Ecosystem Approach in Teaching[1]

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Highlight

Criticisms of current teaching in many biological disciplines are that instruction is fragmented, textbook oriented and lacks interdisciplinary presentation. It is, therefore, suggested that college curricula in Range Science be reoriented to present material in a coherent manner that will give a holistic concept of biological systems. Course material should be updated and scheduled in context for a logical sequence of study for student matriculation. Teaching, research, and the application of academic learning must, by necessity, become more meaningful and more precise if range management is to maintain professional stature and retain identification with a discipline or area of expertise.

The Range Ecosystem

A suggested method of teaching Range Science is through the ecosystem approach whereby the structure and function of biological systems are presented to the student as an integrated whole of an interdisciplinary subject matter. The ecosystem is a matrix of fundamental knowledge and understanding that yields the many unifying concepts that are necessary for coordinated land resource management.

It has been suggested that the ecosystem approach to teaching biology start in the elementary schools (Reed, 1969). Such an approach presents biology as a functional system of plants and animals in relation to their environment. The new methodology of teaching mathematics in elementary schools provides a model of teaching the biological sciences to students in a sequential manner during their first introduction to plant and animal life. There can then be an integrated program for teaching mathematics and biological science which will prepare students in college to study biological systems at an advanced level.

A single method of presenting both structure and function of the ecosystem is through a flow chart showing six compartments (Fig. 1). The compartmental enclosures contain the components that characterize the structure of the ecosystem. This could be referred to as descriptive ecology involving natural biotic communities which represent an assemblage of organisms and their environment. The connecting lines within the hexagon represent the interdependence between compartments or the function of the ecosystems. These show the interactions among structural compartments of the system; the darker the line the greater the interdependency or interaction among compartments.

An ecosystem can be viewed as a living entity or as a plant-animal-place unit that operates under the control of many regulatory mechanisms. "Life" of the ecosystem depends upon the amount of solar energy converted to biochemical energy by the primary producers and the amount of energy transferred from one trophic level to another. Thus, nutrients are cycling within the system in a somewhat balanced state. This process could represent the circulatory or transference function of the ecosystem. The ecosystem likewise responds or reacts to stimuli. If weather brings about a metabolic interruption, the functions of the ecosystem are subsequently disturbed. If a limiting factor or a regulatory control is changed by natural factors or is manipulated by man, the chain of events may affect many components of the ecosystem. Like a living organism, the ecosystem may adjust physiologically or physically to minimize the influence of a disturbance. This would involve a change in population structure and dynamics.

The ecosystem can be any area of any size, large or small, any plant and animal assemblage, or any site, including all of the biotic expressions and all of the abiotic or physical factors that affect these expressions.

The ecosystem approach to education involves acquiring and synthesizing information and subsequently presenting it in a total systems context. Such an approach brings to light the voids in our knowledge of the system. Thus, inquisitive minds are stimulated to carry on intensive research in areas where information is meager or completely lacking.

Undergraduate Training

Course schedules in the ecosystem approach would first consider the basic material to be covered. These should include the newly organized method of teaching biology through animal and plant relationships including a general understanding of biological systems and their development. This replaces the conventional introductory courses in botany and zoology. Courses in physics, chemistry and molecular biology can logically be included as an integrated sequence.

The current trend is to allow the students in Range Science more freedom to use elective courses. Therefore, an abundance of suggested electives gives the student and his advisor an opportunity to select from any number of a half dozen or more options. These might be ranching, land appraisal, wildlife range management, range recreation management, range conservation, range entomology, range watershed management, forest range management, range plant pathology, range economics,

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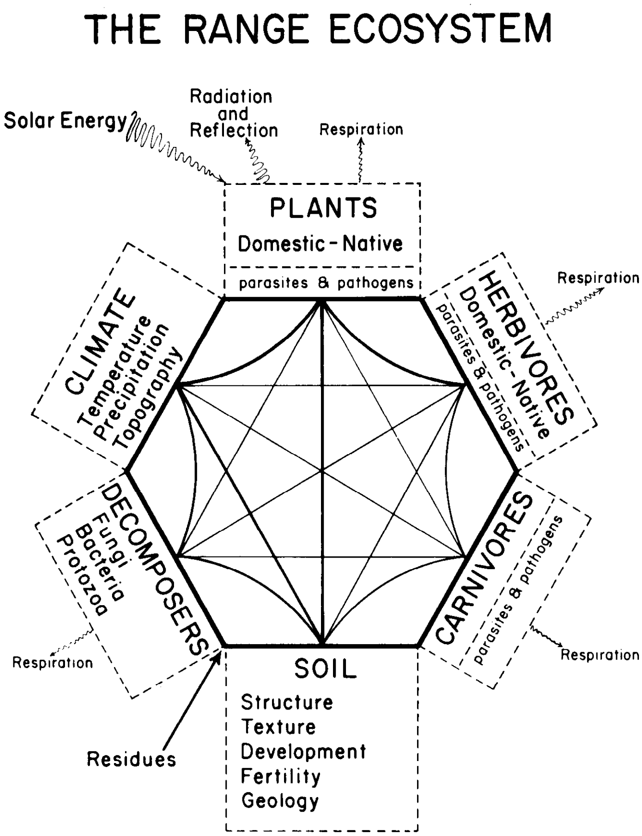

FIG. 1. A flow chart showing structural characteristics of the ecosystem in six compartmental areas and connecting interaction linkage among compartments as a function process.

range nutrition or range ecology. These electives should be selected as a course sequence in a related or complementary discipline and not in a haphazard fashion.

Curriculum

The basic core of courses outlined by the panel for education in natural resources (Natural Academy of Sciences, 1967) suggested a curriculum of foundation training through the freshman and sophomore years. The course outline presented in Table 1 is a minor deviation from the curriculum recommended by the NAS panel. Suggested basic courses include statistics and mathematics through at least one course in calculus and preferably three courses in calculus if the student plans graduate work. At least two courses in physics, four courses in chemistry including inorganic, organic and biochemistry, and a course in each of plant physiology, taxonomy and agrostology should be considered.

Training beyond the two-year program would consist of specialized professional courses dealing with the range ecosystem. The course outline in Table 1 allows for 25 quarter credits of free electives. These free electives could be concentrated in a second discipline to gain another area of competence. Another alternative might be a selection

Table 1. A suggested course outline for a B.S. degree in Range Science.

Courses	No. courses	Quarter credits
Basic core		
Biology attributes of living systems	3	13
Chemistry—inorganic, organic, biochemistry	4	20
Mathematics—algebra, trig., calculus	4	16
Physics	2	8
Plant classification	2	8
Soil microbiology	1	5
Weather and climate	1	5
Geology	1	5
Genetics	1	5
Soils	2	10
Plant physiology	1	5
Animal physiology	1	5
Animal nutrition	1	5
Economics	2	8
Communications	3	9
Statistical probability	1	3
Sociology	2	6
Political science	1	5
Total	33	141
Professional		
Principles of ecosystem structure and function	1	3
Range ecosystem structure (descriptive)	2	7
Range ecosystem function	3	9
Range ecosystem measurements	1	4
Range economics	1	5
Range ecosystem planning	1	6
Total	9	34
Total suggested courses	42	175
Free electives (optional specialties)	—	25
Total	—	200

of courses to broaden the student's training in other resource areas by distributing the 25 credits among several related disciplines. A third choice by the student might be courses to broaden his knowledge in social science related disciplines such as philosophy, psychology, sociology, and political science and/or humanities.

The ecosystem approach to training a range management specialist assumes first of all that the range scientist must have a thorough understanding of the structure of the ecosystem and all of the physical and biological principles by which an ecosystem functions. Therefore, professional courses must cover ecosystem structure and function and their measurements.

Structure of the Ecosystem

The courses in structure of the ecosystem should be concerned with biotic composition of the community, population densities, constancy, age classes, heterogeneity, and life forms. Abiotic factors such as soil texture, soil parent material and soil profile features, along with weather, and micro- and macroclimates; latitude, altitude and exposure are all important in describing the range ecosystem. The structure involves the descriptive trophic structure and the physical features of the ecosystem. Courses in measurements of the structure of the ecosystem can be used to introduce analysis methods which will aid in eventual management decisions.

Function of the Ecosystem

Courses dealing with the function of the ecosystem should focus on the ecological and physiological processes within the biological system. The order of events is influenced by the activity of organisms and their responses to interactions from other organism or environmental conditions. Both physical and biological factors in the ecosystem enter into the dynamic forces that regulate the processes of the system.

Functions and interactions of the ecosystem are indeed complex. In many respects the driving forces and responses of the internal functions of the system are not well understood. In theory all exported materials leave a deficit in the biological system. However this deficit is at least partially replaced through the import of minerals and nutrients that enter the system through parent material, dust, silt, rain and ingress of native fauna. The requirements of the detritus feeders compared to the macroconsumers are not known. Such a holistic evaluation that brings to light the many voids in knowledge is a major reason for accepting the ecosystem approach in research and teaching in range science. Research should complement teaching by furnishing information where voids appear. Otherwise continued fragmented research and teaching in special interest areas will leave many weaknesses in our knowledge of the complicated interplay of the physical and biological processes of the range ecosystem.

Ecological efficiency of the ecosystem is frequently evaluated on the basis of energy flow among the trophic levels. Parameters of energy flow into and away from the ecosystem include incident sunlight transformed into photochemical energy by the primary producers, energy converted to animal tissue and for physiological functions by the secondary producers, losses by radiation, and that remaining matter that is fixed in residues. The net efficiency of energy conversion can be calculated for each trophic level as the quantity of energy is passed along the food chain until it reaches the decomposers.

Plants convert solar energy into organic material that can be transferred in the system from one food level to another and finally respired into the atmosphere, exported from the system, or returned to the soil. Bioenergetics of the ecosystem concerns the total energy fixed through photosynthesis and the use and transfer of energy by the complete biomass of organisms.

The flow of energy and the cycling of elements through the organic and inorganic compartments of the ecosystem present a challenge to scientists in synthesizing and presenting information revealed by the matrix of the ecosystem. Elements and compounds originate from parent materials, through the atmosphere, as sediment from adjacent areas, or as soil amendments. These move through the various compartments of the ecosystem in a complicated manner. The conversion of energy within the ecosystem is of paramount importance because of the transfer of solar energy for sustenance of all life in the system. The existence of the ecosystem itself depends upon this phenomenon. The function of the ecosystem is more than the flow of energy or the cycling of nutrients. Organism competition, interaction, and development of biota expressions are also functions of the ecosystem.

Development and Maturity of the Ecosystem

Most conventional ecological concepts still apply to ecosystem development and management. There are a great number of basic ecological principles that have evolved from our study of community ecology that apply to both the structure and function of the ecosystem. The ecosystem may be in a state of development, or can be fully developed. This does not preclude the older concepts of plant succession and the dynamic climax or a balance of life in the ecosystem. The ecological system changes over time by means of its biological activity and the influence of the physical environment. Ecological succession may be defined as an orderly progression of community development that terminates in a reasonable state of stabilization or balance until perturbed by man or some natural catastrophe. According to Odum (1969) this process of development is both directional and predictable. The structure at a particular time may be an interim expression of the biota in any stage of development. The process is reversible and, as stated above, may be brought about by drastic and unusual climatic conditions or through manipulation by man.

Trophic dynamics of the ecosystem may be a known range of activities or events and therefore may be limited or influenced by any of the many components of structure of the ecosystem, but the actual changes are a function of the ecosystem. Both structural and functional changes occur during development of the ecosystem. The degree and rate will depend upon the climatic, edaphic, biotic and physiographic conditions.

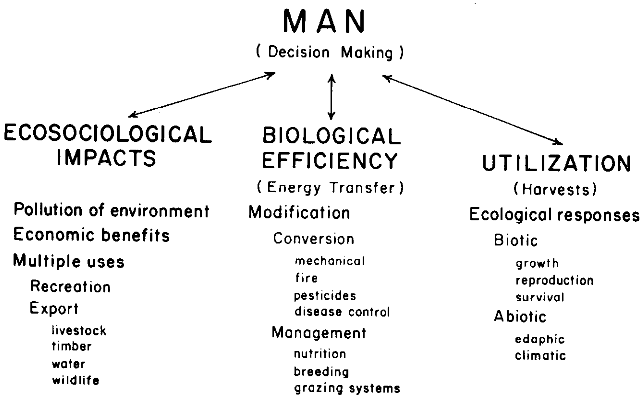

FIG. 2. Decisions to increase biological efficiency through modification of the ecosystem considers all adverse or beneficial effects upon other components or users of the ecosystem.

Biological Efficiency of the Ecosystem

Applied learning or conventional range management courses should be identified with instruction concerning ecosystem functions. Such material could be taught under the broad heading of biological efficiency of the ecosystem. In addition to the natural perturbances in the ecosystem, man may alter certain processes by deletions or additions of heretofore controlling factors. This is the area where conventional range courses have contributed knowledge to the student. The material studied in these courses has been applied subject matter and oriented toward special use of the ecosystem by domestic livestock and game animals.

Multiple uses such as forestry, range, wildlife, recreation and watershed all contribute to the management practices and amount of export material to be taken from the ecosystem. Decision-making in manipulation and management of the biological system must consider all the ecological and ecosociological impacts (Fig. 2).

Manipulated or modified ecosystems may actually produce more useful export material than natural ecosystems even though the natural ecosystem is in a climax state. Management which requires altering the ecosystem must be done in a prescribed manner that is cognizant of the benefits to be accrued and perturbances to be wrought. Sometimes modification of the ecosystem to increase export productivity conflicts with ecological principles involving the theory of balance in the climax community.

Course material must recognize that biological systems are regulated by many complicated processes and factors involving complex interactions among both the biotic and abiotic components of the system. For instance the biological efficiency of the ecosystem may be limited by transformation of energy by the primary producers or by physical limitations of the ecosystem such as water, soil, fertility and climate.

Graduate Work

Terminal courses at the graduate level should include systems ecology courses designed to analyze ecological principles, to study techniques in high-speed digital and analog computers, and to synthesize ecological information and formulate mathematical models that will optimize the predictability of complex functions in the range ecosystem. A system analysis procedure which evaluates all of the major ecological activity of the ecosystem and the ecosociological impacts of prescribed manipulation would bring to light voids in scientific information about the ecosystem.

In the ecosystem approach to graduate education in Range Science the programs leading to the Master of Science and Doctor of Philosophy degrees are based upon foundation courses which have developed a thorough knowledge of the structure, function and usefulness of the ecosystem.

Graduate programs, like undergraduate studies, should provide a select area for specialization. This might be centered in any compartment of the ecosystem (Fig. 1) or in any of the many complicated functions or interactions within the biological system. Complementary areas of specialization include soil chemistry, animal nutrition, plant or animal physiology, hydrology and others. Interdisciplinary course work and research should be emphasized.

Graduate training to the Ph.D. level would include intense academic and theoretical approaches in identifying and measuring structure and function of the ecosystem. Advanced courses that instruct the student in measuring functions of the ecosystem are important in a graduate program. Measuring interactions among organisms, and organism response to physical factors of the system are paramount features of the ecosystem approach in higher education. A Ph.D. program would be remiss if it did not include some quantitive systems analysis courses. These would include modeling and simulation of biological systems, synthesis of data and use of high speed computers. These are important to our understanding of and prediction of biological phenomena within the range ecosystem.

Research programs to complement the teaching program are necessary for complete fulfillment of a student's graduate education.

Summary and Conclusions

Range management is an integral part of land resource management. The range scientist will have an area of competence only after he demonstrates to other related disciplines that he has a sound understanding of the ecosystem, its structure and its functions. He must know how manipulation or modification of the ecosystem affects the various components of the system. In decision-making the range scientist must defend his action logically and scientifically so that his views are clearly understood.

Three courses dealing with the structure of the ecosystem during the sophomore year, three courses concerning the function of the ecosystem during the junior year and three ecosystem analysis courses along with planning and decision-making courses during the senior year would be needed to earn a B.S. degree in range ecology.

Supporting courses would be similar to most degrees in biological sciences, i.e., three courses in biology which form a foundation for advanced ecology, six courses in chemistry and physics, four courses in mathematics and statistics, two or three courses in calculus, and at least one course each in weather and climate, microbiology, geology, and soils.

Initial courses dealing with the range ecosystem would involve the description of the biotic components of the ecosystem such as the trophic levels; (1) primary producers—species composition, life forms, constancy, age classes, and heterogeneity; and (2) consumers—the species composition of herbivores, carnivores, population densities and distribution. Ecosystem structure courses would also include the abiotic factors such as soil profile descriptions, micro- and macroclimates along with geographic, topographic, and other land form features that identify a particular ecosystem.

Courses in ecosystem function must follow a sequence that presents all the biotic and abiotic interactions. A simple method is to initiate the sequence of events by starting with energy flow which introduces the interdependence of plants, animals and soils and the relation of climate to these biological phenomena. The complementary and antagonistic relations among organisms are omnipresent interactions in the ecosystem. These processes are further complicated by the influences of physical factors of the system. Soil bacteria, fungi and the detritus feeders all serve as decomposers which carry on a very important function in enhancing soil fertility, organic breakdown and mineral cycling. Increased biological efficiency as a directed function of the ecosystem may be accomplished through conversion of the vegetation type, range improvement practices, use of grazing systems and other desirable management methods.

Graduate programs should include more intense academic training in identifying and measuring structure and function of the ecosystem. A doctoral program should include systems analysis involving modeling and simulation of ecological systems.

The educational program in Range Science should be relevant to social changes and sustenance of the land resources under wise use.

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