MODELLING METHODS IN
SYSTEMS ECOLOGY

I. INTRODUCTION TO SYSTEMS ECOLOGY
SYSTEMS ECOLOGY

Theoretical: ecosystem theory

Analytical: conceptual and modeling theory

Experimental/application: modeling tools

SYSTEMS ECOLOGY - Theoretical

Background of:
- Systems
- General system theory
- Ecology and Ecosystem ecology
SYSTEMS ECOLOGY- Analytical

Background of:
- Ecological modeling
- Modeling elements
- Modeling procedure
- Conceptual models

SYSTEMS ECOLOGY- Experimental

Background of:
- Models from data
- Models from hypotheses
- Models from existing knowledge
SYSTEMS ECOLOGY - Theoretical

Background of:
- Systems
- General system theory
- Ecology and Ecosystem ecology

T-System

"Any phenomenon, either structural or functional, having at least two separable components and some interaction between these components may be considered a system."
Hall, Day

"The whole is more than the sum of parts."
Bertalanffy

Common to the most definitions: ”A system is a combination of parts that interact and produce some new quality in their interaction”. 
T-General systems theory

- Science about **abstract properties** of systems.

- It attempts to find **commonality** in things as diverse as atomic particles, ecosystems and political parties.

- It was defined in 1940’ and 50’by Ashby and Ross (1961 - cybernetics) and Bertalanffy (1969 - GST).

---

T-General systems theory

- The idea: ”**Whatever object interact, they must do so in certain well-defined ways.**”

- They hoped that **patterns** of interaction would be **fairly limited** / they could be **cataloged** = > This has **not come** to pass.
**T-General systems theory**

GST offers to systems ecology:

- A structured **world-view**.
- A structured **approach to problem** solving.
- A theory of possible system **behavior**.
- A **set of power techniques** for analyzing system behavior.

---

**T-Ecology**

Ernest Heinrich Haeckel (1866):

- Ecology: *Oikos* = household, home
  *Lagos* = knowledge

- Ecology = Economics of nature

"The body of knowledge concerning the **economy** of nature – the investigation of the total relationship of the **animal** both to its organic environment; including, above all, its friendly and inimical relations with those animals and plants with which it comes directly or indirectly into contact – in a world ecology is the study of those complex interrelations referred to by Darwin as the conditions for struggle for existence. ”
T-Ecology

living system : environment : science

What is a living system?
- Open self-organizing thermodynamic system
- System consists of elements that exchange energy and matter through semipermeable membranes with its environment
- Function of living system is to perform matter-energy transformations
- Elements of living system are interrelated with flow of energy and matter cycles
- Outputs from one component are inputs for another component: production-consumers structure
- Part of the energy and matter flows is used for control
- Physical structures that use energy and matter form their environment for growth and development and have hierarchical structure

What is an environment?
- Set of elements that are not part of living system but are inseparable from it
- Set of conditions (biotic and abiotic) to which living system is exposed
- Abiotic elements: elements of non living environment => source and sink of energy and matter, they put physical constraints to living system (climate, soil conditions) => very unpredictable dynamic systems
- Biotic elements: living creatures in interactions with living system => different types of interactions: source of food, effects on elements of non living environment
T-Ecology

• Permanent attempts toward deeper definition:

“The study of structure and function of the nature.” (Odum 1971)

“The scientific study of the relationship between organisms and their environment.” (McNaughton and Wolfe 1979)

“The study of organisms and their environment – and the interrelationships between the two.” (Putman and Wragten 1984)

“The study of the patterns of nature and how those patterns came to be, and how they change in space and time” (Kingsland 1985)

“The study of the relationships between organisms and their physical and biological environment” (Ehrlich and Roughgarden 1987)

T-Ecology

• Functional definition - the most suitable and applicable:

“Ecology works at characterizing the patterns seen in nature, studying the complex interactions among organisms and their environment, and understanding the processes involved in biological diversity.”
T-Ecology

Development of Ecology:

• According to the object of interest:
  • Plant ecology
  • Animal ecology
  • Population ecology
  • Community ecology
  • Ecosystem ecology

• According to the object of application:
  • Ecological Economics
  • Ecological Informatics
  • Ecological Engineering
  • Ecosystem based management
  • Nature protection
  • Conservation biology
  • Restoration ecology
  • Landscape ecology
  • Ecological Modelling

T-Ecosystem ecology

Mailstones in development of ecosystem ecology

Henry Allan Gleason (1882–1975):

- Plant community is composed from *randomly selected species* that have adopted to prevailing environmental conditions on particular site.
- Community is not handicapped if some of the species are eliminated from it. It’s properties are just the sum of its parts.
T-Ecosystem ecology

Mailstones in development of ecosystem ecology

**Frederic Edward Clements** (1874-1945):
- Plant community is like living organism – super-organism and its properties are defined by the interactions between the its components.

**Charles Sutherland Elton** (1900-1991):
- Trophic interactions between species are crucial for existence of plant or animal community
- Pyramid of numbers is introduced as the indicator of the stability of community structure
- Concepts of food chains and nutrient cycling are introduced in studies of communities
Organisms that compose the community are under permanent influence of its environment and they make influence on the environment as well.

Community and its physical environment are linked together.
T-Ecosystem ecology

sir Arthur George Tansley (1871-1955)

1935: "...We can not separate (the organisms) from their special environment with which they form one physical system... it is the system so formed which (provides) the basic units of nature on the face of the earth... These ECOSYSTEMS, as we may call them, are of the most various kinds and sizes"

---

T-Ecosystem ecology

Bitoic and abiotic components of ecosystem can not be studied separately
Biotop + biocenosis = ecosystem (bio-geo-cenozis)
What is a science?
Science (from the Latin *scientia*, meaning "knowledge" or "knowing") is the effort to discover, and increase human understanding of how the physical world works. It applies systematic approach to derive cognitions and knowledge about studied phenomena:

<table>
<thead>
<tr>
<th>Two approaches:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Analytical</td>
<td>Holistic</td>
</tr>
<tr>
<td>parts</td>
<td>wholeness</td>
</tr>
<tr>
<td>elements</td>
<td>processes</td>
</tr>
<tr>
<td>classification</td>
<td>relations</td>
</tr>
<tr>
<td>structure</td>
<td>patterns</td>
</tr>
<tr>
<td>quantity</td>
<td>quality</td>
</tr>
</tbody>
</table>
Systems ecology

Definitions:
- The new ecology deals with the **structure and function** of levels of organization **beyond** that of the individual and species.” E.P. Odum
- “Systems ecology is the **application** of general system theory and methods to ecology” B. Patten
- “Systems ecology is the application of general system theory and methods in ecology and introduction ecological modelling based on calculations performed with computer” H.T. Odum.
- “Branch of **ecosystem ecology** (the study of energy budgets, biogeochemical cycles, and feeding and behavioral aspects of ecological communities) that attempts to clarify the **structure and function** of ecosystems by means of **applied mathematics**, mathematical **models**, and computer **programs**.” Encyclopedia Britannica

Systems ecology

- **Not** a hypermathematical, abstract study.
- It deals quite well with **qualitative** data as well.
- SE aims to incorporate in logical structure as much of scientist’s **intuition** and **feelings** for an ecosystem as possible.
- SE is the study of the development, dynamic and disruption of ecosystem.

**Systems ecology = mathematical rigor + predictive power of general systems theory + tools from operational research and engineering + knowledge of natural history and ecology**
Systems ecology

**CONNECTEDNESS**
- Properties of the whole are not similar to any property of its parts

**RELATIONSHIPS**
- Characteristics of the whole emerge from the interactions between its parts
- Characteristics of the system must be recognized in the context of its function for the system in which it is embedded
- Systems ecology is focused on the principles of organization of the system and not on its parts

**CONTEXT**
- Systems ecology applies both system and analytical thinking.
- Systems ecology is focused in process and nonlinear approaches.

**Systems ecology**

It involves:
- Construction **conceptual models** of ecosystems
- Statistical **manipulation** of data
- Building **dynamic models** of ecosystems
- **Computer simulation**
- Applying **systems analysis** techniques to ecosystem models
- Using of all above to formulate **new hypothesis** and **tests** for hypothesis in the field
Systems ecology

Energy flow diagram of an agroecological system

Systems ecologist

- Can **not be expert** with each analytic tools but he/she must be **aware** of their applications and limitations in the study of components and processes of ecosystem.

- He/she must be **able to talk** with the specialists in other disciplines.
- Systems ecologist

- He/she will still **require** tools of conventional ecology, but he can not rely on them alone.

- **Problem** should dictate the tool to be used and the opportunity to use a complex tool **should not dictate** the problem to be studied.

- **Systems ecologist**

- The systems ecologist is a **specialist in generalisation**.

- Applied ecologists (e.g. foresters) are closer to systems ecologist then conventional ecologist.
Systems ecologist

- He/she will require **better education** in mathematical, computer, chemical and physical subjects than **conventional** ecologist.

- He/she must have abilities to **coordinate** interdisciplinary team of workers – multidisciplinary nature of systems ecologist.