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Natural Disturbance Effects on Riparian Areas

Fred Swanson
USDA Forest Service
Pacific Northwest Forest and Range Experiment Station
3200 Jefferson Way
Corvallis, OR 97331

Abstract

Naturally occurring abiotic disturbances have a tremendous effect on riparian systems. Geomorphic and fluvial disturbances are discussed in this paper. These disturbances help form the complex habitats found in these systems. The type of geomorphic disturbance and the recovery of the riparian ecosystem depend on the geology of the area and on the extent of the disturbance. Fluvial disturbances are also constrained by the geologic strata. Natural disturbances tend to be distributed in both time and space. This leaves numerous undisturbed sites that act as inoculum sources to speed the recovery of the disturbed parts of the system. The aquatic portions of the riparian systems recover faster than the associated riparian vegetation, but both need the undisturbed areas to ensure recovery.

INTRODUCTION

Natural disturbances in riparian systems occur in three major categories: geomorphic, other abiotic, and biotic. This paper will focus on geomorphic and some of the other abiotic disturbance types. It will focus on their frequency, extent, and effect on riparian systems. Consideration of these disturbances is important when managing riparian areas.

To manage a riparian area, an ecosystem-function perspective is the most useful perspective because it provides for the management of the area by defining and utilizing objectives (Gregory et al. 1991). In forest riparian zones, the forest influences the stream through various functions such as (1) fine litter falling into the stream, which provides food for aquatic organisms, (2) large woody debris falling from the adjacent forest, which helps to structure the stream system, and (3) streamside forest shading the stream, which affects water temperature and regulates light available to fuel growth of aquatic plants. Depending on the objectives of the manager, various components of the stand can be managed to achieve those objectives. If fish habitat complexity is an objective, for example, attention would be focused on the woody-debris function. Within this framework, there are two major functional relationships between the vegetation and the aquatic organisms. Riparian vegetation influences the structure of aquatic systems through the influence of roots in stream banks, live stems in channels and floodways, and dead woody debris in the channel. It also influences the food resources both by regulation of light for primary production and by the amount of litter falling into the stream. There are cross linkages between these two functions in that the complex structures help retain floated food resources (litter) within the aquatic system. The influence of these two functions on the structure and food resources of an aquatic system is important to both intact riparian systems as well as to the recovery of disturbed systems that were altered by management or by natural disturbances.

GEOMORPHIC

The geomorphic features and processes, which transport sediment across landscapes, define and influence the riparian system. Landforms provide the physical stage on which biological and physical interactions occur. They constrain the behavior of the ecosystem. Geomorphic processes, such as lateral channel shifts and streamside landslides, can be viewed as one class of disturbance in the ecosystem. There are biotic and other types of abiotic disturbances as well. To understand how natural disturbances affect riparian systems, the geomorphic stratification of valley floors must be considered. This consideration also provides a basis for stratification of ecosystem functions from one segment of the stream to another, and it provides an understanding of human effects upon the riparian ecosystem.

Stream segments have individual functions and values. These characteristics are best explained in a hierarchical framework (Swanson and Franklin 1992). This hierarchy is divided among the various channel and valley-floor structures, starting with the finest scale of the individual particle of sediment or organic matter. Aquatic and invertebrate interests can be concerned with scales as fine as a boulder to determine which species use a particular side of the boulder as influenced by the flow regime over the boulder.

Two crucial scales used to evaluate disturbances are the channel-unit scale, such as pools and riffles, and the next coarser scale of resolution, the reach scale. Each stream reach contains numerous channel units in sequence. They are distinguished based on the type and degree of constraints on the channel and valley-floor structure by geologic agents. These constraints may be active, such as large landslides or alluvial fans growing at the mouths of sediment-productive tributary streams, or passive, such as hard-rock zones where the channel cuts a narrow gorge. Other reaches may be free of these constraints, resulting in a different structure often referred to as "unconstrained" reaches.

Examples of contrasting reaches are (1) a narrow, constrained valley floor with a single meandering channel and (2) a wide, unconstrained valley floor that has developed multiple channels. Constrained reaches form where alluvial fans composed of accumulations of bed load and debris-flow material are constructed at the mouth of tributary streams or where large, dormant, or active landslides have pinched the valley floor. All of these types of reaches and others can affect the same riparian system.

Narrow valley floors resulting from active or passive geomorphic processes are highly constrained and tend to have a reduced frequency and extent of the lateral movement of the stream channel. There can be some streamside landslides and small-scale, shallow, rapid sliding at the toe of the large landslides. These processes are generally rather restricted, but they do have persistent effects on channels, such as accumulation of large (up to car-size) boulders from the landslide. The boulder size depends on the debris associated with the landslide. Large landslides commonly push the channel against bedrock on the opposite valley wall. These areas have very restricted riparian habitat and recreational values.

Unconstrained reaches tend to be wide valley floors with multiple age classes and varied composition of vegetation, reflecting the complex disturbance history. In many forested systems in the Western United States, there are distinct upland conifer types indicative of past wildfires. In contrast, stream channel changes have been the dominant disturbance process in riparian zones. There are many secondary and tributary channels that flow through the forest to provide a very extensive zone of interaction between the terrestrial and aquatic environments. These provide extensive habitat for wildlife, aquatic, and human activities.

The geomorphic characteristics of the system help define reach structure and long-term geomorphic and biotic behavior. These reaches range from narrow, sediment-poor, stable, rock-defended channels with little room for meanders to sediment-rich reaches that have numerous lateral channel changes caused by sediment deposition. This conceptual framework of landform template and ecosystem functions allows the prediction of the extent and type of natural disturbances in riparian zones in reaches of passive and active constraints and in unconstrained reaches (Table 1).

The reach-type constraints control the frequency and extent of disturbance processes. If the geomorphic characteristics of a reach type are known, the disturbance regime can be predicted. In bedrock-constrained reach types, fluvial (lateral channel) adjustments have a very low potential but are frequent and dominant in unconstrained types.

Riverine systems are very dynamic in their long-term behavior. In forested mountain systems, there are narrow and wide reaches. In these systems, fluvial disturbances tend to be focused in the wide reaches where there is room for them to operate. In these areas, floods periodically reopen the riparian canopy over the channel. Evidence of earlier disturbances are commonly erased by the most recent disturbance.

In other systems, such as the meandering river systems (e.g., the Little Missouri River), the disturbance regime is very different. In some areas, the river is constantly eating away at a wide spectrum of forest age classes, leaving a zero-age-class substrate in its wake.

In a multiple-channel system with multiple live channels and bits of abandoned channels, such as oxbows, a different valley floor geomorphic and riparian dynamic occurs. Little lateral cutting is needed for one active channel to intercept another active channel or an abandoned channel, causing the main flow to move into another channel. This results in varied age classes and composition of vegetation and their associated influences on the stream ecosystem. These vegetation differences are caused by inherent differences in the geomorphic dynamics in each reach or system of river dynamics.

Flooding is the major process that can destroy riparian vegetation. Riparian vegetation has both positive and negative effects on the potential for this damage to occur. Woody debris floating down the channel can be lodged against standing trees and can serve as a tool to aggravate disturbance of riparian vegetation. However, the rooting of plants in the bank and gravel-bar material impede fluvial disturbance.

Landslides of a variety of types have important influences on the stability of riparian zones. One landslide class is large, periodically moving slides. The lateral encroachment of this slide type deflects a river's course and pinches it against the opposite valley wall. Areas of landslide movement greater than a few percent of channel width per year result in frequent streamside slides and severe bank erosion, keeping riparian vegetation from establishing and stabilizing the site in the short term.

Another class of landslide is large landslides at the heads of channels. This type is the major source of debris flows that move down channels affecting riparian zones. These are typical of the Wasatch Front area of Utah. In the steeper channel units, debris flows scour the channels. Where the channel gradient decreases to the point that movement stops, debris flow deposits accumulate, commonly on alluvial fans.

OTHER ABIOTIC DISTURBANCES

Riparian zones are subject to very high levels of natural disturbance. They are subjected to both the disturbances imposed by the riverine environment and to the disturbances imposed on the upland terrestrial environment. In some cases, there may be a decoupling of these disturbance regimes.

Wildfires often do not remove the vegetation structure in riparian areas where topography influences microclimate and fuel moisture and, therefore, fire behavior, impeding the movement of high-severity fires into valley bottoms. While wildfires may be the major disturbance on the upslopes, valley bottom disturbances are dominantly fluvial in many landscapes. Where the stream runs against the valley wall, the riparian zone is subjected to both the fluvial and upland disturbance regimes. Management must account for these various effects on the different stream reaches.

Different stream reaches have a role in the generation, propagation, and cessation of disturbances. Some types of reaches are very good at stopping the movement of disturbances through the system while others may facilitate disturbance movement. For example, large landslides that pinch the channel against the opposite valley wall often decrease the gradient above the landslide, which increases the deposition of sediment. This deposition of sediment then increases the opportunity of lateral channel changes above the slide.

In the landslide zone, small streamside slides are common, causing periodic outbursts of boulder and woody, debris-laden flood surges. These surges may damage the riparian zones downstream. This one feature controls the disturbance regime for a very long section of the channel in both upstream and downstream directions.

This type of disturbance also affects the biotic responses. In an altered forty-year-old hardwood stand, a large debris flow resulted in zones of scour and of deposition (Lamberti et al. 1991). The immediate effect on the physical system was that channel unit structure (size and spatial distributions of pools and riffles) became shorter, more disorganized, and more transient. Five years after the event, the physical system was still adjusting to this disturbance. In the areas with scouring, the channel was simplified, causing water to move through quickly, which reduced the potential for uptake of dissolved nutrients and opened up the vegetation canopy above the channel (Lamberti et al. 1991).

Table 1. Areal extent and frequency of riparian disturbances.

	Reach type		
	Constrained		Unconstrained
Disturbance Process	Bedrock	Earth flow	
Fluvial	very low	moderate	high
Streamside	very low	high	low
Debris flow	low	moderate	low

The immediate effect on the biotic system was catastrophic in the zone where the debris flow altered habitat completely. However, within the first year, primary production reached very high levels because of the canopy opening. This canopy opening allowed algae to flourish and to dominate the food base in the most disturbed segments of the channel. The macroinvertebrate community, in terms of its density and taxonomic richness, also came back within a year, though it was dominated by species grazing on the algae. Species dependent on stems and leaves were not present in these reaches.

The trout were originally decimated, but after one year the young-of-the-year trout were back to predisturbance densities. However, these populations have fluctuated from year to year, reflecting the instability of the system (Lamberti et al. 1991).

The quick recovery of the aquatic systems is related to the frequency and location of the natural disturbances. Many natural disturbances are episodic and scattered in space, leaving many undisturbed reaches in upstream and downstream areas. These undisturbed reaches create numerous refuges for the aquatic organisms and act as sources of inoculum to reoccupy severely disturbed sites (Anderson 1992). Channel complexity in this system has been recovering because woody debris was left in the system so that refuges of pool and slack-water habitats, at the scale of individual logs, were created. Recovery of riparian vegetation is much slower than recovery of the in-channel community.

An example in which disturbances provide a beneficial role in aquatic systems is the Elk River in southwest Oregon. This river is an important salmon fishery that requires rather specific water temperatures. Water temperature is an index of the habitat quality for native species. This fishery is maintained by two major areas in the river system, i.e., the "flat" reaches of low gradient and wide valley floor basins and the steep, narrow valley types. The flats have a high natural disturbance regime, resulting in an open canopy above the river. This open canopy allows high primary and invertebrate production but increases the water temperature. This increased primary and invertebrate production results in concentrations of salmon. The salmon in the flats benefit by the steep forested tributaries, since these reaches provide the cooler water required to keep the water temperatures in the basin within the salmon's tolerance. If disturbances removed tree cover over the steep tributaries, the system's fisheries value would decline.

Several of the flats on the Elk River have their origins in great, catastrophic disturbances. One of the best habitats is the product of a landslide out of a major tributary stream more than 100 years ago. This highly productive area is a very complex habitat resulting from abundant woody debris. The woody debris is derived from reworking the deposits, including logs, that were carried down with the landslide as well as from streamside slides bringing in new trees.

SUMMARY

The key to system recovery is maintaining the important elements of the system that help the system function. These elements include the vegetation, which regulates the food base and helps the physical stability of the system, and large woody debris. The pattern of disturbance is crucial. Many of our natural disturbance mechanisms tend to be scattered in both time and space, leaving many refuges. Some of our management practices tend to be more chronic or extensive in time and more pervasive geographically, thereby reducing refuges, recolonization, and recovery potential.

There is a high potential to predict the long-term system dynamics based on geomorphic considerations. Ecosystems have a high potential to recover from natural disturbances if allowed to do so with natural recovery agents, such as vegetation and large woody debris.

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