Introduction to Systems Ecology

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Definitions of Systems Ecology

Systems Ecology is …

"The study of **whole ecosystems** and includes measurements of **overall performance** as well as a study of the **details of systems design** by which the **overall behavior** is produced from separate parts and mechanisms"

H.T. Odum, 1994
Ecological and General Systems: An introduction to Systems Ecology

"… focuses on **the properties of ecosystems** and tries to reveal them by use of a **systems approach**"

Ecosystem theory. Holistic approach

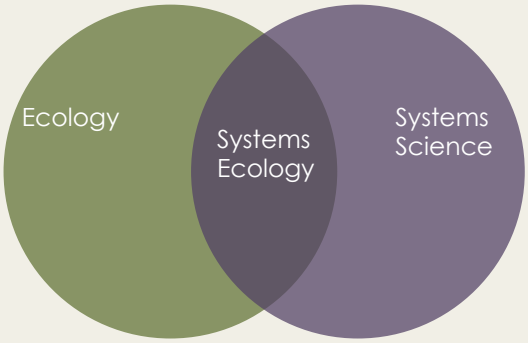
S.E. Jorgensen, 2012
Introduction to Systems Ecology

"…the study of the **development**, **dynamics**, and **disruption** of **ecosystems**.

…two main phases —a **theoretical and analytical phase** and an **experimental phase**."

Van Dyne, 1966
ECOSYSTEMS, SYSTEMS ECOLOGY, AND SYSTEMS ECOLOGISTS

Visually



What is Ecology?

Ecology is …

the scientific study of the relationship between organisms and their environment
Smith & Smith

the study of the distribution and abundance of organisms
Andrewartha & Birch

scientific natural history
C. Elton

that branch of physiology which deals with the organisms as a whole, with its general life processes
V. Shelford

the science of environment
K. Frederick

Ecology is …

By ecology, we mean the body of knowledge concerning the economy of nature --

the investigation of the total relations of the animal both to its inorganic and its organic; including above all, its friendly and inimical relations with those animals and plants with which it comes directly or indirectly into contact --

in a word, ecology is the study of all those complex relationships referred to by Darwin as the conditions of the struggle for existence.

E. Haeckel, 1866

Ecology Foundations

Natural History

Evolution

System Science

F. B. Golley

Borrett, 2013

Ecology is a Science - Scientific Method

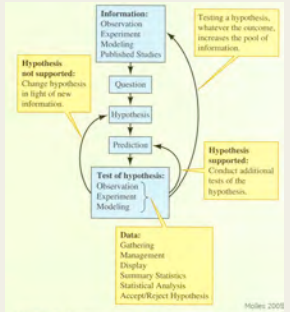


Figure 1 Graphic summary of the scientific method. The scientific method centers on the use of information to propose and test hypotheses through observation, experiment, and modeling.

Epistemic Enhancers

Humphries 2004

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Ecological Levels of Organization

Biosphere

What role does concentration of atmospheric CO_2 play in the regulation of global temperature?

Community

How does disturbance influence the number of species in communities?

Region

How has geologic history influenced regional diversity within certain groups of organisms?

Interactions

How does soil nutrient availability affect the exchange of materials between plants and mycorrhizal fungi (fungi associated with plant roots?

Landscape

How do hedgerows and other vegetated corridors affect the rate of movement by mammals among isolated forest fragments?

Populations

What factors control population growth rates?

Ecosystem

What factors control rate of energy fixation by ecosystems?

Individuals

How do plants or animals regulate their internal water balance?

Figure 1.1 Levels of ecological organization and examples of the kinds of questions asked by ecologists working at each level. These ecological levels correspond broadly to sections II to VI of this book.

Molles 2005

Borrett, 2013

"To solve biological problems by studying only one, in many respects self-contained, organism is impossible"

"We know that an organism in a sphere is not a chance agent – it is part of a complex regular order"

Vernadsky as quoted in Golley 1998

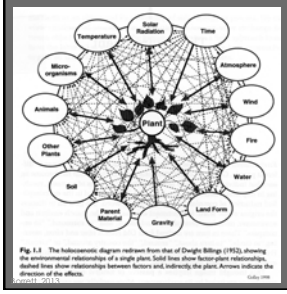
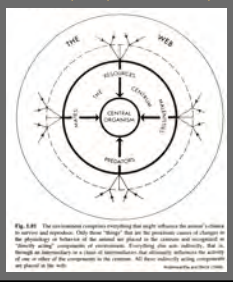


Fig. 1.1 The holocenotic diagram redrawn from that of Dwight Billings (1952), showing the environmental relationships of a single plant. Solid lines show factor-plant relationships, dashed lines show relationships between factors and, indirectly, the plant. Arrows indicate the direction of the effects.



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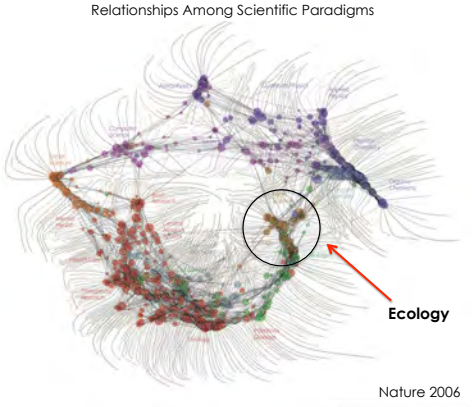
Relationships Among Scientific Paradigms



Nature 2006

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What is Systems Science

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Slinky Demonstration

http://www.buyingamericaback.com/wp-content/uploads/2011/04/slinky-metal.jpg

Slinky Demonstration

The hands that manipulate the slinky release the behavior that is latent within the structure of the spring

As Donella Meadows puts it,
this is the central insight of systems theory:

There exists a relationship between structure and behavior.

What is a System?

System Definition: Working definition 1

A set of *things*/objects/subjects inter-connected by one or more *relationships* such that they generate *behavior*.

$$S = \{T, R\}$$

A system can be forced by external influences, but its behavior is in part generated by its own structure.

Klir 2001

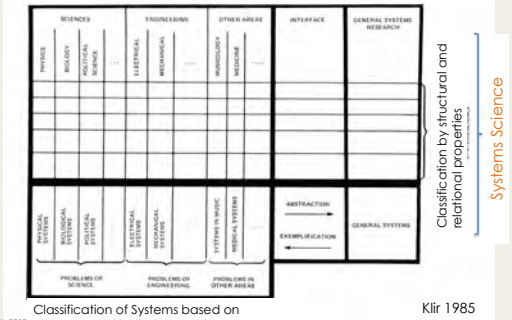
Systems Theory Promise

By understanding the relationship between system organization and their behavior:

- We can understand the system
- We can better manage the system
- We can adapt to the possibilities of the system

Systems Science: Two ways of Classifying Systems

(a) Set of systems based on **things**
(b) Set of systems based on **relationships**



Classification of Systems based on Phenomena Studied or Problem Type

Klir 1985

Systems Science

Domain of SS

Relational properties valid for particular classes of systems

Knowledge of SS

Knowledge regarding classes of relational properties of systems
Emergent properties or behaviors

Methodology

Modeling
Simulation
Analysis
The computer is the laboratory for systems science

Focal Questions

What is the organization of the system?
- Components, relationships, boundaries, environments, external forcing

What are the consequences of system structure?
- Behavior (potential and realized)
- How can it be managed, manipulated, or controlled

What forces caused the system to assemble in its current form?
- Attractors?
- Goal functions?

How can the system change over time?

Systems Ecology Reconsidered

What is Systems Ecology?

Systems ecology
uses the concepts and tools of *systems science* to investigate ecological systems, questions, hypotheses.

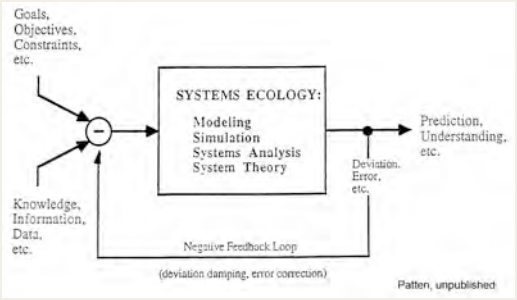
Some Characteristics

Tools include modeling, simulation and systems analysis

Tend to include humans as "just another organism"

More than just ecosystem theory

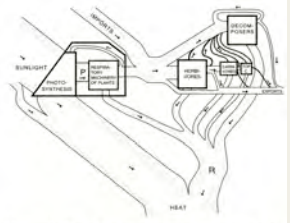
Elements of Systems Ecology



Systems science applied to ecological systems

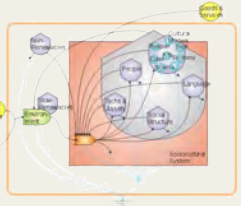
III. Examples

Ecosystem Energy Flux

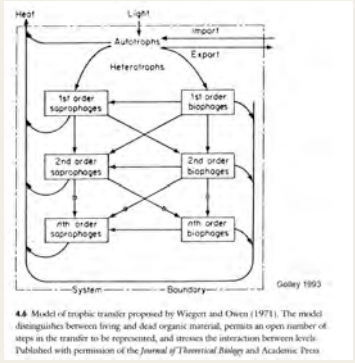


4.5 Howard T. Odum's diagram of energy flow in natural communities, used for his study of Silver Springs, Florida (Odum, 1957). In the diagram, *P* symbolizes the gross primary production, *R* is total community respiration. Trophic levels are indicated by square boxes, and the size of flows are roughly indicated by the width of the stream. Published with permission of the Ecological Society of America Golley 1993

H.T. Odum

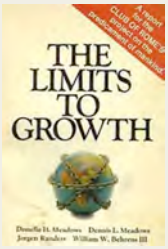


Wiegert & Owen's Trophic Transfer



4.6 Model of trophic transfer proposed by Wiegert and Owen (1971). The model distinguishes between living and dead organic material, permits an open number of steps in the transfer to be represented, and stresses the interaction between levels. Published with permission of the *Journal of Theoretical Biology* and Academic Press.

Limits to Growth



1972

In their words ….

- For the first time, computer based models were used to describe sustainable and disastrous scenarios.
- The report started an intensive discussion about the future of humankind.
- Used Forrester's Systems Dynamics technique and combined social, economic, ecological and biospheric ideas

http://www.clubofrome.at/

Additional Examples to Come

- Aquatic Ecosystems
- Ecosystem Theory
- Urban Ecosystems

II. Origins

Origins of Systems Ecology

General Systems Theory

- Bertalanffy (1920s) – proposed General Systems Theory
- Wiener (1948) – Cybernetics
- Jay Forrester (1950s @MIT) – Systems Dynamics

4 Epicenters of Systems Ecology (1960s and 70s)

C.S. Buzz Hollings (Canada, then Florida)

Oak Ridge National Laboratory
S. Auerbach
J. Olson
G. Van Dyne
B.C. Patten (then Georgia)

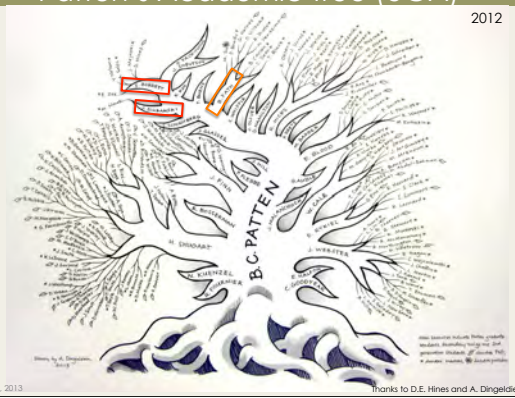
K. Watt (California)

H.T. Odum (North Carolina, then Florida)

Golley 1996

Patten's Academic Tree (UGA)

2012



Thanks to D.E. Hines and A. Dingeldein

Van Dyne (1966)

Systems Ecology requires a new kind of scientist

- Able to use mathematics
- Having a synthetic mind
- Willing to deal with applied problem solving

…More than the outgrowth of systems or operations research and cybernetics.

Golley 1993

Borrett, 2013

Another Perspective

Operations Research
Electrical Engineering
Chemical Engineering
Computer Science
Biology & Ecology
Cybernetics
Thermodynamics
Feedback Control Systems
Mathematics & Statistics

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Systems Ecology Foundations

Thermodynamics

Networks

Information

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V. Concluding Thoughts

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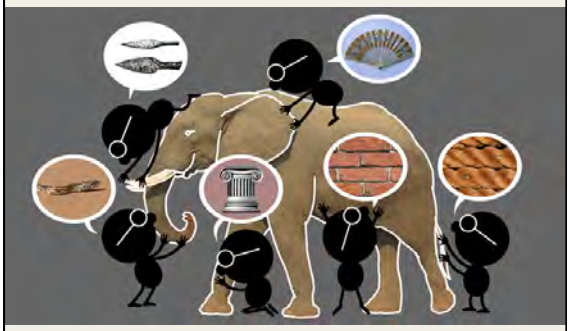
Parable of the Blind Men and the Elephant



http://blog.ninapaley.com/wp-content/uploads/2009/12/BlindMenElephant_720.png

Ancient Sufi Story

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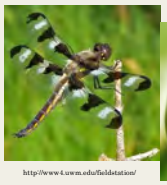
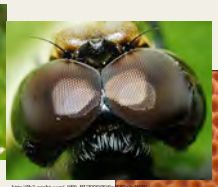
Multiple Lenses to…

see more with ecological data



http://www4.uwm.edu/fieldstation/



http://jannrik.net/MiscSubj/2010/DragonflyEye20101026/PMax_1690-1782_Surface.jpg

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Systems Ecology Foundations

Thermodynamics

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