A SYLLABUS

FOR

AN INTERNATIONAL TRAINING COURSE

ON THE

ECOLOGICAL BASIS OF NATURAL RESOURCE

MANAGEMENT

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PREFACE

A syllabus is a summary or outline of a course of study. This syllabus is intended for use in an international training course on the ecological basis of natural resource management. The course is presented in the Great Smoky Mountains International Biosphere Reserve. In the near future it will also be presented in the Loquillo Experimental Forest at El Verde, Puerto Rico. Although the syllabus is intended for use in this course, it may be of limited use in similar courses offered elsewhere. The purpose of the syllabus is to provide information necessary to develop an understanding of ecological concepts and their relevance to natural resource management. Those participating in the course are, for the most part, already involved in resource management. Therefore, the emphasis in this course is upon a scientific approach to resource management policies and practices. A major component of the course is the demonstration of scientific methods and technology which can be used to gather information needed to make management decisions or to implement management practices.

A major activity which cannot be included in the syllabus is the discussion of resource management needs, problems and solutions in the specific countries represented in the course each year.

In order to fully understand the purpose of this syllabus, it is necessary to understand the context in which it is intended for use. The

course is presented at a location which provides unusual opportunities to demonstrate field and laboratory applications of scientific research and technology. If the best science and technology currently available were in use in one or more underdeveloped countries, that would be the best location to present the course. The alternative selected is to present the course where contemporary ecological science and environmental technology are being used to support natural resource management, and where experienced manpower is readily available. It is assumed that participants in the course are familiar with resource management problems in their own countries. It is the responsibility of the course director to have participants identify, discuss and prioritize resource management needs of the developing countries represented. It is also the responsibility of the course director to relate information, demonstrations and discussions to the specific needs of participants. The United States Department of Agriculture has sponsored professional training seminars which prepare course directors for these complex and demanding tasks.

In this context, the purpose of the syllabus is to organize topics in a rational sequence and to present basic information which will assist participants in relating scientific concepts and practices to examples of resource management they will witness first hand. Therefore, in the syllabus the emphasis is upon a review of fundamental concepts and upon the application of these concepts and natural resource management.

This syllabus is based upon experiences gained in offering the course for the first time in The Great Smoky Mountains Biosphere Reserve in July, 1980. The course was sponsored by the Man and the Biosphere program of the United States Department of State, the International Training Division of the United States Department of Agriculture, and The University of Tennessee. This syllabus is to be used in the same course when it is offered a second time in July, 1981. The syllabus should be revised based upon comments of course participants and the broader range of experiences in 1981. The proposed course outline for the 1981 course is included as Appendix A. Consistent with that outline, this syllabus places an emphasis on concepts of ecology (Chapter 1) and the application of these concepts to natural resource management (Chapter 2). Subsequent chapters provide explanations for the inclusion of specific field trips, lectures and demonstrations.

CHAPTER I

PRINCIPLES OF ECOLOGY

INTRODUCTION

The intent of this chapter if threefold: (1) Provide an overview of what ecology is, and is not; (2) Review briefly a few major concepts of ecology, and explain their derivation by means of selected examples; and (3) discuss the application of these ecological concepts to natural resource management and environmental assessment. Normally, this is the subject of entire text books. In this case we will review only the most fundamental topics, and depend upon individual initiative and experiences to expand on this introduction.

WHAT IS ECOLOGY, AND WHAT IT IS NOT?

Ecology is a science. The application of ecology to the solution of contemporary problems is an art. Accordingly, it is most appropriate that ecology often serves as a cornerstone for curricula in the Arts and Sciences.

It is exceedingly difficult to identify or acknowledge the point at which one exceeds the limits of science and becomes an artist. Too often, in an effort to solve problems, extrapolations or predictions come more from imaginative art than from scientific perceptions. Both approaches are necessary and productive, but professional credibility is dependent upon proper identification of each.

The work activity of scientists is research. The work product of professional ecologists is ecological research. Although an ecologist, like anyone else, may wish to fill various roles at different times, the termination of the research effort is the termination of professional involvement as an ecologist. This distinction proves most useful in distinguishing between ecology and a large number of equally rewarding careers such as impact assessment, land use planning, or policy analysis.

Ecology is the science which investigates the environmental relationships of populations, communities and ecosystems. Others define ecology as the study of ecosystems; their history, behavior, structure, and function. Still others define ecology as the scientific study of the environmental relationships of plants, animals, microbes, and man. Each definition emphasizes a different point; the relevance of which depends upon the audience. The first stresses a hierarchical approach proceeding from specific system components to entire ecosystems. The second embodies the biological concept of reciprocity; the relationship of structure to function. The third embodies the concept of man in nature, of man functioning as one of several biological compenents in a world ecosystem.

Without exception, ecology is defined as a science which analyzes relationships. This partially explains the very recent emergence of ecological science from its centuries-old roots in natural history, agriculture, biology, geography, and anthropology. It is more difficult to study relationships between entities than to study entities themselves. The entities which

comprise ecosystem inclu populations of species and abiotic components of the physical environment. Another way of describing the work activity of ecologists is to compare and contrast it with the work activity of two related sciences, biology and environmental science. Biologists sutdy structural and functional relationships of organisms. Environmental scientists investigate properties of the environment. Ecology bridges the gap between these two sciences. Ecologists investigate environmental relationships of populations of organisms. Most studies focus upon the factors which influence the abundance and distribution of species, or upon factors which influence exchanges of energy or matter between species.

Ecology emerged as a science at the end of World War II as technology became available to investigate complex relationships. Major advances in science most commonly result from the development of new technology. Each science has numerous examples. Computers partially relieved constraints imposed upon ecological research due to the large number of environmental and biological variables with which we must contend. Radiosotopes made it possible to study processes and to relate them to structure, both in the field and in the laboratory. Hybridization of systems analysis and ecosystem concepts provides a conceptual framework within systems ecology which facilitates hypothesis testing, improved experimental design, and adds a new dimension of

temporal and spatial predictability. The mid 1900's was a period of increased awareness of ecological problems, increased awareness of a deteriorating environment, of diminishing resources. Pessimistic predictions regarding the quality of life provided a rationale for increased financial support of ecological research.

In addition to the constraints imposed by the number of variables and difficulties in analyzing relationships, ecological research had to contend with two additional variables of lesser importance to other sciences. These are the dimensions of environment--space and time. Within ecosystems, change occurs constantly with time and through space. Extrapolation from place to place or time to time is a violation of scientific procedure; perhaps the one which most often marks the transition from science to art. Each science has its own principles, techniques, philosophy, and power of prediction. The rest of this chapter will be devoted to familiarization with those ecological principles and techniques which are most relevant to resource management and problem-solving.

Power of prediction in ecology is quite limited, because of the numerous one-to-many and many-to-one relationships which occur in natural ecosystems. Predictive power in ecology is best described as the ability to reduce sets of contingencies to the smallest possible number.

The single most important characteristic of ecological science is its unique philosophy--the philosophy of holism. It is the holistic philosophy which has caused ecology to be described by some as a subversive science. It is the application of the holistic philosophy to natural resource management and environmental planning which caused ecology to challenge the practices of most resource agencies. The ecological concept of holism, "that the whole is greater than the sum of its parts, due to interactions between the parts" is the best of what ecology has to offer society. This concept is a challenge to other sciences, because all the rest of science emphasizes "reductionism" in philosophy and experimental inquiry. Throughout our universities and throughout the mid-century emergence of molecular biology, we have sought greater understanding through identification of increasingly smaller parts of biological systems. Coupled with reductionism is comparative analysis of differences between structures, functions, and species. Dissimilarity is stressed almost to the exclusion of comparative analysis of similarities. Baldwin's classic text on Comparative Biochemistry develops a rare appreciation for the similarities between life forms and their common contributions to a world ecosystem.

Ecology is subversive to traditional resource management and planning activities which do not consider both indirect as well as direct consequences of proposed actions; which do not consider long-term as well

as immediate effects; which conflict with, rather than take advantage of, natural processes; and which are often based upon political rather than natural topographical boundaries.

Throughout this decade, the holistic philosophy of ecology has gradually been included in science and resource management to the degree that it is now a reluctantly accepted concept in both the arts and sciences.

Principles of Environment

First, let us distinguish between climate, weather, and environment. Climate is the long-term pattern or cycle of occurrence over large geographic regions of physical conditions, primarily those driven by the dissipation of solar energy. Primary among these are temperature, pressure, wind, and precipitation. Weather refers to local and short-term flunctuations within climatic patterns. To an ecologist, environment is the sum of factors or conditions external to an organism which directly or indirectly affect the organism or the population of which it is a component. It is important to acknowledge influences upon populations as well as individuals, for individual organisms are mortal, populations transcend time. Interactions of populations with changing environments are responsible for the process of natural selection.

The concept of ecological niche refers to the functional role of a species within its habitat. We have often heard, and validly so, that nature abhors a vacuum. No habitat and no niche goes unfilled.

A corollary is that two species cannot occupy the same niche. Competition for environmental resources results in the eventual displacement of one or the other species. Competitive displacement is a consequence of natural selection and evolution. There is little opportunity for new varieties of life unless new habitats arise. Individuals or populations of new or different genetic stock are seldom as well adapted to environmental conditions as are those organisms which already exist under those conditions.

Habitat is the spatial dimension of the environment occupied by an organism or population. Habitat is described in terms of qualitative and quantitative characteristics which are responsible for the organisms occurrence.

It has long been recognized that disturbed or altered habitats offer the greatest opportunity for genetic variants and hybrid or exotic species. Two appropriate examples are the explosive population growth and geographic expansion of the water hyacinth and the pinchote juniper.

Case Studies

The water hyacinth is an emergent aquatic plant which was accidently introduced to streams in the Southeastern United States. This introduction would not have created so serious a problem if streams, reservoirs and lakes had not become mineral rich due to wide spread water pollution. The water hyacinth flourished in the warm nutrient rich waters and spread throughout the region. Water resources in the

region have been seriously affected and most uses of this valuable resource have been jeopardized.

The pinchote juniper is a small tree or shrub which suddenly appeared on the rangelands of the Southwestern United States in the late 1940's. Within a decade this previously unobserved species spread across vast areas of Southwestern rangelands replacing grasses and other shrub species more desirable for grazing. The rangelands most affected were those which had been overgrazed during World War II. Soil erosion contributed to habitat modification. For many centuries hybrid populations of Juniperus had persisted in remote canyons and on the slopes of a few mountain ranges in the Southwestern United States. These populations were the product of interbreeding between usually allopatric species which had overlapping distributions during glacial advances and retreats of the Pliestocene. Among the great variety of hybrid individuals was one which was particularly well suited for a habitat of limited occurrence prior to extensive overgrazing in the 1940's. This particular genetic recombinant, the pinchote juniper, spread rapidly across the eroded rangelands. It was characterized by prolific reproduction and wide distribution of seed, primarily by birds.

Home range, territory, and carrying capacity are ecological concepts which also pertain to spatial and temporal dimensions of

environment. Home range is the area habitally visited by an organism. Territory is the area actively defended by an organism. It is an expression of social organization and competition for food or breeding space. Carrying capacity is, in some ways, the reciprocal of the latter. It is the population density of a species which can be supported by a defined area.

A major ecological concept regarding the distribution and abundance of organisms is the Continuum Theory. This theory is based upon the fact that, in many instances, environmental factors vary gradually in intensity along spatial and temporal gradients. When intensity gradients of environmental factors are mild and unidirectional, vegetation changes gradually and in a predictable direction (Continuum Theory). An appropriate example is the latitudinal variation in the vegetation of the great prairie of North America, or forest transitions throughout the midwestern region. On the other hand, where environmental discontinuities are sudden and severe, as for example along the front range of the Rocky Mountains, the organic world responds with discrete communities of plants and animals. The activities of man often contribute to environmental discontinuity, thereby increasing ecological discontinuity; for example, forest islands in agricultural regions, or dams along rivers used by anandronous fish.

A related concept is that of microenvironment. This is the environment immediately surrounding an organism; that small segment of the universe to which the organism is directly and immediately sensitive.

This may be the monomolecular layer of air surrounding the leaf of a plant, the environment of a mountain lion perceivable by touch, smell, sound, or sight, or the conditions of a ghetto on North 14th Street in Washington, D.C. as compared to those two miles away on Pennsylvania Avenue. An appropriate example of the practical application of this concept is research which led to the demise of the malaria-carrying mosquito in south Georgia.

Case Study

In this case, the United States Public Health Service wished to eradicate or greatly reduce populations of the mosquito, Anopheles. The practice had been rather indiscriminate spraying of pesticides in locations where the mosquito was most likely to come into contact with man.

Ecologists proposed to identify the specific microenvironment required by the mosquito, the microhabitat in which these conditions are most likey to occur, and the coincidence between these times, places, conditions and critical stages in the life cycle of the mosquito. The study was successful, the quantity of pesticide and the area affected was reduced by several orders of magnitude, and they achieved complete success in reducing malaria.

Organisms may encounter specific environmental factors in the form of limiting factors, intensity gradients, trigger factors, or as compensating factors. Compensating factors may substitute for one another

without apparent effect on the organism, as in the compensation of altitude by latitude or by the biochemical substitution of cesium for potassium.

Trigger factors are those which set in motion a series of events which irreversibly alter ecosystem structure and function. Examples are more often anthropogenic than otherwise. These may include eutrophication of lakes, acid rain or ozone depletion.

Any factor which approaches or exceeds the limits of tolerance of an organism is a limiting factor. Shelford's Law of Tolerance states that all organisms live in a range of conditions between the maximum and the minimum. This range establishes the limits of tolerance. Competitive ability declines as conditions vary from the point of central tendency within this range.

Finally, a most significant environmental concept is holocoenosis: which means to be without crosswalls. Environmental factors exist as an interacting complex, They do not operate independently, but as a whole, An organism is not impinged upon by moisture stress from 8 to 10 a.m., temperature 10 a.m. to noon, and by acid rain on Tuesdays and Thursdays. Specific and individual factors are not walled off from one another. Figure 1 illustrates this concept.

Population Ecology

Populations are aggregations of individuals of the same species which share a common environment and have a common evolutionary history.

Populations of species are the units of minimal biological complexity of direct interest to ecologists. The next lower level in the organizational hierarchy, entire organisms, is the central subject of biology, botany, and zoology. Ecologists study populations primarily as units of growth and as units of evolutionary change.

Growth occurs in but two ways; by an increase in the size of existing units, or by an increase in the number of units. Ecologists investigate population growth in terms of species abundance and distribution, usually seeking clues as to the factors which most strongly influence distribution and abundance.

Natural selection is the most fundamental of ecological concepts; it is a process of interaction betwen populations of organisms and their environment.

Biological evolution is the process of genetic chance in populations over time.

Speciation occurs when evolutionary change results in a degree of population dissimilarity sufficient to cause populations to occupy distinctly independent ecological niches. Characteristics most commonly used to measure change and dissimilarity include structure (morphology and anatomy), function (physiological processes) or reproduction.

Natural selection is the driving force which causes evolution to occur. It is the process of non-random change in gene frequencies within populations. Change is non-random because specific environmental conditions

favor the survival of individuals with certain characteristics relative to those with other characteristics. The environment serves as a natural agent of selection amongst variable individuals within populations.

As Thomas Malthus pointed out from the church pulpit in destitute Ireland in the 1800's, all species have the innate capacity to reproduce more offspring than actually occur in succeeding generations. Success in adapting to a changing environment determines which ones survive. Since environment is changing constantly, both through time and space, the direction and intensity of selection pressure may vary widely among populations of the same species.

One example of natural selection leading to speciation was provided earlier when Juniperus pinchotii was described as a species of hybrid origin which exploited a hybrid habitat. In this case, one genome was selected from a highly variable gene pool. Genetic variability was due to hybridization of species. There was an unusual opportunity to occupy a unique habitat.

Case Study

Another study is used to demonstrate speciation. In this case, geographic isolation is responsible for the gradual retention and accumulation of genetic changes within populations. This results in distinct ecotypes. An ecotype is a population of a species which has become genetically distinct through adaptation to an identifiable

ecological factor or factors. Ecotypic differentiation helps to explain the wide-spread distribution of species which appear to be successful in a variety of environments.

For example, several grass species are characteristic of the great prairie of the Central United States. These species occur throughout much of the prairie which extends from Southern Canada to Northern Mexico. As the environment varies gradually and continuously throughout this vast area, so does the genetic composition of populations of individual species. It has been demonstrated that the genetic basis of population tolerances to environmental conditions varies in accordance with the intensity or duration of specific environmental factors. The more dissimilar the environments, the more dissimilar is the genetic composition of populations of each species.

Population density is influenced by initial density, mortality, natality, immigration, and emigration. Reproductive rate, so important to the theoretical essays of Malthus, is of less direct interest to ecologists than the number of offspring which actually survive to any given age from conception to senescence. This rate of mortality is computed in the same manner as insurance companies compute actuarial tables to affix policy rates for individuals with varying probabilities of survival. In simplest terms, one merely conducts an age class census of the population, gathering information regarding susceptibility to factors associated with high mortality. Two examples of actuarial

life tables are provided, one of an animal population and one of a plant population (Tables 1 and 2). The x column can be graphed as a survivorship curve which illustrates most crucial periods in the life cycle. Survivorship curves are of three basic types: (Figure 2). (1) organisms with high survival until late in life; (2) organisms which have a constant rate or mortality; and (3) organisms with high mortality early in life. Survivorship of most plants conforms to the latter, while survivorship of animals more closely follow curves 1 or 2 of Figure 2.

Population growth can usually be expressed by one of two basic curves. Populations of species which are components of relatively stable ecosystems, which have high survivorship, relatively low reproductive rates, relatively low growth rates, and limited dispersal usually exhibit growth best represented by a sigmoid curve (Figure 3, line A). Those which have traits to the contrary usually exhibit growth best represented by a J-shaped curve (Figure 3, line B). The latter, which best represents human growth, is indicative of over-exploitation of environmental resources and/or intervention by a catastrophic event.

No population increases indefinitely, including man. At some point, populations must come to a dynamic equilbrium related to the availability of resources necessary to support growth. For man, the unequal distribution of resources and unequal ability to exploit resources have allowed certain populations of the species to increase

exponentially, others to come to an equilibrium, and others to crash precipitiously.

Population densities are regulated by density-dependent and density-independent forces. Annual, seasonal, or long-term changes in climate or weather are examples of the latter. Predator-prey systems are appropriate examples of the former. Increases in prey populations usually attract increased predation. Increased predation, in turn, usually reduces prey populations. Thus, cyclic fluctuations in population densities have density-dependent origins. Several hypotheses have been proposed to explain the unusual and dramatic fluctuations of lemming populations. The reproductive stress hypotheses proposes that as populations increase exponentially toward a level which might deplete food resources, stress due to crowding causes female reproductive organs to atrophy. This direct and effective form of density-dependent population control is considered necessary in order to insure a continued food resource. Overgrazing by even a single generation could lead to destruction in the in the tundra environment where plant growth and ecosystem recovery are exceedingly slow. The nutrition hypothesis proposes that, as lemming populations over graze the food resource, the nutritional quality of that resource diminishes. These, and additional hypotheses, may all be correct at one time or another, or in one situation or another.

Interactions between two or more populations take the form of every possible combination of positive (+), neutral (o), or negative (-) impacts upon participant populations. Interspecific competition (--)

is perhaps the most common of these populations interactions. Competition occurs when two or more individuals, populations or species are dependent upon the same limiting resource. Competition is a process of negative interaction between two or more individuals or species populations. Competition often provides the mechanistic explanation for population mortality, genetic divergence, loss of populations by migration, and replacement of one species by another. Viewed on a temporal scale, interspecific competition proves the mechanistic explanation for community succession. It is not sufficient to discuss competition without identifying the limited resource required by both species. Ironically, it has seldom been demonstrated in nature that competition regulates population density or abundance. One example comes from the same set of case studies used to demonstrate the actuarial life table.

Case Study

In this case, two species always occur as distinct but adjacent populations in a natural community. On the basis of observations it was hypothesized that as soil, depth and moisture became more favorable for growth, competition for available moisture was responsible for one species replacing the other. Soil depth and moisture were monitored in habitats of both species throughout the growing season. Results were used to design an experiment which placed pure populations of each species, and mixed populations of both species in environments typical of each species.

All factors were identical except soil moisture. Each species replaced the other under conditions which simulated soil moisture conditions of that species. Neither species dominated under immediate conditions. Results were the same when the experiment was conducted in the field and in the laboratory.

Each species has a competitive advantage for this limiting resource under different conditions of resource availability.

In this study it was demonstrated that competititon for available moisture is responsible for the replacement of one species by another.

Community Ecology

Communities are associations of species populations which are inter-dependent, and which share a common environment. Communities are ecological units of structure. They are usually described in terms of the relative abundance of unequally successful species. Traditionally, communities are named in accordance with the most successful, or important, species; for example, beech-maple or oak-hickory forests. Criteria used to compute success or relative importance include density--how many per area; frequency--how evenly distributed; and dominance--how big they are. Three major concepts dominate thought and activity in community ecology. Two of these attempt to explain spatial discontinuities; that is, changes observed in plant and animal associations as one surveys the landscape. The third addresses temporal discontinuities, or changes in species composition through time. This latter process is known as

succession. Before discussing each of these concepts in some detail, it is important to discuss the re-emergence of community ecology as an active field of endeavor. As experimental and theoretical ecology become increasingly popular and possible during the 1950's and 60's, community ecology with strong roots in descriptive natural history, became relatively unattractive to many. Renewed activity and interest is related to the fact that classical descriptive community analysis provides the majority of the ecological information sought in Environmental Impact Studies. Likewise, renewed interest in succession, the natural process of ecosystem recovery, is related to legislation requiring reclamation of disturbed ecosystems.

One concept of communities is that they occur as discrete entities; an association of species which, better than any other association, utilizes the resources of a particular area. The concept of climatic climax states that there is but one stable association of species in a single climatic region. Variances from this climax community are due to factors such as history of land use, or special edaphic or topographic features.

A different viewpoint is the Continuum concept. The Continuum concept proposes that many of the environmental factors which most strongly influence species distributions vary gradually and continously across large geographic regions. If species are adapted

to their environment, and if environmental changes occur gradually and continually, it follows that community composition should change accordingly. It is not surprising that the Continuum concept gained early and strong support from ecologists who are surrounded by a vast and relatively homogenous landscape where change of any nature is slow and gradual. The continuum concept is graphically represented in (Figure 4).

It is reasonable to conclude that where environmental discontinuities are sharp and extensive, communities are correspondingly distinct. Where environmental conditions vary quite gradually, changes in plant and animal associations can best be explained by the Continuum concept.

Succession is a natural process of change over time. It is the process of ecosystem development. This developmental process includes changes in species composition, the flow of energy, the transfer of matter and internal structure. The physical environment influences the rate, pattern, and direction of succession through resource limitations and the imposition of stress to species growth and survival. Environment is the ecological stage, and populations of species are the actors. At present there is considerable debate as to the relative importance of environment, chance opportunity, and homeostatic or autogenic controls over succession. Regardless of mechanistic explanations, this process of ecosystem development is directional, and therefore reasonably predictable.

Succession begins when substrata become available for colonization. This happens occasionally due to natural phenomena such as island formation, shifting of unstable substrata such as deltas or dunes, rock slides, and other catastrophic events. More often, succession occurs following perturbations of human origin; for example, abandoned agriculture. For most biomes in most regions of the world, terrestrial and aquatic successions have been described in terms of the sequence of species which replace one another, and the duration that each persist. These studies provide a reasonably good basis for predictions of ecosystem recovery following perturbations of various sorts.

Case Study

The infamous Chestnut Blight substantially altered forests of the Eastern U.S. during the first two decades of the 20th Century. This fungal infestation removed the largest and most abundant species throughout the Appalachian forests. The subsequent half-century has provided an opportunity to study natural succession, or ecosystem recovery, on a large scale. The pattern and mechanisms of recovery are relatively well understood.

During the first quarter century, trees which had previously been associated with chestnut persisted and, at least partially, grew into canopy openings. In certain instances, understory species benefitted from increased light and grew rapidly to share in dominance with persistent canopy trees. A third group of species were those which invaded forest gaps resulting from the death of chestnut. Collectively these three processes of recovery resulted in a forest little different from that

prior to the blight, except for the loss of chestnut. Only during the second quarter century did species replacement become as important as species persistence. Depending upon site conditions, chestnut was eventually replaced by a variety of speices. The important points are that several processes contributed to the eventual recovery of the ecosystem, and it took a half century before the eventual pattern of recovery was discernable.

In addition to species replacement which occurs during succession, there are directional changes in whole ecosystem attributes as well. For example, as an ecosystem matures, the following changes are thought to occur in energetics, structure, and nutrient cycling:

Energetics:	P/R ratio decreases and approaches 1
	P/B ratio decreases
	B/E increases
	Net production decreases
	Food webs become increasingly complex
Structure:	Total Organic matter increases
	Nutrients become increasingly tied to biological structure
	Species diversity increases
	Stratification and spatial heterogeneity increase
Nutrient Cycles:	Cycles become increasingly closed
	Exchange rates decrease
	Role of detritus increases

In general, resource management activities of man, especially agriculture, run counter to the natural tendencies of ecosystem regeneration and maturation, which lead to stability. Agriculture mimics young nature; it exhibits high rates of growth but inefficient use of resources. Agriculture is sustained by external subsidies, including energy, nutrients, water, and

toxins. Only in the last few years, and primarily in tropical forest regions, have we begun to develop agricultural systems which mimic stable ecological systems in terms of structure, energetics, and nutrient cycling. Initial demonstrations of agro-ecosystems suggest that there are successful applications in the Central and South American tropics.

Ecosystems and Systems Ecology

The ecosystem is both a useful concept and physical reality. Ecosystems are dynamic, four-dimensional units of nature possessing structural and functional characteristics which vary in magnitude or rate within three-dimensional space and a fourth dimension, time. A major goal of ecology is to quantify relationships between structure and function in these natural units.

If you could place a pond, a forest, or a salt marsh and its total environment in a hugh plastic bag, you would have captured an ecosystem. The only external input required to maintain this system would be solar energy.

All systems have components, and it is the interactions between structured components that produce a functional system as opposed to the coexistence of randomly located independently operating entities. The components of ecological systems are populations of species usually associated with one another into communties. In addition, there are abiotic products of biological activity, substrata, and various physical features of the environment.

Most ecosystem studies focus upon the movement of energy, nutrients, water, and matter into, within, and out of natural ecosystems.

Ecosystem research often begins by considering the ecosystem as a large black box. Initial studies may examine input/output ratios of energy, nutrients, water and perhaps biota. These ratios provide early indications of which factors may be most limiting to internal processes. Transfer coefficients provide understanding of rates of ecological processes. Sampling and analysis of biomass of specific ecosystem components provides information on accumulation and storage of energy or matter. Estimates of storages, coupled with estimation of transfer rates between storage compartments, provides information necessary to develop dynamic models of ecosystem structure and function.

Because of the size and complexity of natural ecosystems, concepts and techniques have often been tested and derived from synthetic laboratory systems, or microcosms. With these small scale synthetic ecosystems, ecologists attempt to mimic ecological processes which occur in nature. Analog computers have also been used to examine the consequences of manipulations which are unfeasible to attempt in nature. Most common are mathematical models which attempt to simulate ecosystem properties. An approach similar to the use of microcosms, is to use small, natural ecosystems to investigate ecosystem properties and to test hyptheses.

These properties or hypotheses are later investigated in large systems of greater concern to resource managers.

Three characteristics of natural ecosystems are of special interest in resource management; these are productivity, species diversity, and stability. Perhaps of greatest concern is the relationship of the three characteristics to one another. Can we design and engineer agricultural systems which come closer to attaining the productivity of young natural ecosystems? At present, U.S. agriculture is the least energy efficient agriculture in the world. As energy becomes increasingly scarce or expensive, efficiency may be as important as productivity. Can we combine high net productivity characteristic of developing ecosystems with the efficiency and stability of mature ecosystems? Is there a mix of species diversity, and ecosystem structure which will optimize productivity and stability?

There is a popular misconception that species diversity is related directly to ecosystem stability. This is an attractive but unsupportable hypothesis. Throughout the world there is a growing effort to reclaim land that has been devastated by a variety of activities. We are only beginning to understand the innate recovery capacity of natural ecosystems. Current research focuses upon the properties and processes which contribute to recovery and the limits of disruption that can be tolerated without loss of these properties. Ecologists have identified components of stability as resistance, persistence, and resilience. We need to advise resource developers how to take maximum advantage of each of these properties.

Resistance is the ability to tolerate stress without significant change taking place in ecosystem properties. Persistence is the ability to survive in spite of change which does occur. Resiliency is the ability to recover, once disturbed.

More often than not, questions are asked regarding management of resources which cannot be answered on the basis of scientific evidence. The area in question may be too large; for example, the forests of lowland Costa Rica. The time scale may exceed descriptive records, or one may wish to identify trends or relationships which defy quantitative analysis. One question recently asked, was, what will be the nature of our forest resources fifty years in the future, under varying land use practices in the meantime? Systems analysis was used to research this question, a question which transcends the limits of traditional experimental analysis.

Case Study

The first step was to identify the magnitude of forest types which presently occur. In this case the Forest Service provided the information required for the specific area. Knowing the composition of the present forest stands, the next step is to construct a model of the direction and rate of succession as it is known to occur in the region.

The third step is to compute the relative area of each forest type which will occur if natural succession proceeds undisrupted.

Another task is to develop a model of historical changes of land area based upon past land use, and to compute change in the area of each forest type based upon these known land use practices. This computation

can be modified to include anticipated changes in the intensity of any land use.

A final step is to develop independent simulations for each forest resource.

Land management practices can then be implemented to achieve various quantities and qualities of forest resources by the target date.

Summary

In summary, the major goal of this presentation is to provide an introduction to a few ecological concepts and practices which can be applied to resource management and environmental assessment. During the course we will have opportunities to discuss and witness current programs and activities in applied ecology.

CHAPTER 2

Ecological Considerations in Natural Resource Management

INTRODUCTION

The course outline identifies the renewable natural resources we are most concerned with as air, water, soils, vegetation, fisheries and wildlife. Ecologists and resource managers must be able to monitor and inventory these natural resources in order to obtain quantitative and qualitative descriptions of their distribution, abundance, growth and value. It is especially important to understand the rate of change in these characteristics. With shocking frequency administrators of resource programs attempt to develop management policies or practices without adequate knowledge of the resources to be managed.

The preceeding chapter provided a conceptual basis for considering various natural resources as individual components of larger natural ecosystems. Management practices and policies must also be sensitive to whole system properties and interactions between whole system components. Too often, natural resources are managed on an individual or piecemeal basis in order to meet narrow or short term objectives. Robert Herbst, former Assistant Secretary of the U.S. Department of the Interior, addressed the shortcomings of this approach when he identified his intent to "build management systems which fit the natural systems to be managed." One question to be asked is whether the management

system is sufficiently flexible to accommodate unexpected behavior in natural systems? An appropriate example of an unexpected behavior might be an insect epidemic. Is the management system sufficiently sensitive to respond to events which require immediate corrective action? Are data readily retrievable and in a form useful to managers? Are all participants in the management system aware of all other participants and the policies which guide their actions? Management systems are most often organized into landscape units which correspond to territorial boundaries or units of government. Boundaries of natural systems, such as watersheds, seldom correspond to political boundaries. Another common practice is to attempt to manage one resource in an ecosystem for one purpose and other resources or components for conflicting or competing purposes. In such cases, even the best intended efforts to cooperate usually fall short of providing effective management for the entire system. These criteria, and others, should be included in management systems used to manage natural resources.

What Can Ecological Science Contribute?

Ecological science has revealed the importance of identifying interrelationships among the various resources within natural ecosystems. Ecology provides both a conceptual and pragmatic basis for estimating the intensity or extent of disturbance that ecosystems can tolerate without incurring undesirable acceleration in the rate of ecosystem change. The interrelatedness and interdependence of all renewable resources

contributes to the conclusion that watersheds are the smallest units of the landscape for which effective management plans can be formulated. Watersheds have sufficient structural and functional integrity that inputs and outputs of energy, nutrients, water and other ecosystem characteristics can be monitored. This is precisely the information needed to make management decisions.

Ecological science has two major contributions to make to resource management. The holistic philosophy of ecological science dictates that we must develop and implement management practices which are compatible with the functional and structural integrity of entire ecosystems. To the resource manager this means it is insufficient to manage for a single species or single resource without managing for the long term stability of the entire ecosystem. The ecosystem concept is a product of the holistic viewpoint. Ecosystem concepts are largely responsible for the acceptance of habitat management as the favored means of species management.

The second major contribution of ecological science is power of prediction. Managers of natural resources must be able to predict the consequences of management practices and policies. Predictive power comes from experience and from the scientific method. Experience usually enables us to anticipate the consequences of specific practices, even without understanding why the events occur as they do. However, it is often necessary to understand why events occur as they do in order to adjust management practices to accommodate changes in the environment, in the habitat, or in the market place. The scientific method provides some power of predictability,

and the relevant science is ecology. Admittedly, ecological science is sufficiently complex that the power of predictability is somewhat limited. However, at the very least ecological research can reduce the contingencies associated with natural resource planning, practices and policies. The greatest benefit of providing an ecological basis for resource management may not be a greater degree of success, but rather, a greatly reduced chance of failure. A good understanding of structural and functional relationships within an ecosystem may help to explain why particular forms of management have been successful and others have not.

Management Strategies

Management strategies should be based upon scientific research and practical experience The relevant science is ecology. The best experience comes from working directly with natural resources under realistic conditions. Ecological science is most advanced and has greatest predictive power in the area of population ecology. Population concepts are directly applicable to the determination of limits for harvest, hunting and other forms of resource consumption. Questions of sustained yield are readily addressed by concepts and methods of population ecology. Population models are relatively simple and have proven to be of significant value in predicting the impacts of various technologies upon individual species. On the other hand, the science is relatively weak in precision and accuracy of predictions regarding ecosystem level processes. Recent advances in systems analysis and mathematical modeling have provided significant

improvements in our ability to predict the consequences of alternative management strategies at ecosystem, regional and global scales. Examples range from water resource and forest management in individual watersheds to global impacts of increasing levels of CO_2. However, several factors limit our ability to use ecosystem models in the decision making process. Ecosystem models are difficult to validate because sufficient empirical information is seldom available. The cost of obtaning this information is usually high and the time required is often prohibitive. Also, complex ecosystem models are difficult to explain, let alone defend. The future use of ecosystem models apparently depends upon our ability to reduce complexity.

Few ecosystems and few natural resources on this planet remain unaffected by human activity. Atmospheric and aquatic transport of industrial effluent has escalated local impacts to global dimensions. Considerable ecological research has been conducted to determine the environmental impacts of a great vareity of technologies, especially those associated with the production of energy. On the other hand, relatively little research has been conducted to determine ecosystem resiliency, the ability of ecosystems to recovery following disturbance. There are numerous exapmples of fragile ecosystems (those which do not recover) and resilient ecosystems (those which recovery quickly and extensively following disturbance). However, our knowledge of properties and processes which confer high or low resilience is very incomplete. Effective management requires an understanding of the resiliency of the systems to be managed.

Habitat management is the preferred way to manage species and to preserve those threatened with extinction. In most cases species are rare or threatened because of the rarity or diminished quality of their habitat. Botanical gardens, zoos, seed banks, and embryo banks are being used as last gap efforts to avoid extinction and loss of genetic material. However, extinction is inevitable if a species habitat is lost. Only recently have we developed methods of habitat evaluation which can be used for planning and assessment purposes. Habitat evaluation procedures and methods of data storage, retrieval and analysis are an important part of this course.

Certain ecosystems and natural resources have been exploited so intensively or extensively that no degree of management, short of habitat preservation, is sufficient to avoid extinction. In even greater peril, because of the cryptic nature of the problem, are natural resources jeopardized by policies and practices whose consequences are as slow to appear as they are inevitable. A local example of the former is a small fish known as the snail darter. The numerous rivers and streams it formerly inhabited have been so completely altered by agricultural and industrial run off and by hydrolectric dams, that the species is known to exist in fewer than a half dozen locations. As is the case for most endangered species, the danger is due to destruction of the habitat rather than due to any biological characteristic of the species itself. A local example of the latter threat is the impact of forest management practices upon the red cockaded woodpecker. This bird depends upon large, old, disease infected pine trees as a source of food and/or shelter. Modern forest

management practices remove these trees. As ever increasing portions of the landscape are managed in this fashion, the habitat of the species is gradually diminished to an area insufficient to support breeding populations.

A less intense and generally more acceptable form of natural resource management is conservation. Conservation practices set limits upon the rate or extent of resource consumption in order to insure the long term viability of the resource. Both experience and scientific research are necessary in order to identify limits of consumption under the variety of conditions which might prevail. An understanding of ecosystem resiliency is especially important in determining conservation policies and practices.

Another, rather controversial, concept of resource management is beginning to receive scattered support throughout the world. The TRIAGE concept assumes that natural resources fall into one of three catagories:

1) Those which are self maintaining or which require very little attention;

2) Those which are not as healthy or productive as possible and which could benefit from effective management;

3) Those resources which have been so devastated or disrupted that only a massive effort might restore them to acceptable quality.

The TRIAGE strategy is proposed for situations when human or financial resources are in short supply. The strategy is to focus effort and management opportunities upon catagory two resources. The following assumptions are involved: 1) Catagory one will survive for the time being without attention; 2) The cost-benefit ratio is excessively high for corrective

management of catagory three resources; 3) Greatest benefit will be achieved at the lowest cost and effort by focusing upon catagory two. This management strategy is often modified to account for the value of the resource to man. For example, if man is highly dependent upon a resource it may receive considerable attention even though it is in catagory one or three.

Values

The assignment of human values to natural resources is an art, not science. Realistic approximations of value require cooperation between economists, ecologists, sociologists, political scientists and planners. A key role of the ecologist is to identify the importance of relationships between specific resources and to the rest of their environment. Unfortunately, cost-benefit ratios are too often misinterpreted as being rigorous quantitative measures of the feasibility of a particular management strategy. The assignment of human values to natural resources is a subjective exercise and subsequent quantitative calculations should not be interpreted as having a valid quantitative basis. The use of cost-benefit ratios in policy decisions is often misleading.

The current strategy of the U.S. Government, under the administration of President Reagan, is to protect environmental quality and human health as long as a reasonable cost-benefit ratio is maintained. However, this is impossible as long as we are unwilling or unable to place a value (cost) on human life and human health. Without these values it is not possible to calculate a cost-benefit ratio for most threats to human life and environmental quality.

Special Concerns in Developing Nations

The consequences of inappropriate or ineffective management of natural resources can be especially devastating in underdeveloped nations or in underdeveloped regions of industrialized nations.

In some cases a nation or a region may be rich in natural resources but remain relatively undeveloped because of economic, cultural, or political constraints. Natural resources in these countries are vulnerable to sudden and rapid exploitation due to sudden changes in foreign or domestic investment or political policies. Under conditions of sudden change or rapid exploitation it is exceedingly difficult to implement management practices which satisfy both short term and long term goals for natural resource development. Under such high risk conditions, it is especially important to use a scientifically valid framework for resource development and management. It is imperative that we consider future consequences of present day decisions. Science offers one source of predictive information.

In other cases, nations or regions may be underdeveloped because they are deficient in one or more natural resources. In such cases the demands upon science, technology and management may be quite different. Scientific problems may be those primarily associated with limiting factors and limits to population growth under such constraints. Under these conditions technological solutions hould focus more upon conservation and efficiency.

CHAPTER 3

Examples of Current Research Which Contributes Directly to Natural Resource Management--A Case History Approach

Coweeta Hydrologic Laboratory. U.S. Forest Service, Southeastern Forest Experiment Station. Franklin, North Carolina*

The training course will visit the Coweeta Hydrologic Laboratory to witness scientific research being conducted in order to meet specific management needs of the U.S. Forest Service and a great many other federal and state agencies with which they cooperate. This 144 ha watershed was acquired for U.S. Forest Service research in 1914 (Figure 5). Permanent vegetation plots were established and first monitored in 1935. Precipitation and stream flow has been monitored since 1937. Fish and wildlife monitoring began soon thereafter. Coweeta has an extensive atmospheric monitoring program and is a participant in the National Atmospheric Deposition Program (Figure 6). Current research projects call upon this increasingly

*When this course is presented in Puerto Rico a similar field trip to the Experimental Forest at El Verde will address the same problems.

valuable long term data bank in order to interpret highly variable climatic and biological data characteristic of short term research.

One example of such research is the test of the multiple use concept of natural resource management. A ten year case history is available to assess the success of managing forests for multiple uses, including timber, water, wildlife and recreation. We will visit sites used to evaluate the effects of clear cutting on nutrient availability, effects of timber management on water quality and quantity (Figure 8), effects of acid rain on forest ecosystems, and soil erosion and nutrient losses due to logging roads (Figure 9), or burning. This exercise is intended to demonstrate the importance of understanding the dynamics of entire watersheds when attempting to manage water resources.

II

Oak Ridge National Laboratory-- Biomass for energy project.*

Several tropical countries are attempting to utilize solar energy indirectly by converting plant biomass to alcohol or other chemical products. The United States and several other countries are still in exploratory stages of developing this natural source of energy. A case study developed by ecological scientists at Oak Ridge National Laboratory will demonstrate a scientific analysis of the feasibility of biomass conversion to energy. Topics include plant-site relationships, nutrient depletion, and the use of plantations vs. natural forests.

* When this course is presented in Puerto Rico similar projects will be reviewed which include tropical species. Scientists will also discuss related and more extensive projects in Central and South America.

Multiple use resource management in
The Great Smoky Mountains National Park.*

National parks may provide the greatest of all challenges to managers of natural resources (Figure 10). There are conflicts between different user groups for access to and use of our national parks. Managers are expected to maintain our parks as pre-Columbian ecosystems. At the same time the impacts of roads, trails, visitor centers; campgrounds, repression of fire and historic preservation create irresolvable conflicts. Of growing concern are impacts from outside the parks. These are both local and global, including acid rain, airborne pesticides and competing uses of water resources. These most complex problems are most deserving of rational and ordered management policies and practices. Management and science must work together to develop these practices. The Great Smoky Mountains National Park was selected as the site for this course because of extensive scientific research and monitoring being conducted in support of management needs. It was also selected because, as an International Biosphere Reserve, international education and research are a part of its mission. Park scientists will renew management problems and will present case studies of projects which attempted to provide a scientific basis for dealing with these problems. Specific topics include wildlife management, selection and rotation of public use areas, protection of endangered species, air and water pollution, and conflicts between recreation and other uses.

*When this course is presented in Puerto Rico field trips to El Yunque will provide similar opportunities.

CHAPTER 4

Resource Inventories and Environmental Monitoring

A series of lectures, field trips, demonstrations and class participation will be utilized to provide instruction on theory and methods of conducting environmental monitoring and natural resource inventories.

INTRODUCTION

When the natural resources of an area are to be developed or managed for human use, decision makers should have assessments of the distribution, abundance, and quality of the resources. Course participants will review and conduct systematic resource inventories developed for forest, rangeland, fish and wildlife resources. The greatest source of error in inventories of biological resources is taxonomic precision. While it is inappropriate that we become proficient in the identification of local species, it is very important that the class review methods of sampling and classifying biological resources.

Decision makers and managers should also benefit from assessments of the distribution, abundance and quality of physical resources such as air, water and soils. In the Great Smoky Mountains and elsewhere we will review environmental monitoring programs. Demonstrations and group activities will vary from site specific inventories of small mammals to atmospheric monitoring stations which are part of a global network attempting to monitor CO_2 and acid rain.

Remote Sensing

Environmental monitoring and resource inventories will begin with the "big picture". Remote sensing, specifically LANDSAT imagery, has been identified as an important and useful form of advanced technology which the United States can provide at low cost to lesser developed nations. LANDSAT imagery provides opportunities for creative planning and management. The LANDSAT system can provide images of almost any part of the earth at nine day intervals. A variety of sensors sensitive to different spectral bands send signals to digital computers which print black and white images. These images distinguish between various biological and physical resources such as, water, forests, agriculture, rangelands, urban areas, etc. Features as small as 300 feet can be detected. Sequential images of given areas can monitor flood stages and recovery from floods or other disturbances.

History, concepts and technology, feasibility and cost of LANDSAT imagery will be reviewed (Figure 11). Participants will analyze LANDSAT images from several continents and will learn to interpret and classify natural resources and land use. Land use and classification in Bolivia will be used as a case history for potential applications of remote sensing to resource management. Participants will receive instruction in specific steps to be taken in using remote sensing data for resource mapping.

Soil Inventories and Classification

Most natural resources studies must begin with descriptions of the geology and soils of the region. Patterns of distribution and abundance of most renewable natural resources can most often be explained in terms

of soils, climate and land use. Management problems directly related to soil properties include forest and agricultural productivity, water quality and flow, and erosion and flood control.

A major problem in underdeveloped, especially tropical countries, has been a scarcity of soil maps. Soils cannot be mapped without first having a system of classification. Atempts to apply North American classification systems to tropical soils have not been successful.

Class participants will review recently developed classification systems. We will identify and discuss soil properties used in soil classification. Case histories will be presented for management problems which incude soil erosion, flood control, water discharge capacity and biomass production.

Air and Water Monitoring

Several activities will include direct participation and demonstrations of air and water monitoring concepts and methods. At Coweeta Hydrologic Laboratory we will observe and review watershed management practices designed to meet water quantity and quality goals. At Coweeta and also in The Great Smoky Mountains National Park we will examine air monitoring stations which are a part of the National Atmospheric Deposition Program. Demonstrations of water quality monitoring will range from inexpensive and relatively simple methods sufficient for teaching and range finding tests to the most advanced technology currently available (Figure 12). Each demonstration will be preceded by a discussion of the management problems which require air or water quality information.

Only in recent years have government agencies begun to understand that physical-chemical measurements of water quality are of very limited

value. The best indicators of water quality are biological indicators (Figure 13). Participants will be introduced to concepts and case studies of biological monitoring and bioassays. Laboratory exercises will acquaint participants with relatively simple and inexpensive methods of measuring physical-chemcial characteristics and microbial activity. Ecological water quality criteria will be examined during field trips in the national park.

Numerous hydroeclectric dams in the Tennessee valley provide special opportunities to review assessments of the impacts of this energy technology upon the water resource.

Vegetation Inventories

Renewable natural resources are constantly changing in quantity and quality. Perhaps none change so rapidly and constantly as forests and rangelands. Continuous forest inventories are conducted by federal and state agencies which have responsibilities for forest and wildlife management and by the timber industry. These inventories employ satellite images. In most cases a series of permanent plots are established as reference points for repeated analyses at intervals of 10-25 years.

Inventories of forest resources are required to develop a variety of management plans. These include fire prevention, rotation of public use areas, planting schedules and selection of species for planting, prediction of harvest potential, habitat management for wildlife and estimates of water quality, storage capacity and discharge. If results of individual inventories

are to be aggregated to calculate estimates for counties, provinces, states, regions, nations or continents, methods of sampling, data processing, storage and retrieval must be standardized.

Participants will review standard techniques used by the U.S. Forest Service and the local Tennessee Valley Authority to conduct forest inventories. We will visit forest inventory sites in The Great Smoky Mountains and participants will conduct an inventory using standard techniques. We will also review methods for recording and analyzing data. Sample reports will be available.

Wildlife Inventories

The variety of wildlife in The Great Smoky Mountain National Park create a variety of management problems. Wild boar populations are expanding and destroying vegetation being managed for historic preservation, recreation and as scenic wilderness. Skunk populations are attracted to picnic grounds and are, at times, a serious problem. Tourists endanger black bear and themselves by attempting to feed them or give them rides in automobiles. Bears in turn are targets for illegal poachers. These are a few examples of management problems which cannot be resolved without knowledge of fundamental demographic, ecological and behavioral characteristics of each species.

The class will participate in nocturnal inventories of wildlife populations in The Great Smoky Mountain National Park. Participants will observe techniques of extracting and analyzing blood samples as well as

methods of evaluating the health of individuals and the distribution and abundance of populations. The information obtained is precisely that utilized in the standardized national wildlife inventory of the U.S. Fish and Wildlife Service. It is appropriate that participants understand how this information is obtained because they will use fish and wildlife procedures in a subsequent exercise on data synthesis and analysis. Participants will be provided copies of the FWS/OBS 79/19 Appendix I Booklet entitled A Procedure for Describing Fish and Wildlife.

Fisheries Inventories

Ecologists in The Great Smoky Mountain National Park are actively involved in inventories of fisheries resources. Cold water streams found throughout most of The Great Smoky Mountain National Park are the natural habitat of the native brook trout. This species is disappearing at an alarming rate. In many instances it is being replaced by rainbow or brown trout. The latter species were introduced to create a more productive fishery resource. It appears that one management goal, to improve recreational fishing, is in conflict with another management goal, to preserve the native species. Research programs have been initiated to determine trout distribution and abundance. At first it was assumed that the native species could not withstand competition with introduced species. Initial results of research suggest the problem is more complex and may involve the influence of timber harvests approximately 50 years ago. The class will examine this case study.

We will participate in current inventory projects which address these problems and which are also used to establish the length of the fishing season and the size of the harvest (Figures 15 and 16).

CHAPTER 5

Integration of Resource Information For Use in Planning, Management or Environmental Assessment.

In making management decisions one must be able to integrate information from scattered and diverse sources. Data derived from resource inventories or from environmental monitoring stations must be available in a form which is useful to the decision maker. In this course we review procedures developed by the U.S. Fish and Wildlife Service to make decisions regarding best land use. These procedures were developed for the purpose of determining the impacts of energy technologies upon natural resources. One successful application has been predictions of the impacts of surface mining upon fish and wildlife resources. This approach to environmental assessment has focused upon HABITAT as the unit of study. The rationale for this approach is described in a document entitled "Habitat as a Basis of Environmental Assessment". That rationale is consistent with concepts and experiences presented earlier in this training course. Habitat evaluation involves the holocoenotic approach which was discussed at the beginning of the course. Habitat management was earlier described as the preferred approach to species management, including endangered species. Specific procedures for habitat evaluation will be reviewed. Descriptive information used to characterize habitats is integrated by the development of a habitat suitability index. The class will review publications which describe evaluation procedures and standards for developing the index, and

models for use in evaluating habitat. The class will enter field data into standardized data banks and will retrieve inventory data in a form which responds to specific management questions. These exercises involve low cost portable computer terminals which provide access to information via telephone. Procedures and experiences identified in Chapter 4 provide the type of data retrieved during this exercise. Methods and case studies developed by the U.S. Fish and Wildlife Service demonstrate how diverse information can be integrated into a form which can be used to support a management decision. Additional publications to be consulted in this exercise include "A Procedure for Describing Fish and Wildlife: Coding Instructions", "Species Description Booklets, Volumes I and II". "The Habitat Evaluation Procedures", and "Standards for the Development of Habitat Suitability Index Models for Use with the Habitat Evaluation Procedures". Instruction will be provided by individuals involved in the development and application of these procedures.

CHAPTER 6

Application of Concepts and Methods to New Environments and Different Resources

A field trip from The Great Smoky Mountains National Park across the great prairie of North America, will terminate in the Rocky Mountains of the Western United States. This trip is intended to achieve two objectives.

The first of these objectives is to provide an opportunity for participants to observe management practices used in rangelands and mountains of the relatively arid central prairie of the United States. The class will review ecological research projects at Kansas State University. Results of these research projects are used to develop management plans for rangelands and reservoirs in an environment where water resources are more limiting than in the moist forests of the Eastern United States. The final days of the course will be spent on the eastern slopes of the Rocky Mountains. We will visit the Pawnee Grassland site which served as the focal point for grassland research projects of the International Biological Program (IBP). Results of this research are being used to support management of rangelands, forests, livestock and wildlife in the rain shadow environment of the front range of the Rocky Mountains.

The second major objective of this field trip is to provide an opportunity for participants to apply recently learned concepts and methods to new environments and different resources. This exercise provides

a test of the ability of participants to apply concepts and methods acquired in this course to resource management problems in their own countries.

In addition to observations during field trips, range scientists and ecologists at Colorado State University will present lectures on rangeland ecology and resource management. Ecologists at Kansas State University will lecture on reservior and grassland management.

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TABLE 1. Life Table for Cottontail Rabbits

of 10,000 Rabbits in Uteri

AGE INTERVAL IN MONTHS	Number alive at beginning of month of age	Number dying during month of age	Mortality Rate[1]	Complete Expectation Of Life[2]
X	l_x	d_x	1000_{qx}	e_x
0-4	10,000	7,440	744	6.5
4-5	2,560	282	110	6.6
5-6	2,278	228	100	6.5
6-7	2,050	246	120	6.5
7-8	1,804	307	170	6.4
8-9	1,497	150	100	6.4
9-10	1,347	175	130	6.3
10-11	1,172	164	140	6.3
11-12	1,008	212	210	6.3
12-13	796	143	180	6.3
13-14	653	98	150	6.2
14-15	555	55	100	6.0
15-16	500	65	130	5.8
16-17	435	31	70	5.6
17-18	404	24	60	5.3
18-19	380	49	130	5.0
19-20	331	36	110	4.9
20-21	295	47	160	4.6
21-22	248	20	80	4.4
22-23	228	39	170	4.2
23-24	189	32	170	4.0
24-25	157	13	80	3.7
25-26	144	7	50	3.4
26-27	137	30	220	3.1
27-28	107	12	110	2.9
28-29	95	13	140	2.6
29-30	82	32	390	2.4
30-31	50	7	140	2.3
31-32	43	9	210	2.1
32-33	34	11	330	1.9
33-34	23	16	700	1.9
34-35	7	3	350	2.3
35-36	4	----	---	2.0
36-37	4	----	---	1.5
37-38	4	----	---	1.0
38-39	4	4	1000	0.5

[1]Number dying per 1,000 alive at beginning of mongh.
[2]Average number of months of life remaining at beginning of month of age.

Lord, 1961.

TABLE 2. Life Table for a natural population of Sedum smallii

X	D_x	A_x	A'_x	l_x	d_x	$1000q_x$	L_x	T_x	e_x
Seed produced	4	0-4	-100	1000	160	160	920	4436	4.4
Available	1	4-5	- 10	840	630	750	525	756	0.9
Germinated	1	5-6	+ 13	210	177	843	122	230	1.1
Established	2	6-8	+ 35	33	9	273	28	109	3.3
Rosettes	2	8-10	+ 81	24	10	417	19	52	2.2
Mature Plants	2	10-12	+126	14	14	1000	7	14	1.0

TABLE 3. Life Table for a natural population of Minuartia unifloria

X	D_x	A_x	A'_x	l_x	d_x	$1000q_x$	L_x	T_x	e_x
Seed produced	4	0-4	-100	1000	790	790	605	2632	2.6
Available	1	4-5	+ 52	210	146	695	137	212	1.0
Germinated	1	5-6	+ 90	64	53	828	38	74	1.2
Established	2	6-8	+128	11	3	273	10	37	3.4
Rosettes	2	8-10	+204	8	3	375	6	18	2.2
Mature plants	2	10-12	+280	5	5	1000	2	5	1.0

From Sharitz and McCormick, 1974.

Life cycle stage duration. D_x, the number of months composing the stage of the life cycle.

Age, A_x, age of the population at each life cycle stage expressed in months.

Percentage age, A'_x, age of the population at the beginning of each life cycle stage expressed as a percentage of the mean length of life of the population.

Survivorship, l_x, number[1] of individuals surviving at the beginning of each life cycle stage.

Senescence, d_x, number[1] of individuals that die during each life cycle stage, obtained successively subtracting from the number alive at the beginning of the stage (l_x) the number alive at the beginning of the next stage (l_{x+1}).
($d_x = l_x - l_{x+1}$).

Mortality rate, q_x, the fraction of individuals living at the beginning of the life cycle stage that die during the stage. ($q_x = d_x/l_x$).

Stationary population, L_x, mean number[1] of individuals that are alive during the life cycle stage.
($L_x = (l_x + l_{x+1})/2$).

Residual population life span, T_x, total number[1] of individuals times age units (or plant-months) remaining to all presently living members of the population at the beginning of the life cycle stage simplified to ($T_x = D_xL_x + T_{x+1}$).

Life expectancy, e_x, is obtained by dividing the total number of plant-months remaining to be lived at the beginning of any life cycle stage by the number of individuals alive at that time. ($e_x = T_x/l_x$).

APPENDIX A

Sample Course Description and Schedule

Ecological Basis of Natural Management

A course offered by the United Nations - Man and the Biosphere Program, The International Training Division of the U.S. Department of Agriculture and The University of Tennessee Graduate Program in Ecology. The course will be presented in The Great Smoky Mountains - International Biosphere Reserve.

The purpose of the course is to review ecological information needed to effectively manage natural resources. Each participant is expected to submit in advance one or more case studies of natural resource management in the participants country. The course will begin with a review of resource management concerns throughout the countries represented. The course will end with a discussion of the application of science and technology to resource management in these countries. We will examine relevant ecological concepts and review methods of environmental monitoring and conducting natural resource inventories. The class will review methods of data acquisition, data analysis and information transfer which are employed in developing a scientific basis for establishing policy, developing land use plans and managing natural resources. The first two weeks of the course will be held in the forested mountains of the Eastern United States. The final two weeks will include a field trip across the central prairies of the continent in order to examine the ecological basis of natural resource

management in rangelands. A major objective of this field trip is to provide an opportunity for participants to extrapolate concepts and experiences acquired in temperate forests to observations and experiences in different biomes with different management needs. This is precisely what will be required of participants when they return home. The course will draw heavily upon examples of best science and technology being used by the U.S. National Park Service, Forest Service, Fish and Wildlife Service, the Tennessee Valley Authority and Oak Ridge National Laboratory.

THE PROPOSED CLASS SCHEDULE IS AS FOLLOWS:

Day 1 Transportation to GSMNP and Orientation to Program.

Day 2 I. A review and discussion of ecological science and concepts relevant to resource management. Presentation of case studies by participants.

Day 3 II. A review and discussion of concepts of natural resource management. Ecological approaches to the management of natural resources.

III. Identification of ecological information required for effective management of natural resources (Examples of current research programs in support of management needs).

Day 4 A. Visit U.S. Forest Service, Coweeta Research Station.

Emphasis upon water and forest resources.

Day 5 B. Forest management for production of biomass (O.R.N.L.) Emphasis upon sustained yield, soil conservation and energy production.

Day 6 C. Resource management for multiple uses in The Great Smoky Mountains National Park. Emphasis upon recreation, historic presentation, tourism, air and water monitoring and environmental protection.

Day 7 & 8 Weekend--Free Time

	IV.	Theory and Methods of Resource Inventories and Environmental Monitoring.
Day 9		A. Remote sensing, soil classification, erosion control. productivity, water storage.
Day 10		B. Soils, classification, soil erosion, water holding capacity, productivity.
Day 11		C. Vegetation inventories
Day 12		D. Wildlife inventories
Day 13		E. Fisheries inventories
Day 14 & 15	Weekend--Free Time	
Day 16	V.	Integration of resource information for use in planning, management and policy analysis.
Day 17-20	VI.	Field Trip from eastern forests to western prairies and rangelands. (Travel)
Day 21		A. Review ecological research in support of rangeland and reservoir management. Kansas State University, natural prairie research station.
Day 22	Free Time	
Day 23	Travel to CSU	
Day 24-26		B. Review ecological research and rangeland management practices in a variety of ecosystems in the vicinity of Colorado State University.
Day 27	VII.	Summany and Evaluation of Course. Relate course to participant needs and case studies.
Day 28		Departure from Denver International Airport.

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Description of Book

Ecology, the science of the environment, has emerged as a distinct discipline only in the years since World War II. The young science has seen especially rapid growth in the past two decades, when the preservation of the natural environment became a worldwide concern. Because it has advanced so quickly, keeping track of developments in ecology has become an almost impossible task. No comprehensive survey has been available that details the rapid growth of the science around the globe. Until now. The Handbook of Contemporary Developments in World Ecology is the first authoritative survey of the evolution of ecological concepts and methodology all over the world. Quite simply, this massive volume tells where ecology is and how it got there.

The heart of this book is a group of thirty-four chapters, each a comprehensive discussion of ecological developments in a single nation. These articles, the work of prominent ecologists from every continent, explore historical antecedents to the new science, significant advances in both theory and practice, major research developments, interactions with other disciplines, government and private participation, major journals and societies, and the seminal literature in each nation. From Brazil to Singapore, these essays provide a complete and accurate accounting of the advance of modern ecology.

Three additional chapters examine the worldwide application of ecology to solving environmental problems. Appendices list important international journals and societies. Every professional ecologist, every student of ecology, will welcome this book as a long-awaited means of keeping up with their fast-moving discipline.