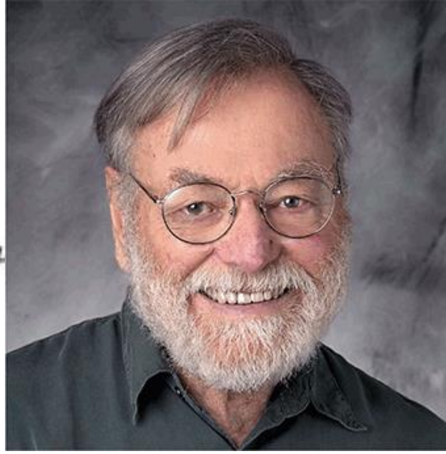
Species often replace another along physical gradient, such two barnacle species in the intertidal zone.

Conell hypothesized that this zonation was maintained by **physical competition** between the barnacles **for space** rather than by different tolerances to physical stresses along the intertidal gradient.

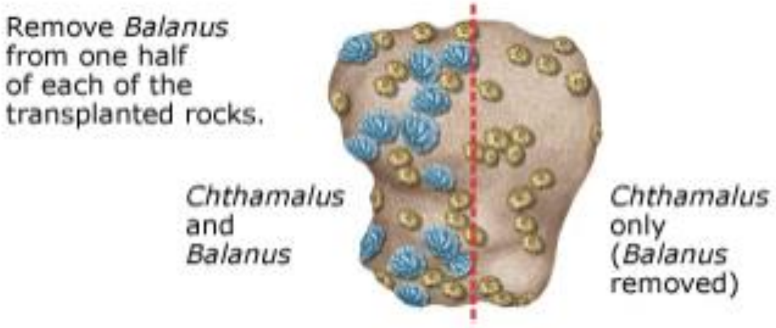
He removed the larger, faster-growing species from rocks and transplanted the rocks between upper and lower zones. The slower-growing species survived to adulthood well outside the upper zone.

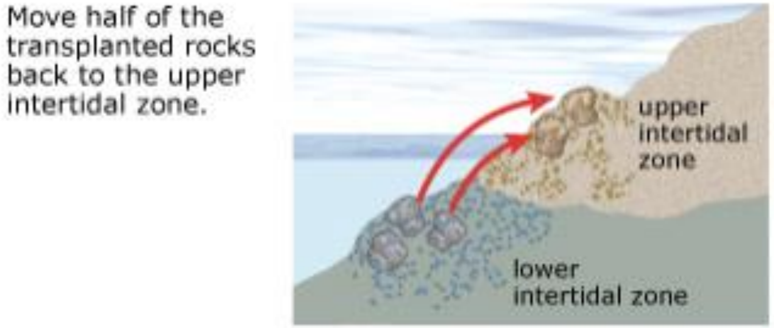
=> Important insights for fundamental and realized niche.





Joseph Conell

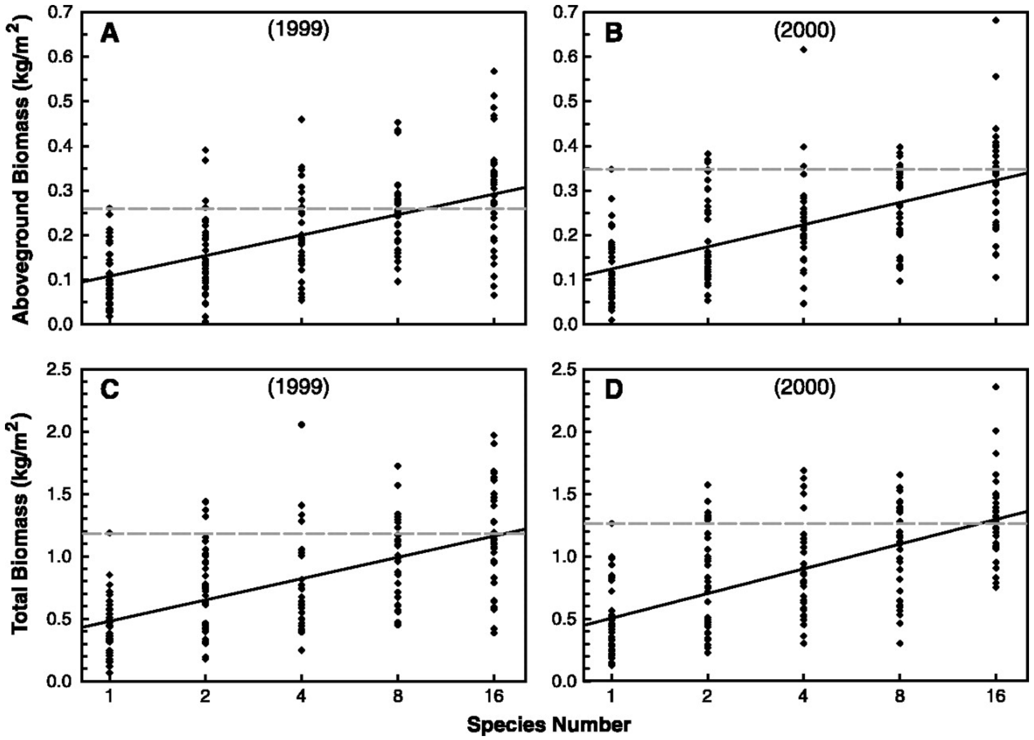




Big Biodiversity Experiment

plots of 9×9 m

manipulation of plant biodiversity



David Tilman

Cedar Creek Ecosystem Science Reserve

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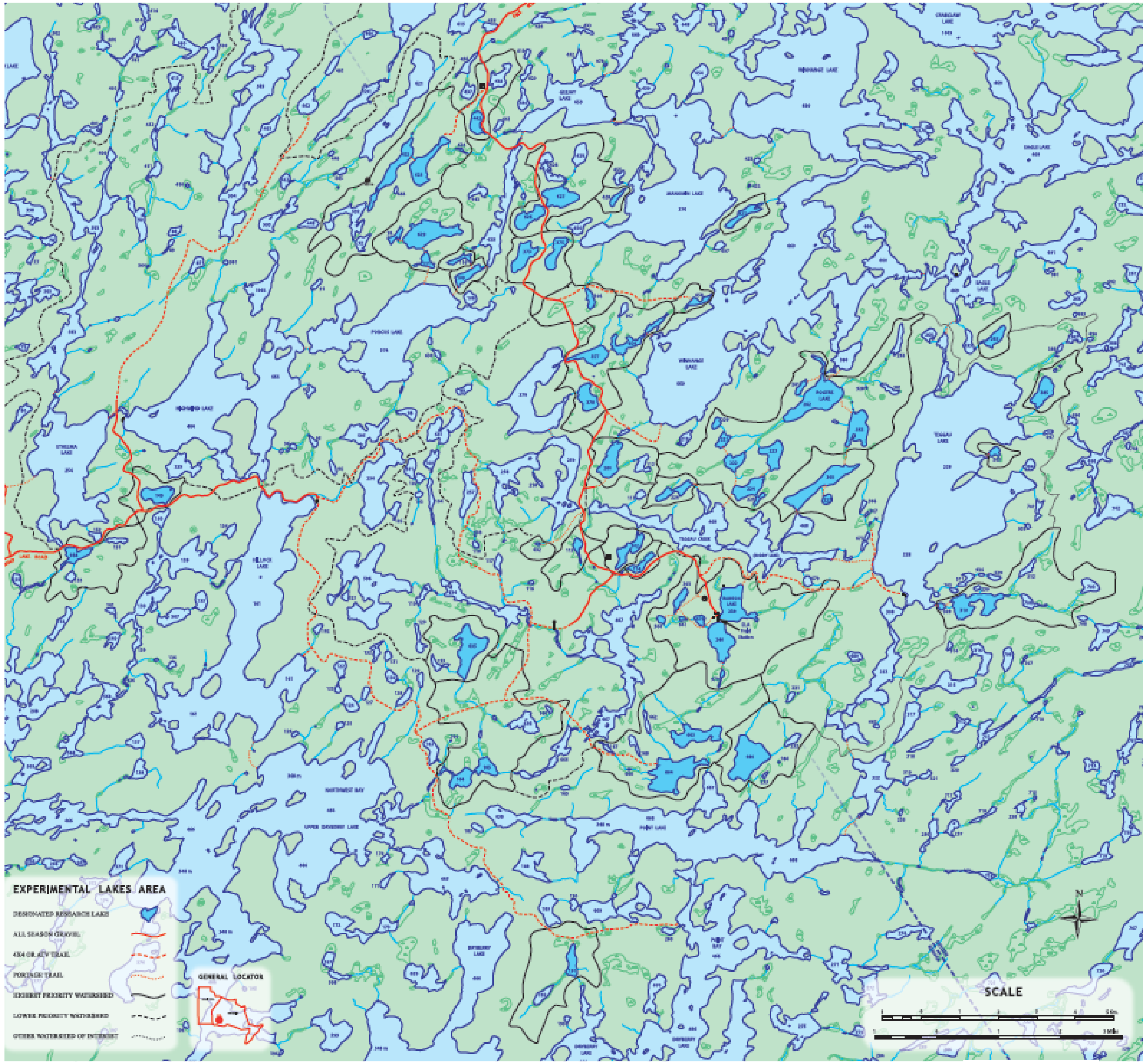
Experimental Lakes Area (ELA)

- The ELA consists of 46 lakes (< 100 ha in surface area), their watersheds, and several streams protected for research purposes in near-pristine boreal forest
- Since ELA's creation in 1968 in Northwest Ontario, Canada, scientists have amassed one of the **longest and most comprehensive data sets on freshwater lakes** in the world.
- Long-term records important to **study climate change and its effects on freshwater lakes** and used for regional and global climate **modelling**
- Experiments on a range of environmental issues:
    - **impacts of nutrients, mercury and other contaminants**
    - **acid rain**
    - **freshwater aquaculture**
    - **hydroelectric reservoirs**
    - **emerging chemicals (e.g. synthetic hormone disruptors, flame retardants, antibiotics)**



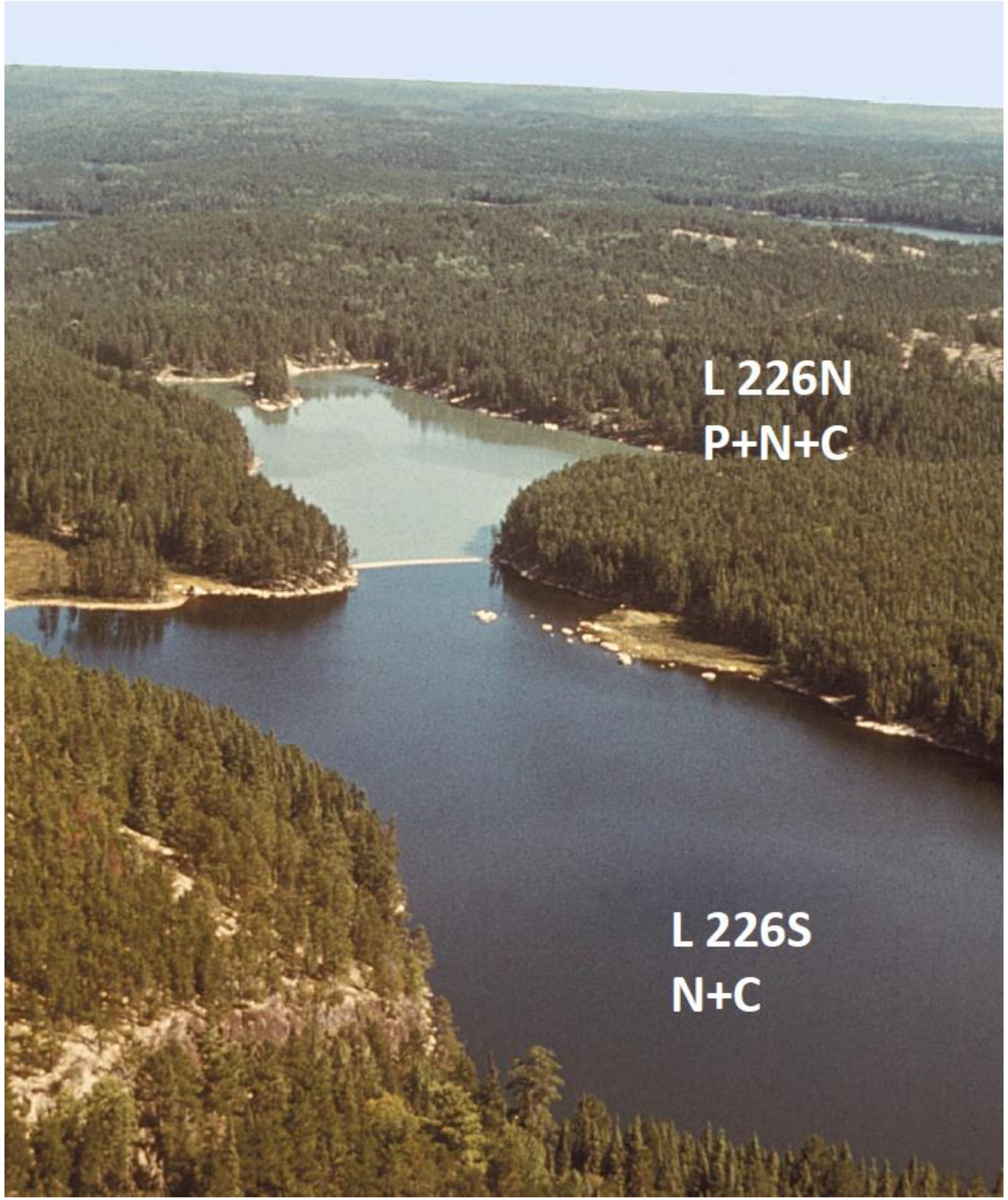
Eutrophication

David Schindler

Lake 227

Before nutrient addition

After adding P+N



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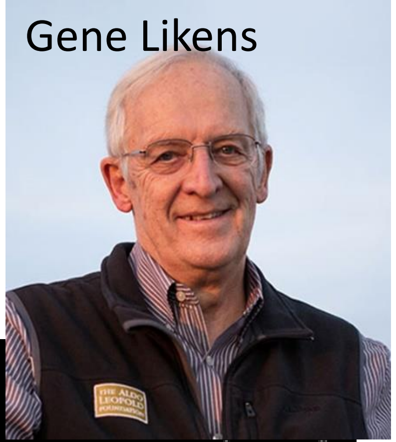
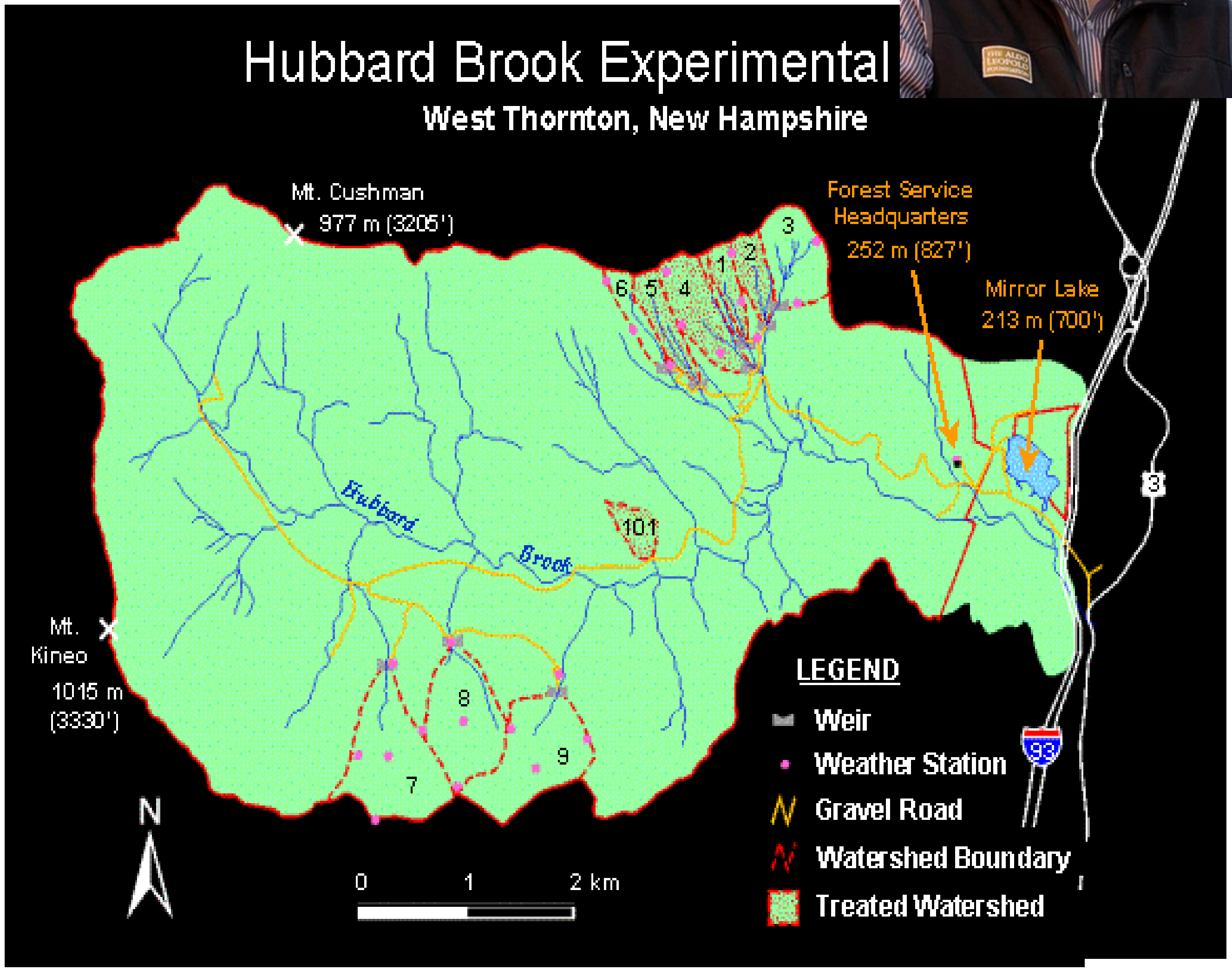
Hubbard Brook Experimental Forest (LTER)



- Study of the biogeochemistry of forests and streams
- Discovery of acid rain in North America and the connection to fossil fuel burning
- important work on deforestation and its potential impact on the chemistry of watersheds

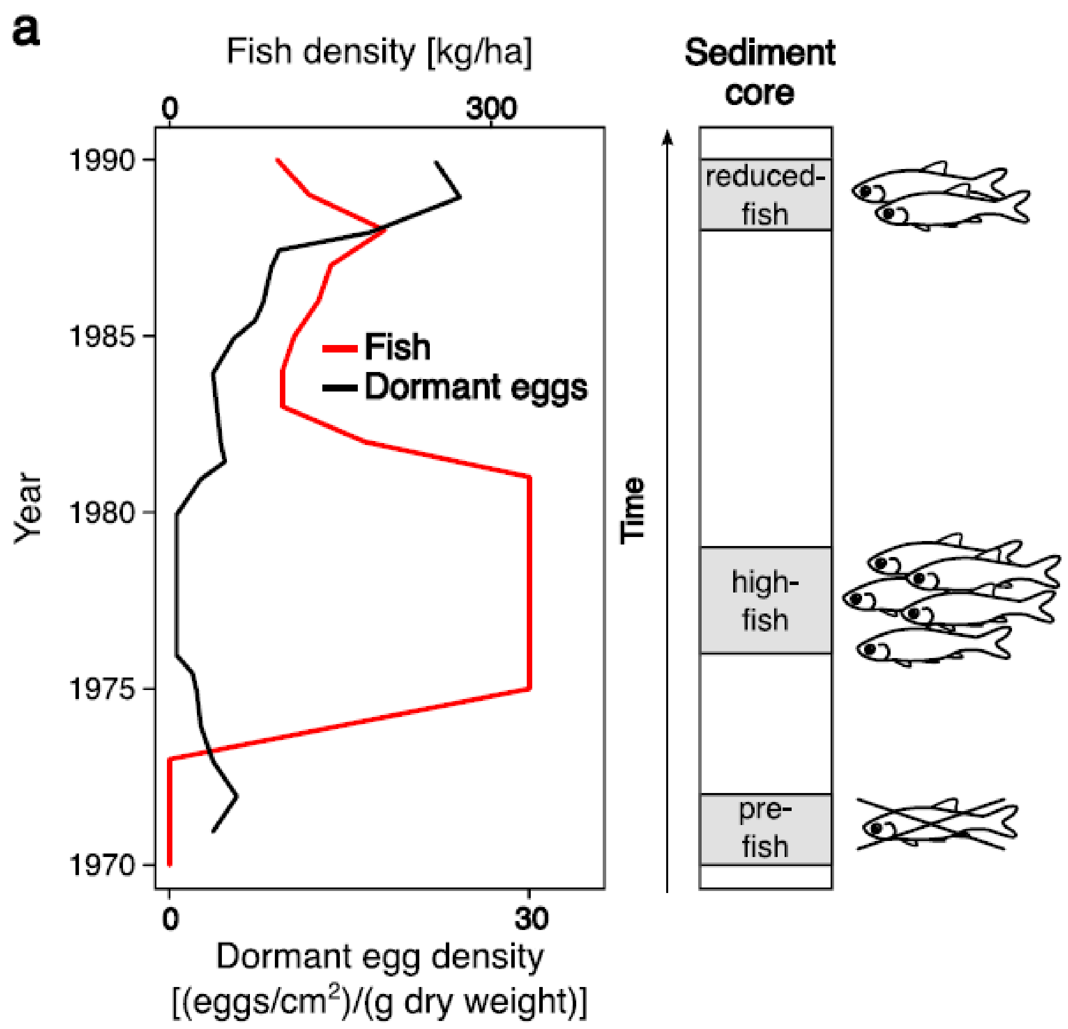


Climate-change experiments

Manipulation of air temperature and precipitation intensity, frequency

- Interactive effects often not accounted for.

Eco-evolutionary feedbacks



Resurrection of resting stages (e.g. dormant eggs of Daphnia) allows «going» back in time

Ecology and evolution often occur on similar timescales
=> eco-evolution feedbacks

Chaturvedi et al. 2021