PhD Program:
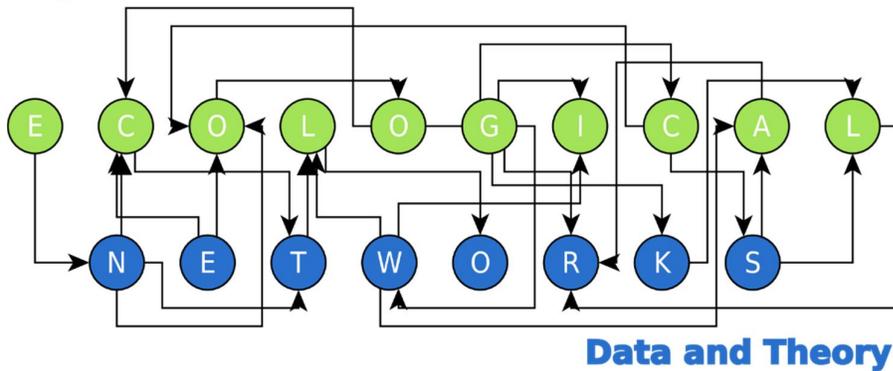# Evolutionary Biology and Ecology
University of Parma, Ferrara and Florence (Italy)

International Summer School

TITLE 2017 EDITION: "Networks in ecology"

June 13-15, 2017 University of Parma (Italy)

"There are always connections; you have only to want to find them"
Umberto Eco - Foucault's Pendulum

ð*Nothing is more practical than theory*ö
Richard Levins, Harvard University

Course Description

Networks are a paradigmatic example of complex systems in nature and ecology is one discipline that contributed to the development of network science. The first graphical representation of a food web dates back to 1880, with the pioneering work of Lorenzo Camerano, and nowadays the application of network theory in ecology involves a variety of interaction types that range from trophic relationships (i.e. predator-prey interactions) to plant-pollinator and host-parasite webs. Although networks are routinely used to represent species and their relationships in the ecological communities, they are effective tools for mapping interactions at different levels of the ecological hierarchy (e.g. social networks to depict interactions among conspecific individuals or landscape networks to model metacommunity dynamics). The last frontiers of research in ecology identify networks as ideal means to understand the complexity hidden in ecological systems and that is responsible for their functioning.

The Summer School aims to introduce network analysis and its application to ecological systems. It is intended for graduate students and early postdocs but participation is possible to anyone who has interest in studying ecological networks. The School will introduce theoretical aspects of network theory and show practical examples for the analysis of ecological networks. Theoretical lessons will be followed by practical exercises on network analysis and visualization. In particular, the 2017 edition of the Summer School will focus on three approaches to study ecological networks: network analysis to characterize the functioning of energy flow networks, qualitative modelling of ecological systems and food web analysis.

Instructors

Antonio Bodini
Department of Chemistry, Life Science and Environmental Sustainability, University of Parma, Parma, Italy

Ferenc Jordán
Centre for Ecological Research, Hungarian Academy of Science, Budapest, Hungary

Marco Scotti
GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany

Syllabus

Tuesday, June 13

09:00-09:15
Antonio Bodini (Director of the School)
Welcome to participants, presentation of the School

Instructor: **Marco Scotti**

Title - Algorithms for ecological network analysis (ENA)

Morning (9:30-13.00)

1) Weighted food webs: who eats whom, and at which rate?
   - Ecological network analysis (ENA), a suite of matrix manipulation techniques for the systematic analysis of ecosystem flow networks.
   - Four types of flows: imports, inter-compartmental exchanges, exports and respirations.
   - From the graphical representation to matrices and vectors.
   - Network construction and evaluation of steady-state conditions.

2) Ecological network analysis (ENA).
   - Input-output analysis: partial feeding matrix and partial host matrix; Leontief structure matrix and output structure matrix; total dependency matrix and total contribution matrix; input analysis and output analysis.
   - Trophic analysis: the trophic position of species in ecosystems; the Lindeman spine; the trophic transformation matrix.
   - Cycling analysis: magnitude of cycles (Finn cycling index); structure of cycles (number of nodes in cycles of different length and list of nodes involved in cycles).
   - Whole system indices derived from information theory: total system throughput; average mutual information; ascendency; development capacity; overhead.

3) Application of ENA algorithms to real case studies.
   - Detecting stress at whole ecosystem level: the case of Santo Lake.
   - Supply security in the European natural gas pipeline network.

Afternoon (14.30-17.30)

1) Exercises on ENA using R.
   - How to import data on weighted networks and evaluate the presence of steady-state conditions.
   - Input-output analysis to investigate the magnitude of both direct and indirect effects in ecosystems.
   - How to characterize the trophic structure of weighted food webs.
   - Finn cycling index to quantify the amount of cycling in ecosystems.

2) Network visualization in R.
   - Plotting networks using the *igraph* library; importing network data either as an edgelist or as a matrix.
   - Plotting parameters (node and edge attributes); network layouts.

Wednesday, June 14

Instructor: **Antonio Bodini**

Title - Qualitative models of complex systems

Morning (9:00-13.00)

1) Representing ecosystems and social-ecological systems using signed digraphs.
    - From differential equations to signed digraphs.
    - Links, paths and feedbacks.
    - Empirical rules to represent ecological communities by signed digraphs.

2) Making predictions with signed digraphs.
    - The algorithm for predictions.
    - The table of predictions as a diagnostic tool.
    - Model predictions and data.
    - A simple algorithm in R to make qualitative predictions.

Afternoon (14.30-17.30)

1) Using field data and qualitative predictions to understand cause and effect in ecosystems
    - Case study: Vegetation, herbivores and fires in savanna ecosystems. The students will be requested to build up the models for the savanna ecosystems; obtain the table of predictions. They will be asked to use long term data taken from different savanna ecosystems (literature will be provided) to compare observed trends with predictions and derive cause and effect mechanisms responsible for the phenomenon called bush encroachment.

Thursday, June 15

Instructor: **Ferenc Jordán**

Title - Ecological networks: a hierarchical view

Morning (9:00-13.00)

1) Food webs: indirect relationships in trophic systems. Interaction properties (strength, direction and sign). Non-trophic interactions. Predator-prey interactions, trophic cascades. Keystone species.

2) The network perspective, network analysis - some general basics. Degree, distance, equivalence.

Afternoon (14.30-17.30)

1) Case study: the Prince William Sound network. Local and global properties (TI, TO, K indices and their relevance).

2) Variability, dynamical considerations and potential applications. Spatiotemporal variability, dynamical models, sensitivity analysis, community response. Fisheries management.

3) Outlook: network hierarchy from social to spatial systems. Social networks, landscape graphs. Networks as vertical links among levels.

Equipment and software requirements

Software tools needed (participants are requested to download these software tools):
- GRAPH: http://www.cosbi.eu/research/prototypes/graph
- R: http://www.r-project.org/
the *igraph* and *cheddar* libraries for R should be downloaded and installed
- Cytoscape: http://www.cytoscape.org

Registration

Enrollment is restricted to the first 40 registrants. Enrollment is free of charge but candidates are requested to provide on their own for travel accommodation and living expenses. Registration will be open until the School opening (June 13, 2017). Earlier registration can be achieved by electronic mail to antonio.bodini@unipr.it (Antonio Bodini, Director of the Summer School).

A certificate of attendance will be given to the participants.

Attendants are required to bring their own laptop for doing exercises in the afternoon sessions. We advise the participants to download the free software tools and libraries in advance to secure the proper use during the Summer School.

Date and Location

The course will be held from June 13 to June 15, 2017 at the University Campus, Centro Didattico Polifunzionale (see map below) Parco Area delle Scienze, Parma (Italy). From train station or city center the University Campus is served by bus n. 7, 21. The last stop of the bus is right in front of the Centro Didattico Polifunzionale.

CAMPUS MAP

Main entrance from Via Langhirano (bus n. 7, 21)

Where the course will be held Centro Didattico Polifunzionale