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RIPARIAN AND FLOODPLAIN ECOSYSTEMS:
Functions, Values, and Management

A manuscript will soon be available on the functions, values, and management of riparian and floodplain ecosystems. Its purpose is to document and interpret the information that is available on these ecosystems so that the consequences of their alteration and deterioration can be assessed at a national level. The common functional properties of these ecosystems and their attractiveness to wildlife make it possible to address riparian ecosystems as discrete and manageable entities.

The Fish and Wildlife Service has been involved in several efforts that have led to the development of the document. Much of the earlier concern was for the consequences of channelization and other stream alterations on fish and wildlife communities. It was soon recognized that most alterations could not be considered separately from changes in floodplain vegetation and animal communities. The growing body of literature on riparian and floodplain ecosystems suggested a strong interdependency between stream and floodplain processes.

A national symposium held in 1978 on "Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems" was an attempt to focus attention on the research of individuals that were working largely on ecosystems associated with streams. The publication described below is a "second generation" state-of-the-art whereby we summarize and synthesize what is known about riparian and floodplain functions, values, and management. In order to give a better picture of the contents of the document, a brief synopsis of each of the major sections will be presented.

COMMON PROPERTIES AND UNIFYING PRINCIPLES

There are certain properties that riparian and floodplain ecosystems have in common. The first is that they have flowing water, are linear, and usually are narrow. Their abundance is related, of course, to the abundance of streams which can be quantified as drainage density (number of kilometers of stream length per square kilometer of land area). Drainage density in the northeastern U.S.A. averages about 1.4; thus, there are few places in that region that are very distant from a riparian or floodplain ecosystem.

The second unifying property is that they are corridors where water and materials from the landscape converge. In comparison to upland ecosystems, they tend to be wetter, have larger amounts of nutrients and sediments available to them, and are subjected more frequently to catastrophic forces of water flow.

A final property common to floodplain and riparian ecosystems is the interdependency of the aquatic and terrestrial (or wetland) components. In humid climates floodplain and streamside vegetation is an important source of energy for the maintenance of invertebrates and fish. While inputs of leaf litter may be of less significance to these organisms in arid climates (because of greater in-stream primary production), hydrologic connections may be extremely important, especially where water storage in deep alluvium continues to supply water downstream in the absence of surface flow.

With these common properties and others which are responsible for the function and structure of riparian ecosystems, approaches for their management may be simplified and generalized greatly, as compared with evaluating each ecosystem alteration on a case-by-case basis. We already know that floodplain and riparian ecosystems are sufficiently different from uplands that new and different precautions must be taken to derive benefits from them and live harmoniously with them.

Figure 1 is an illustration of how an index of ecosystem structure--basal area of vegetation--varies with precipitation for a number of sites in the U.S.A. Progressing from high to low precipitation, the transition zone is crossed between upland forests and grassland/desert ecosystems. For upland ecosystems, basal area of trees decreases and trees disappear at approximately 45-60 cm per year precipitation. However, abundant examples of robust stands of floodplain forests are found in regions with less than 50 cm precipitation. Thus structure of riparian ecosystems is relatively independent of local climatic factors as compared with upland ecosystems. Since factors other than local climate also have an influence on the structure of vegetation, it is likely that riparian and floodplain ecosystems have in common other functional and structural properties. This may actually simplify, rather than complicate, approaches to their management.

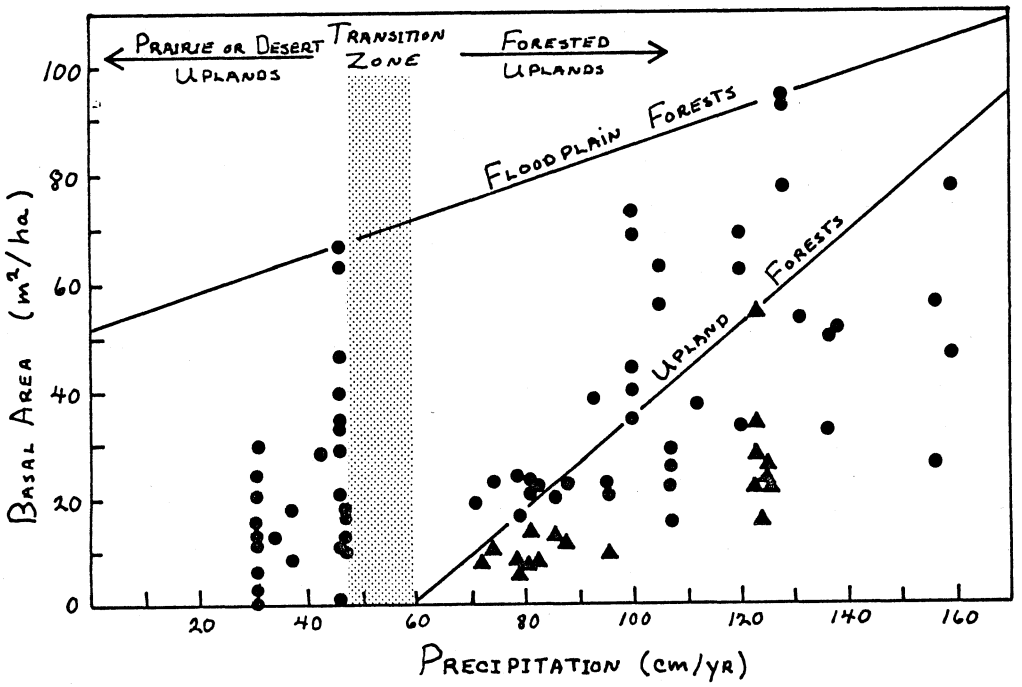

Figure 1. Relationship between precipitation and basal area of floodplain (●) and upland (▲) forests. Sloping lines are drawn for maximal basal area. Maximal development of basal area for upland forests appears to be dependent on precipitation; hence, they do not occur below about 50 cm/year. Basal area of floodplain forests is relatively independent of local precipitation since their water supply is augmented by other sources.

WHY ARE THESE ECOSYSTEMS SO IMPORTANT?

Human society has long perceived the unique values of floodplain and riparian ecosystems. The river corridors in which these ecosystems are found have been used as locations for cities, as conduits for transportation, and in producing harvestable materials such as timber and wildlife. Because riparian ecosystems receive water and erodible materials from upland regions, they represent lines of convergence of materials and energy from broad areas and diffuse sources. It is the energy of water movement that delivers and concentrates these materials. As a result, an abundance of water and rich alluvial soils are among the more important attributes that distinguish floodplain from upland ecosystems.

It is likely that wildlife populations depend on riparian ecosystems for similar reasons to those of humankind. Many species of animals are dependent on floodplain and riparian ecosystems as a source of food, water, and habitat structure. Some other values that have been attributed to floodplain ecosystems are floodwater storage, enhancement of water quality, and production of timber. These values are self sustaining so long as the primary sources of energy and material to these ecosystems are not diverted from them. There has been a strong tendency to try to replace these cost-free services of nature with structures and alterations that require maintenance and further investments of energy.

Since floodplains have high value in their natural state and perform important life support services for society, it follows that the degree of protection should also be high. In one sense riparian ecosystems have been afforded some degree of de facto protection because they are too wet and too flood prone to be considered ideal for many types of development. On the other hand their high fertility and abundant moisture has made them highly attractive areas, especially for agriculture. However, the hazards of developing them have not occurred without costs as demonstrated by the abundance of federally subsidized water development projects for flood control and irrigation.

SYNOPSIS OF THE MAJOR SECTIONS

ECOLOGICAL FUNCTION

Floodplain and riparian ecosystems are adapted to and dependent on the sometimes catastrophic effects of flooding. Over geologic time periods, streams undergo phases of erosive downcutting and alluvial deposition. At the same time stream channels migrate back and forth across floodplains, a process which results in a continual replacement and displacement of the plant and animal communities. In this way a stream is responsible for "organizing" the floodplain into a variety of diverse communities, many of which are controlled by the depth, duration, and frequency of inundation.

Flooding and flowing water are also responsible for depositing and eroding sediments. Both the suspended material and the water that carries it represent supplies of materials from sources outside the floodplain. Since upland ecosystems lack a similar lateral transport system, this is one of the fundamental differences between uplands and riparian ecosystems. Both the abundance

of water and nutrient supply are, in part, responsible for maintaining the productivity and vitality of floodplain and riparian ecosystems.

Primary productivity may be regarded as an indicator of the vitality of an ecosystem. Not only does primary productivity initiate organic energy flow for food webs, but one of its fundamental functions is to maintain the structural integrity of the ecosystem. Studies done on floodplain forests of the Southeast show that they are among the most productive ecosystems in the nation. Riverine wetlands also export a disproportionate amount of organic matter as compared with an equivalent area of upland ecosystem. Thus they augment the amount of energy and structural carbon that downstream aquatic ecosystems, particularly estuaries, receive from continental runoff. Instream communities also are highly dependent on leaf litter from streamside forests for maintaining metabolism and ecosystem structure.

Differences in nutrient cycling between floodplains and upland ecosystems are related to (1) the influence that flooding and an "aquatic" phase has on restricting oxygen availability to soils and sediments, hence altering the metabolic pathways of microbial communities, and (2) the aqueous transport system that provides pathways of exchange through lateral imports and exports of nutrients. Most nutrient cycling studies conducted in southeastern floodplain forests suggest a high capacity to absorb and recycle nutrients. In arid riparian ecosystems, the quantity of water, rather than its quality, is an overriding factor in ecosystem processes. The potential for floodplains to have an influence on the nutrient status of floodwaters depends partly on the length of time and the quantity of water and nutrients that come in contact with the floodplain.

PREDICTING EFFECTS OF ECOSYSTEM ALTERATION

Based on the understanding provided in the forgoing section on natural ecosystem function, it should be possible to predict the severity of damage that a particular alteration will have on normal ecosystem processes. The present section identifies four principal sources of energy and materials--sunlight, water flow, nutrients, and sediments--that are necessary for the maintenance of the normal floodplain ecosystem processes. Alterations of ecosystems can be categorized as changes in geomorphic processes, changes in water delivery patterns, physiological stress, and biomass removal. Stream channelization, containment of stream flow and channel constriction, impoundments and diversions, introduction of toxins, grazing by livestock, timber harvest, and hunting and fishing correspond with one or more of the four alteration categories.

From this analysis it is possible to predict the consequences of the seemingly diverse sources of intrusions into riparian and floodplain ecosystems. If goals of mitigation are to restore the multiple services that these ecosystems provide in their natural condition, some alterations can be mitigated and others clearly cannot. If the principal sources of energy and material continue to be supplied to the system, there is a high probability of recovery. If these sources are blocked or diverted, mitigation to reverse the damage can occur only after great investments of time, energy, and resources.

STATUS OF RIPARIAN AND FLOODPLAIN ECOSYSTEMS

There is no comprehensive inventory of riparian and floodplain ecosystems to evaluate (1) the quantity of land that originally consisted of these systems and (2) the environmental quality of those systems that remain more or less intact. This section provides a summary of existing land resource inventories in addition to some newly acquired data on the extent and distribution of floodplain and riparian ecosystems.

Analysis of stream mileages provides additional insight on the distribution and abundance of ecosystems influenced by or dependent upon the presence of streams. State-by-state surveys on stream length will supplement published accounts on the extent and condition of riparian ecosystems.

Riparian vegetation probably occurred along most of the 2.2 million kilometers of streams in the lower 48 states. Several estimates indicate that flood-prone land is about 6 to 9 percent of the total land surface. Substantial conversion of forests in floodplains to urban and agricultural land uses have sharply reduced the quantity and quality of functional riparian systems. Losses have been most dramatic in the West and Southeast because of the tremendous demand on the water and adjacent land resources.

DEPENDENCE OF WILDLIFE ON FLOODPLAIN AND RIPARIAN ECOSYSTEMS

Many of the attributes of riparian ecosystems that make them attractive to humans are also responsible for the success and maintenance of wildlife populations. These characteristics include the presence of flowing water, moist and nutrient rich soils, relatively high plant productivity, and corridors for migration and travel. The structural complexity of these ecosystems, particularly in comparison with uplands in arid climates (Figure 1), provides many habitat requirements and adds to the landscape diversity of the regional geography.

During the past decade, a large number of studies have documented that riparian ecosystems unquestionably provide essential habitat requirements for a large diversity of vertebrate species. More migratory and nesting species of birds have a higher affinity for riparian and floodplain ecosystems than they do for upland ecosystems. While catastrophic flooding may temporarily reduce the abundance of "terrestrial" vertebrates, these species are adapted to rapid recolonization once flood conditions subside. In fact certain fish populations are augmented by enormous increases in feeding area that floodplain inundation provides in addition to the seasonal supply of leaf fall into the water surface of the stream channel under non-flooding conditions.

The reasons for dependence on and affinity for riparian ecosystems by such a large and disproportionate number of vertebrates are both easy and difficult to explain. The presence of flowing water, high plant productivity, etc., already have been mentioned as contributing factors. Perhaps of more fundamental importance, riparian and floodplain ecosystems represent a combination of aquatic and terrestrial ecosystems that have somewhat separate spatial and temporal dimensions. Habitat features change dramatically with only small topographic differences, such as the gradient from an open water stream channel to a dense gallery forest. The duration and timing of flooding superimposes a seasonal dimension on these gradients. For these spatial and temporal dimensions

to be maintained, it is essential that the changing geomorphic forces that drive floodplain and riparian ecosystems be allowed to organize and reorganize the plant and animal communities.

INSTITUTIONAL AND VALUATION PERSPECTIVES

Allocating land and water in riparian and floodplain ecosystems among various uses and assessing the relative social values of these competing uses are issues of immediate and major concern. Riparian systems are generally considered quite valuable because of their ecological values and natural service functions. However, institutional mechanisms for allocating resources such as land and water are designed to serve perceived human wants and needs. Therefore, the way in which private and public institutions allocate natural resources will determine whether riparian systems are left relatively undisturbed for wildlife, timber, specific kinds of recreation, natural flood storage, water quality enhancement, and groundwater recharge; or whether they are altered for agricultural production, navigation benefits, flood protection or commercial development. Central to this process are the forces and incentives which drive resource allocation in one direction or another and the manner in which preferences and values are weighed in decisionmaking processes which directly affect the resources.

The causes of land use patterns in riparian systems appear to be very complex. In some respects they are. Soybean demand, tax laws affecting property and estates, and public flood control projects are but a few factors which appear to affect land and water use in floodplain ecosystems. However, there are broader and, in some respects, more meaningful categories:

1) market forces affecting private investment patterns (consumer demand for specific goods and services)

2) political forces affecting private investment (world trade policies, regional economic development, public subsidies)

3) institutional factors affecting private and public decisionmaking

   a) market decisionmaking (property rights specifications, failure of markets to capture costs and benefits of private transactions, information problems)

   b) nonmarket (Government) institutions and activities (taxes, subsidies, regulations which affect the incentives of private decisionmakers to engage in particular activities; and publicly conducted and assisted projects).

Having analyzed these categories of factors, one can focus on specific policies, programs and decisions which determine the fate of riparian systems.

Another distinct aspect of economic analysis of resource allocation in riparian systems concerns valuation. How does one value the various competing uses of riparian systems? This problem arises most frequently in the context of public decisionmaking processes whereby public officials must weigh the value of one land use versus another (i.e., through permitting/licensing activities, zoning decisions, funding of public projects, etc.). Typically,

public decisionmakers are confronted with two very different kinds of information regarding values: ecological and "economic". The decisionmaker is faced with the dilemma of evaluating non-comparable values before reaching a decision. However, ecological values have economic significance. For example, if riparian system alteration were to result in lost natural flood storage, lower water quality, and fewer wildlife resources, what is the "cost" of these foregone opportunities? Since we do not pay landowners to maintain land for these purposes, it is difficult to assess society's demand for them as expressed through market prices (reflecting aggregate willingness-to-pay). This necessitates use of some surrogate value (usually derived through some form of benefit-cost analysis).

OPPORTUNITIES FOR MANAGEMENT AND PROTECTION

Although floodplain and riparian ecosystems have recognizable ecological properties, it is difficult to identify all the laws and formal programs that may apply to them. Riparian ecosystems--like many other ecologically defined areas--do not relate to a single well-defined body of law. Rather, the "law of riparian ecosystems" is an accumulation of diverse categories of law including but not limited to property law, tax law, water law, land use control law, water quality regulations, floodplain management regulations, and others.

In this chapter we identify and describe laws and public programs instituted by law which affect use of riparian ecosystems. Questions and issues are addressed pertaining to Federal, state, and local jurisdiction, the permissible extent of private decisionmaking in riparian ecosystems, the purpose and scope of public actions including water and related land resource development projects, regulations, planning, and acquisition programs. Finally, given this description of existing legal/institutional arrangements, the remainder of the chapter summarizes existing and potential administrative and legislative opportunities for the management and protection of floodplain ecosystems.

USERS OF THIS INFORMATION

The approaches and information in this publication are intended to provide a geographically balanced treatment of issues of major concern that impinge upon riparian and floodplain ecosystems. Focusing on the common properties of these ecosystems will simplify recommendations and decisions that affect their management and protection. The manuscript is oriented to provide assistance to decisionmakers who must utilize ecological principles and information within a context of legal and institutional constraints.