Ecological Modelling 368 (2018) 33–40

Contents lists available at ScienceDirect

Ecological Modelling

journal homepage: www.elsevier.com/locate/ecolmodel

Notes from an introductory course on Field Systems Ecology

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ARTICLE INFO

Article history:
Received 4 July 2017
Received in revised form 5 September 2017
Accepted 13 November 2017

Keywords:
Systems ecology
Field ecology
Class laboratory exercise
Models
Observation and measurement

ABSTRACT

For over 40 years, Professor Bernie Patten, offered a course on Field Systems Ecology at the University of Georgia in Athens, Georgia, USA. The course combined systems analysis approaches and natural field ecology in a way that gave the students new perspectives on making conceptual and formal models of the natural world. The course employed extensive use of outdoor field laboratories at a nearby park, which had multiple ecological habitats. The main progression was to go from simple observations to “seeing systems” to modeling by learning how to ask pertinent systems-oriented questions. This started with a structured walk through the six identified subsystems (forest ridgetop, forest slope, field, lake, stream, and wetland) and proceeded to specific field sampling techniques for the terrestrial and aquatic environments. In addition to the field labs, the course required two weekend camping trips, one to the Great Smokey Mountain National Park in the Appalachian Mountains and one to the Okefenokee Swamp/Cumberland Island National Seashore. The idea was to use the two weekend trips to frame the local watershed scale processes at the continental scale. In this manner, students could observe and measure ecosystem processes and interactions at multiple scales. The notes, which are reproduced below, have been further modified for use at Towson University which utilizes a local park in Baltimore County called Oregon Ridge Park and weekend trips to Catoctin National Park and Chesapeake Bay. The general approach of these notes should have universal appeal to anyone teaching or taking a systems ecology course.

1. Introduction: background and overview

A goal of the class is to give the student the background necessary to be able to look at a particular habitat and understand, at least on a small scale, the linkages that make it a functioning unit within the whole of nature. In order to get this understanding, our way of looking at nature must be altered from that of individual units and their interactions to that of the whole. What is a unit in one study may become the whole in another (that is the basis for hierarchical organization). Thus, a global study, with the earth as the whole, may consider each continent as a unit, while a study of the Mid-Atlantic United States may consider the Piedmont a unit among various landscape types. Although we may work on vastly different scales, we cannot forget that what is outside our defined whole can influence the processes within it. The textbook that accompanies this course, *Environmental Systems* by White et al. (1992), does an excellent job working down in scale from global to local interactions and will be referred to frequently in this handout.

The field portion of this course takes one area as the whole, Oregon Ridge Park in Baltimore County, Maryland, and asks you to disassemble it into its various units. The 422 ha (1043-acre) park consists of a forest, a field, a lake, two streams, and a pond; so, on one scale the park consists of six units (habitats). By the end of the course, you should be able to walk through these areas and list the important subunits of each area and have general notions of the functions and interactions of the subunits and finally, some idea of how the units link together.

Oregon Ridge Park, like every ecosystem, is an open system, meaning energy and matter flow within and across its boundaries. Biological and ecological structure within the ecosystem is maintained by the importation of a high-quality, low-entropy energy source. Energy enters the system primarily as solar radiation captured through photosynthetic activities of the primary producers (autochthonous input). Some biomass energy enters Oregon Ridge via organism-driven (animal migration) or physically-driven

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https://doi.org/10.1016/j.ecolmodel.2017.11.014
0304-3800/

(wind, rain, fluvial, slope) processes. Such external input is called allochthonous. All energy input that is ecologically-entrained can be accounted for as an increase in the biomass in the system or as output from the system either as organic matter or as heat. Therefore, an equation balancing input and output of energy can be derived for the system and each of the subsystems. The forest, lake, and pond cycle material through the ecosystem. This material, which can be thought of as currency, is accepted, used, possibly transformed, and then passed on within the ecosystem and eventually outside the system boundary as output. Currency can come in many forms such as carbon, biomass, water, nitrogen, heat and other forms of energy. The experiments and the ease of measurement decide which currency is used. Once the class has decided on a currency, the groups will each model the movement of this currency through different habitats keeping in mind that all models could be integrated at the end. One way to look at this is to think of a jigsaw puzzle. You will need to identify the pieces and how they fit together. You will then put these pieces together into a systems model that will give you the big picture of the park system. The modeling exercise will begin with a qualitative, conceptual, compartmental model that you construct from your observations, knowledge, and research regarding the ecosystem. Following this you are asked to consider how to quantify these compartments and interlinkages from field data or literature values.

As preparation in thinking about the modeling activity, we introduce two important concepts in this introduction: the 4C's of modeling and the state space theory of dynamical systems. While there are many ways to make ecological models (see e.g., Ford 2009; Grant and Swannack 2007; Jørgensen and Fath 2011), one simple guideline is to consider the 4C's of modeling which includes: 1) currency, 2) compartments, 3) connections, and 4) controls. As stated above, the currency refers to the stuff that is tracked in that model such as energy (kcal or J), nutrients (e.g., N, P, C, or S), water (H_2O), biomass, or some other factor that you measure. The units of the model are determined by your choice of currency. The compartments are the stocks or storages that answer the question of how much. This would have units of amount of the currency per area or volume such as $J\,m^{-2}$ or $gP\,m^{-3}$. The connections are the exchanges of the currency between the compartments. As exchanges, they must be rates and have units such as $J\,m^{-2}d^{-1}$ or $gP\,m^{-3}s^{-1}$. Transfers are much more difficult to measure in the field than stocks, but in the end are more important to the functioning of the system. The 4th C refers to controls, which are the parameters or coefficients that determine the rates of exchanges between the compartments. Taken together with the compartments and connections, they help to write the equations that describe the system dynamics. Speaking of system dynamics, a useful, generalized mathematical model of linear systems can be given with a state space representation. In the most basic sense, this framework establishes a formal method for which input into a system both changes that system and how it induces output from that system. This is given in two equations: 1) a state transition function, which shows how the state is affected by input; and, 2) a response function. A common notation for this model is as follows:

$$\boldsymbol{z_t} \times \boldsymbol{x_t} \rightarrow \boldsymbol{x_{t+1}} \quad (1)$$

$$\boldsymbol{z_t} \times \boldsymbol{x_t} \rightarrow \boldsymbol{y_t} \quad (2)$$

where x is the state variable, z is the input vector, and y the output vector at time t (Fig. 1). Eq. (1) describes how the state variable changes from time t to time t+1 due to receiving an input into the system. Eq. (2) describes how output, y, is generated from the input into the state variable. Do not get bogged down in the mathematics right now. The point is to know there are mathematical tools that can help structure your thinking about how systems change and how they generate output due to the various input stimuli that they receive. This is important to keep in mind as you explore out in the field and look for system features of stocks and flows.

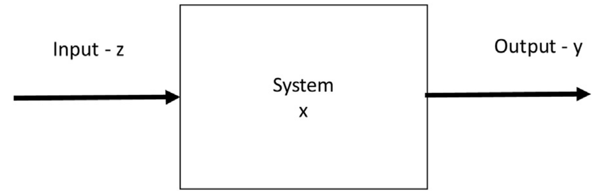

Fig. 1. Simple box-and-arrow diagram of a system with state variable x, input z, and output y.

This handout covers the first three periods of fieldwork at the park. It contains a brief history of the area, descriptions of sampling techniques for terrestrial and aquatic habitats, and questions to give some structure to your initial wanderings around the site.

2. Lab 1: survey and reconnaissance

2.1. *Historical overview*

Maryland is part of six distinct physiographic provinces: (1) the Atlantic Continental Shelf Province, (2) the Coastal Plain Province, (3) the Piedmont Plateau Province, (4) the Blue Ridge Province, (5) the Ridge and Valley Province, and (6) the Appalachian Plateaus Provinces. These extend in belts of varying width along the eastern edge of the North American continent from Newfoundland to the Gulf of Mexico.

"The Piedmont Plateau Province is composed of hard, crystalline igneous and metamorphic rocks and extends from the inner edge of the Coastal Plain westward to Catoctin Mountain, the eastern boundary of the Blue Ridge Province" (Maryland Geological Survey, 2017). Towson University and Oregon Ridge Park are located in the Piedmont Plateau Province. "Bedrock in the eastern part of the Piedmont consists of schist, gneiss, and other highly metamorphosed sedimentary and igneous rocks of probable volcanic origin... Several domal uplifts of Precambrian gneiss mantled with quartzite, marble, and schist are present in Baltimore County and in parts of adjacent counties" (Maryland Geological Survey, 2017).

The topographical features evident in the county are the result of differential erosion of these contrasting rock types, which provides a variety of mineral resources. Mining activities in the past excavated building stone, slate, and small deposits of nonmetallic minerals, base-metal sulfides, gold, chromite, and iron ore. Currently, the region is a source of crushed stone for aggregate, cement, and lime. The area also supplies of small to moderate amounts of groundwater (Maryland Geological Survey, 2017).

2.1.1. *The maryland piedmont through geologic time*

You will be exploring some area of the Maryland Piedmont for most of your fieldwork for this course. For the sake of context, we will review briefly the geologic history of the Piedmont so that you will have some idea of what has happened to this area before you got here, and what kind of events might occur in the future. Most of the following geological information is available in *A Sierra Club Naturalists Guide: The Piedmont* (Godfrey, 1982) as well as other sources.

About 1.1 billion years ago two supercontinents collided, resulting in a massive uplift that stretched from Labrador to Mexico, termed the Grenville Orogeny (Watson et al., 1999). The mountains produced in this uplift were probably the size of the Himalayas. However, since there was no vegetation present to control erosion (the first land plants evolved ~450 MYA), the mountains eroded to the sea within about 100 million years. Following successive uplifts and erosional cycles, about 350 million years ago, two superconti-