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WILDERNESS FOR BASELINE ECOSYSTEM STUDIES

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INTRODUCTION

Foresters are faced with increasingly complex ecological problems as societies struggle to produce an expanded array of goods and services from a shrinking forest land base. How can site productivity be maintained under the pressures placed on it by intensive forest management and harvest systems? What are natural sources of nitrogen and what types and amounts of organic matter are needed to perpetuate favorable soil chemical and physical conditions? What structural components and food sources are needed to provide habitat for the desired diversity of organisms, including threatened and endangered species? What are the natural levels of sediments in streams supporting important fisheries and how are sediments maintained at these levels?

These and many other questions that arise in planning and managing uses on our forest lands are clearly at the ecosystem level with all the complexities that implies. Ecosystem studies needed to provide answers to these questions must include research on functioning of natural forests. What are the patterns and rates of energy and material flows and their controls? What are the roles of various structural elements in forests such as logs and snags? Answers are sure to be instructive for managed forests since our knowledge of ecosystems is still relatively rudimentary. Note, for example, recent discoveries about the large proportions of photosynthate utilized in maintenance of below-ground portions forest ecosystems. Virgin forests are particularly valuable in ecosystem research since components, processes, and (especially) interactions may be absent from the artificial (somewhat simplified) forest stands. There is, of course, the additional need for studies of natural ecosystems as baselines against which we can measure the health of our managed ecosystems and landscapes.

The natural forests and landscapes needed for this research are increasingly confined to specially designated nature preserves. There are a variety of approaches differing (but typically overlapping) in objectives and nomenclature: National Park, Research Natural Area, National Nature Reserve, Wilderness, Biosphere Reserve, and Zapovednik, to name only a few. All such programs are important but some (e.g., Research Natural Areas) involve relatively small areas, while others involve substantial recreational use (e.g., National Parks) or focus on specific organisms rather than ecosystems (e.g., some Zapovednika).

Legally designated Wilderness (denoted by a capital "W"), areas set aside within the United States by acts of Congress, will be the major topic of this paper. Such Wilderness, as recognized in the United States, provides some particularly important opportunities for ecosystem research due to their large size and management for natural values. The opportunities to look at whole drainages and associated land and water interactions are especially critical to ecosystem science. Designated Wilderness will, of course, grow ever more important as ecological research sites, with the domestication of much of the remaining North American landscape.

In this paper I will outline the role of Wilderness and similar areas as baselines for forest ecosystem research. Examples will come from experiences in the United States, particularly in Olympic National Park, Washington, a large forested park most of which is proposed for formal Wilderness designation. My purpose is to suggest the potential such areas have for providing ecological information critical to management of adjacent commodity lands.

GENERAL VALUE OF NATURAL ECOSYSTEMS

Natural forest ecosystems can function as baselines and yield valuable ecological information regardless of preservation status or, to a degree, size. Ecosystem research in the temperate coniferous forests of the northwestern North America provides an example. The natural forests of this region are well known for their high productive potential and accumulated biomass of species, such as Douglas-fir (*Pseudotsuga menziesii*), western redcedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*), and true firs (*Abies* spp.), in stands commonly 250 to 650 years of age.

Functional, structural, and compositional characterizations of natural forests and associated streams, especially in the old-growth state, were accomplished through studies of forests in two National Parks, several Research Natural Areas, a Wilderness, and two Forest Service Experimental Forests as well as in some stands outside preserved areas (Franklin et al. 1981). While many of the individual studies were conducted as basic research under the US International Biological Programs's Coniferous Forest Biome study, the synthesis was prepared specifically to provide information needed by forest managers in the National Forests of the region.

Analysis of the natural forest ecosystems surfaced a number of important and sometimes surprising features (Franklin et al. 1981). Structural features, specifically the large old trees, large snags, and large logs on the forest floor and in the streams, proved to be the key to most of the functional and compositional pecularities of old-growth forest. Coarse woody debris (snags and logs) play multiple roles in these forests by providing habitat for wildlife, sites for nitrogen fixation, sources of energy, nutrients and soil organic matter, and seedbed. In streams, coarse woody debris was found critical to the physical and biological stability of mountain streams by dissipating energy otherwise used in eroding the channels, creating habitat diversity; serving as a source of energy and nutrients, including the major site for nitrogen fixation; and helping retain litter and other organic inputs utilized as food sources by stream organisms. Examinations of younger natural stands (less than 150 years) showed that they were more like old-growth stands than managed forest stands in many characteristics. Most young stands originate following wildfires in which the old forest is killed but not consumed so that amounts of coarse woody debris have characteristically been high throughout natural successional sequences of forest. The wood also provides a bridge across major disturbances for carbon, nutrients, wildlife habitat, and debris in streams.

This information is now being utilized by managers in developing management prescriptions for recreating old-growth conditions using long rotations (300 years). Ultimately, its most important use is in ecologically improving silvicultural prescriptions for the millions of acres of managed forests within the region, such as provision of appropriate amounts and sizes of snags and rotten logs.

SPECIFIC VALUES OF WILDERNESS

Wilderness, in the sense of extensive natural tracts with minimal human interference, provide scientific opportunities not generally associated with smaller preserves or areas used for developed recreational activities. Scale is probably a key factor since, other things being equal, the larger the area the greater the possibilites for natural integrity of ecosystems and their environment. Four particular research opportunities associated with wilderness can be illustrated with examples from North America. All of these involve using a Wilderness for baseline studies of processes, organisms, or environments in the natural state and use of that knowledge in managing resources or interpreting phenomena in developed regions. These four special research opportunities are availability of: 1) whole drainage basins allowing scientists to study relationships between land and water; 2) populations and, often, complete ranges of larger herbivores and predators; 3) sequences of stands of different ages or successional states on comparable sites (chronosequences); and 4) areas for monitoring background levels of environmental pollutants.

Whole Drainages

Resource managers commonly deal with ecosystems at the very large scale of drainage basins involving hundreds or even thousands of hectares; this necessitates development and integration of scientific information at the drainage level. Questions of effects of forestry activities on fisheries, erosion, and water quality commonly require the perspective of a river drainage, for example, as do questions involving large migratory herbivores. The research required to answer such questions is still at the level of basic principles. Natural drainages are needed, therefore, as the laboratories where knowledge of interactions between land and water and biological and physical processes can be developed. Later in this paper I will provide an example of this kind of research in a report on the Hoh River ecosystem study.

Populations of Large Animals

Studies of natural or semi-natural populations of larger herbivores and predators, and their interactions, require large wildland tracts because of the large ranges typically involved. In the United States wilderness areas associated with National Parks are generally much more useful than those of other agency jurisdictions since hunting is not allowed and even fish stocking has been eliminated in many areas. Such National Park Wilderness' have been the site of several classical studies including the relationship between populations of moose (Alces alces) and gray wolves (Canis lupis). In Olympic National Park in Washington State biologists have been studying natural populations of the Roosevelt elk (Cervus elaphus roosevelti), a large herbivore and important game animal. These studies are leading to major revisions in ecological understanding of the species (Jenkins and Starkey 1980a, 1980b; Jenkins 1981). The non-migratory nature of many of the animals was one unexpected finding; essentially all of the elk were previously believed to migrate between the lowland forests (in winter) and the subalpine meadowlands (in summer). Groups in the undisturbed natural Roosevelt elk populations were found to be extremely stable. Finally, floodplain communities of hardwoods, especially red alder (Alnus rubra), proved to be disproportionately important for foraging, especially in the spring. An important management implication, outside of the park Wilderness, is that floodplain habitats are necessary for balanced elk habitat in addition to the clearcut lands and young even-aged forests which were previously thought to provide the required array of food and cover (Jenkins 1981).

Stand Sequences

The extensive natural landscapes found in Wilderness typically are covered with a mosaic of forest types which can be very valuable in ecological studies. These reflect varied environmental conditions and disturbance histories. In the western United States forest composition varies along moisture, nutrient and temperature gradients. Classifications of forest sites based upon studies of natural forest communities and recognition of plant indicator species have made extensive use of existing virgin landscapes which will, of course, be increasingly confined to Wilderness in the future. Large contiguous tracts are particularly valuable for this work since it is possible to study variation over the landscape without complicating geographical disjunctions. Many studies of plant communities in the United States have utilized Wilderness, actual or proposed (e.g., Whittaker 1956). Many of these studies have had practical applications and included a new approach to resource inventory in at least one case (Kessell 1981).

Fire and other disturbances typically have created varied successional stages and forest age classes in Wilderness landscapes. In the western United States forest stands range up to 1000 years or more in age (Hemstrom 1979). Where several forest age classes are represented on the same habitat or site type, the sequence of age classes, or chronosequence, can be used to study time-related ecosystem changes. Structural, compositional and functional features of ecosystems can all be examined. Care is necessary in drawing inferences, however, since the assumptions of comparable site conditions and stand history are difficult to verify. Nevertheless, the chronosequence approach can be instructive and obviously provides an essential short cut to repeated observations of the same forest, something scarcely possible where succession requires a millenium or more for completion. Wilderness and similar large preserves are especially useful for chronosequence studies since they are more likely to include a variety of forest ages on a given habitat type and include the old successional stages obviously absent from managed landscapes. Chronosequence studies not only provide basic ecological knowledge but also information relevant to management. Some examples from old-growth forests were mentioned earlier. Another current example is research by Dr. James Agee (1981) and his associates on six forest burns of ages from 0 to 3 years up to over 500 years. Studies of forest fire fuels have been particularly useful showing that fuel loads peak in relatively young stands not in old-growth forest.

Pollutant Monitoring

Wilderness areas are proving valuable sites for monitoring background levels of environmental polluntants, information of direct societal concern albeit not necessarily to resource management. The National Atmospheric Deposition Program in the United States includes a network of sampling stations where the chemistry of both precipitation and dryfall are monitored. Several sites in preserved landscapes, including Olympic and Great Smoky Mountains National Parks, are used to determine background levels, i.e. levels of chemicals at sites well removed from major sources of pollution. A comprehensive environmental pollutant monitoring system has been developed and tested in wilderness cores of both the Olympic and Great Smoky Mountains National Parks (Wiersma et al. 1978). These sampling programs provide baseline data on pollutant levels in air, plants, soils and water; through repeated samplings it is possible to determine trends in the background levels of important pollutants. Scientists in the Soviet Union are making similar use of some of their Zapovednika/Biosphere Reserves (Franklin and Krugman 1979).

Limitations of Wilderness for Baseline Research

There are two basic limitations on the use of Wilderness for studies on natural ecosystems and as ecological baselines for adjacent managed regions. First, no ecosystem in the World is completely free of human influence and, therefore, some modification of natural conditions. Even the most pristine of Wilderness in the United States, excluding Alaska, reflects significant human influences due to fire control programs and introductions of pests and pathogens (Franklin 1978). Some human activities, such as grazing, hunting, and fishing, are permitted to continue in Wilderness areas except for those in National Parks. Roads and other activities adjacent to Wilderness boundaries can influence pollutant levels. The key point here is simply that the nature and extent of human influences needs to be clearly recognized when such areas are used as ecological benchmarks. Human influence will vary in degree and avoidability and its importance will vary with the objectives of the research.

Legislation and regulation provide the second limitation on scientific use of Wilderness by determining the types of studies, equipment, markers, access, manipulations, collections, etc., that will be allowed. The United States Congress provided general direction for Wilderness management in the United States. Regulations provide the specific direction, however, and these vary substantially by agency. Limitations on items such as access and equipment are most severe on Wilderness managed by US Department of Agriculture Forest Service and there are fewer local options. Gas-powered and some electronic equipment is not allowed, for example, nor (except in a very few cases) is helicopter access or aerial drops of equipment or supplies. Such limitations are not as severe and allow more local interpretation in Wilderness managed by agencies of the U. S. Department of Interior. Needless to say, the logistical problems and expense can be very significant even when the objectives and sampling methodology are approved by the agency managing the Wilderness.

HOH RIVER ECOSYSTEM STUDY

The potential value of Wilderness for ecosystem research can be illustrated by a study that was conducted on the South Fork of the Hoh River in Olympic National Park in September, 1978 (Franklin 1980). This study focused on relationships between geomorphic processes, terrestrial communities, and aquatic communities in a major river drainage. Broad river terraces with forests of Sitka spruce (*Picea sitchensis*), western hemlock, and red alder and the glacially-fed river and its tributaries were of particular interest. Research was needed on these systems to provide information for management of similar lands being used for commodity production as well as for management and interpretation of the parklands and for basic science.

Study Area

The 11,480 ha South Fork Hoh River drainage is located on the western slopes of the Olympic Mountains. The river extends for about 25 km from its glacial origin on Mount Olympus to its confluence with the main fork of the Hoh River. The valley is generally broad and U-shaped with precipitous valley walls. The floodplain in the lower valley is exceptionally wide occupying nearly 25 percent of the total width of the valley. The maritime climate is wet and mild with average precipitation of over 3200 mm and mean temperatures of around 10°C.

The valley-bottom forests were the main interest and varied from red alder stands on recent alluvial deposits to forests of Sitka spruce and western hemlock on higher river terraces. The best developed forest had a basal area of 82 m^2/ha and included Sitka spruce which averaged 118 cm in diameter and 75 m in height. These forests are sometimes called temperate rainforests (Franklin and Dyrness 1973).

Objectives and Logistics

The overall objective of the research was the description of components and their interrelationships in the valley-bottom ecosystems of the western Olympic Mountains. Specific tasks or objectives were developed to guide the detailed work (Table 1). Several objectives, such as definition of aquatic habitats and their relation to geomorphic processes and to terrestrial vegetation, were strongly interdisciplinary tasks.

The research itself was carried out over an 11-day period by 46 technical personnel representing a broad range of disciplines and institutions. Base camp for the team was set up about 6 km inside the Wilderness on a river bar so as to minimize the expedition's impact on the river valley ecosystems.

Table 1--Major objectives of South Fork Hoh River ecosystem studies.

I. Describe the valley landforms with specific interest in
   - A. Role of vegetation in landform development;
   - B. Formation of different aquatic habitats; and
   - C. Use of vegetation to date landforms.

II. Develop baseline descriptions of the valley-bottom forest including:
   - A. Live, standing dead, and down trees;
   - B. Relationships of forest types to landform; and
   - C. Establishment of permanent sampling system during description.

III. Analyze the amounts and role of dead and down wood in the valley-bottom forests.

IV. Analyze the regeneration dynamics of forest trees in the valley-bottom forests.

V. Describe and analyze aquatic habitats in the lower valley.
   - A. Define aquatic habitats and determine their relation to geomophic and terrestrial processes;
   - B. Determine biology of habitats--energy base and intertebrate communities; and
   - C. Collect baseline data on sediments.

VI. Analyze use of aquatic habitats by fish:
   - A. Species distributions;
   - B. Habitat use by anadromous fish; and
   - C. Overall importance to total fishery.

VII. Examine interactions between Roosevelt elk and vegetation.

Results of the Research

The major findings of the South Fork Hoh River research team involved relationships among components of the Olympic valley-bottom ecosystems (Franklin, Swanson and Sedell 1980). Reports have been published on the geomorphology (Swanson and Lienkaemper 1980), composition and structure of forest communities (McKee et al. 1980), levels and decomposition of coarse woody debris (Lambert 1980), Roosevelt elk (Jenkins and Starkey 1980), and aquatic habitats, communities, and productivity (Ward and Cummins 1980, Sedell et al. 1980). Some important highlights are as follows.

Landforms are the template on which the terrestrial and aquatic communities of the valley-bottom ecosystems develop. Ecological processes determine the initial conditions with biological processes as significant modifiers. Vegetation-geomorphic interactions are particularly important in the cases of small streams and river bars and terraces which result entirely from the interplay between vegetation and fluvial processes.

Woody debris is a conspicous vegetation influence on geomorphic processes. The river mobilizes large amounts of woody debris by undercutting and uprooting trees on forested alluvial flats and higher terraces. Stabilized debris in the main river channel is important in setting up gravel bars, protecting pioneering vegetation, and regulating flow into river side channels, thereby creating the especially productive off-channel aquatic habitat. Wood debris in off-channel and tributary habitats also provides physical stability, habitat diversity, and an energy base by retaining fine organic materials and directly through decomposition. Large organic debris is an important factor in shaping microhabitats in each of these types of stream environments.

Four major categories of aquatic habitat are identifiable in river valleys: the main river channel with fast, turbid, silty water; river off-channel, such as side channels partially isolated from the main stream; terrace tributary, which is low gradient and generally carries clear, slow-moving water; and valley wall tributary, typically a high gradient stream with clear, fast water.

Off-channel and terrace tributary habitats are of overwhelming importance for productivity of aquatic ecosystems of the South Fork and similar, broad, alluviated valleys in western Washington. These relatively protected sites have abundant, diverse food resources for both invertebrates and fish. Coho salmon (*Oncorhynchus kisutch*) and cuttthroat trout (*Salmo clarki*) use these areas for rearing. Terrace tributaries provide important shelter when the main channel is in flood.

Glacial silt limits productivity of some parts of the main channel ecosystem, but not others. Primary production in faster water areas of the channel is severely limited by the scouring action of silt and fine sand being transported in suspension much of the year. Silt deposition in the few quiet water sites of the main channel prevents development of potentially very productive areas. Fine sediment levels are within the acceptable range for salmon spawning despite the high natural levels of sediment in this river.

The forest communities are strongly related to landform or geomorphic surface. Red alder stands dominate youthful fluvial deposits and mature Sitka spruce-western hemlock forests occupy older, higher surfaces. Different spruce-hemlock communities are formed on various terrace levels and have lower densities than those found elsewhere in the coastal Picea sitchensis Zone of the Pacific Northwest (Franklin and Dyrness 1973). Sitka spruce reproduces successfully, earning recognition as a climax tree species along with western hemlock on these sites. Grazing by Roosevelt elk may favor survival of spruce reproduction over that of hemlock. The elk utilize all forest types and the alder flats appear particularly critical at some times of year.

Coarse woody debris is an extremely important structural feature of the terrace forests. Woody debris occupies much of the forest floor and contains large masses of carbon and nutrients. Reproduction of trees on older terrace surfaces is confined almost exclusively to rotten logs and associated stumps and root wads. Logs vary significantly in their value as nurseries depending upon log species, decay state, and terrace level. Forest renewal is dependent on seedbeds of coarse woody debris.

Applications of Research

Results of the South Fork Hoh River research project have helped National Park managers to better understand and manage their resource but they are also proving important on lands managed for timber and fish production outside of the park. Foremost has been recognition of the importance of river off-channel and terrace tributary habitats for aquatic organisms. Over 90 percent of the fish production is associated with these habitats which have typically been ignored in regulatory and management programs aimed at protection of streams and fisheries. Forestry activities must clearly be designed to protect these features which are both biological hot spots and refuges.

The data on percent of fine sediments in the spawning gravels of the main river channel have provided a baseline or standard for similar rivers that are subject to forestry activities. Natural levels were acceptable for spawning of anadromous fish even in this silt-laden river.

The importance of woody debris was further documented for resource managers. Debris is seen as playing important roles in larger streams and rivers, roles which must be considered in programs of riparian management and stream cleanup. The role of woody debris as critical seedbed in coastal forest types has implications on lands managed for timber production as well as on lands reserved from development.

Summary of South Fork Study

The South Fork study demonstrates the use of a Wilderness as a benchmark site for scientific research and a control area for adjacent manipulated landscapes. The only remaining natural examples of river valleys in the coastal region are within the Wilderness of Olympic National Park and the research could, therefore, only be done there. The knowledge gained has extended understanding of northwestern ecosystems to a distinctive variant (the rainforest) and a larger scale (river drainage). Information proved to also have immediate practical application.

CONCLUSIONS

In this paper I have tried to illustrate the value of Wilderness and similar areas as sites for ecosystems research and baseline monitoring. Research on these natural ecosystems contributes to management of commodity lands as well as to basic scientific knowledge; the best answer to many of our resource problems--maintenance of site productivity, preservation of biotic diversity, etc.--are to be found in these natural ecosystems. Their importance will obviously grow in the future as natural ecosystems become increasingly rare outside of preserves.

Keywords: Baseline, Wilderness, nature preserves, ecosystem, forest.

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