# Interactions between Aquatic and Terrestrial Systems*

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## Introduction

Terrestrial ecosystems and the aquatic systems that they border are intricately interconnected physically, chemically, and biologically. A direct expression of the influence of the aquatic system on the terrestrial is the formation of the riparian zone, an area adjacent to the watercourse in which soils are often saturated and inundation may occur periodically. The impact of the aquatic system on the riparian zone results in a vegetative community substantially different from that upslope. In turn, the terrestrial system may influence the aquatic by dictating the channel form of streams, controlling material passing through the system, and providing a primary source of energy and nutrient inputs to the channel. These interactions affect the biotic character of riparian areas and of the waterways draining them.

This paper will briefly outline the major interactions between aquatic and terrestrial ecosystems and delineate some of the factors responsible for dictating the relative magnitude of these processes. Streams and rivers will be the aquatic systems considered, since they represent the majority of the land/water interfaces found on forested lands in the Pacific Northwest (Oakley et al. 1985). Interactions have been separated into two broad categories, those dictating structural attributes of the systems (such as soil characteristics, composition of vegetation, and channel morphology) and those primarily influencing functional characteristics (such as energy flow and nutrient cycling). Special emphasis will be placed on examining the changes in the relative importance of the interactions between the aquatic and terrestrial systems as a result of changes in stream size.

## Aquatic/Terrestrial Interactions Influencing System Structure

Many features of the riparian area are dictated by the presence of the aquatic system. The most obvious difference between riparian areas and adjacent upland sites is in the composition of the vegetation (Campbell and Franklin 1979). Development of this distinct vegetation is due to proximity to surface water, which produces water and soil conditions peculiar to this area. Riparian plants commonly found along streams in the Pacific Northwest include a variety of hydrophytes, as well as species that are also found on upland sites but that tend to proliferate in the riparian zone due to favorable conditions for their germination or growth. Included in the latter category are trees such as red alder and black cottonwood as well as shrub species such as salmonberry and vine maple (Franklin and Dyrness 1973, Campbell and Franklin 1979). The stream may also provide a vehicle for dissemination of riparian plant seeds, further influencing the composition and distribution of streamside vegetation (Daubenmire 1968).

Soils of riparian areas typically differ from those on upland sites in a variety of characteristics. Much of the mineral content of riparian soils originates as stream-deposited

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sediment, while the parent material of upland soils is usually the rock underlying the site. The difference in parent material creates the potential for riparian soils to have a more heterogeneous mineral character than adjacent upland sites in those basins having a varied geology. In addition to influencing the composition of the soil, deposition of sediment in the riparian zone during floods, coupled with flushing of organic litter, produces a bare soil surface, a rare condition in upland areas under natural conditions (Bell and Sipp 1975). The relative proportion of ground surface covered with terrestrial litter increases with distance from the stream channel (Figure 1). Seeds of certain common riparian plants require a bare soil surface for successful germination (Newton et al. 1968).

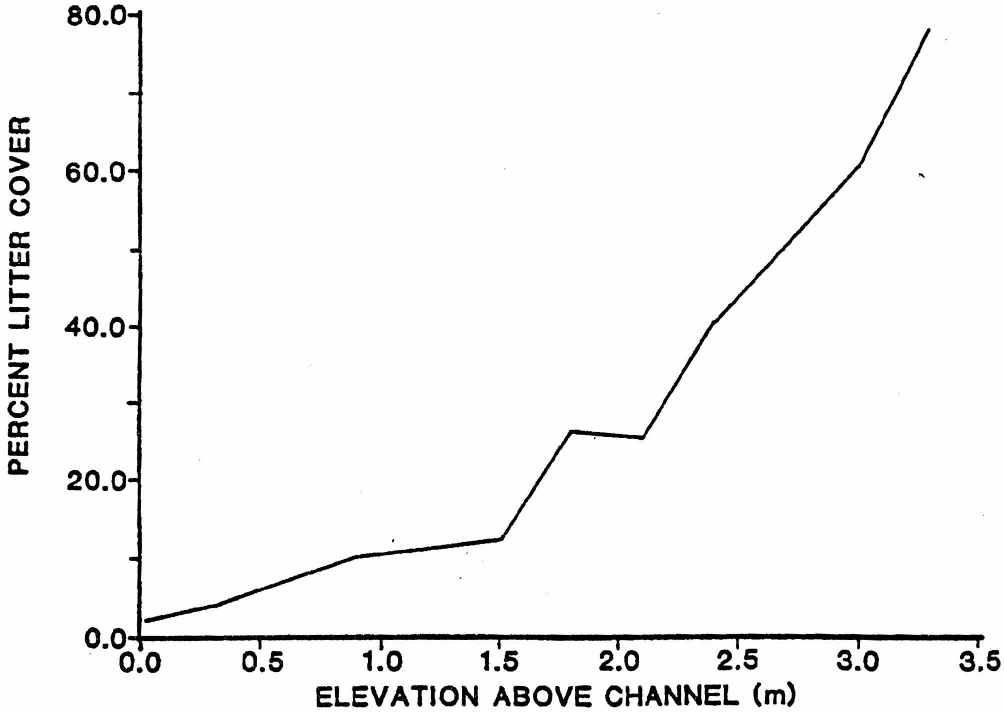


**Figure 1. Change in the proportion of the ground covered with leaf litter as a function of elevation above the stream channel (redrawn from Bell and Sipp 1975).**

The redistribution of organic matter during flooding in the streamside area influences the organic content of riparian soils. Large quantities of organic matter may be flushed from some areas and deposited in others. As a result, the organic content of riparian soils tends to range widely depending upon the topographical and hydrological characteristics of the site. In those areas where flood flows possess fairly high levels of energy as they move through the riparian area, the streamside litter stratum typically gets flushed downstream, leaving a bare mineral soil surface (Bell and Sipp 1975). However, in situations where the energy of overflow water from the channel is low, large depositional sites for organic matter flushed from upstream areas may develop, as in streamside swamps, producing soils high in organic content (Brown et al. 1979).

In addition to altering the amount of organic matter present in the riparian zone, the aquatic system also influences levels of soil organic matter by producing higher soil moisture conditions. These higher moisture levels often accelerate decomposition of the deposited organic matter (Bell et al. 1979), although water tables high enough to produce year-round standing water may retard decomposition if conditions of low oxygen concentration are produced. This situation commonly occurs in swamps and marshes (Brown et al. 1979).

Decomposition rate is also influenced by the type of organic matter present on the site. The riparian plants common in the Pacific Northwest generally produce material that decomposes much faster than the litter of common upland species (Edmonds 1980). Thus, the amount of organic matter in streamside soils may be quite low as a result of both higher moisture and more easily decomposed material.

Infrequent catastrophic events can also dramatically influence the physical structure of the riparian zone. Periods of very high discharge may damage or uproot riparian vegetation due to the battering action of floating debris or of sheets of ice (Sigafoos 1964). Streambank erosion, also occurring during these very high flows, may undermine vegetation on the channel margins and topple it into the stream. The severity of the effects of this process depends on various characteristics of the site, such as the topography of the riparian area and the morphology of the channel, as well as the magnitude of the discharge event. However, the distinctive features of the riparian zone are in large part due to these periodic disturbances.

Debris torrents are another catastrophic event influencing riparian structure. The torrents follow streams downslope and typically occur only in very high gradient channels; hence, they tend to be restricted to small stream systems (Swanson and Swanston 1977). Torrents typically remove all vegetation from a zone immediately adjacent to the channel. Depending upon site characteristics and the severity of the torrent, the resulting riparian substrate might be bare mineral soil or predominantly bedrock. The resultant soil conditions determine the rate of re-establishment and the characteristics of the post-torrent streamside vegetation (Swanson et al. 1982).

The terrestrial system may also have a pronounced effect upon the physical characteristics of the stream system. Roots of riparian vegetation aid in stabilizing streambanks and streambeds, thereby decreasing sediment input to the system and influencing the morphology of the channel (Swanson et al. 1982). In addition, riparian zones are the primary source area for large organic debris in streams. This woody material, composed of tree boles, root wads, and large branches, has been recognized as an important structural component of stream systems. Large organic debris forms pools (Swanson et al. 1976), retains sediment and gravel (Zimmerman et al. 1967, Bilby 1981, Megahan 1982), retains organic matter such as needles or leaves used as a food source by invertebrates in the stream (Naiman and Sedell 1979, Bilby and Likens 1980), and provides a source of cover for fish (Bryant 1983, Koski et al. 1984, Sedell et al. 1984, Grette 1985). Dramatic changes in channel structure, typically from a system displaying a mixture of pools and riffles to one dominated by riffles, have been documented following the removal of woody debris from a channel (Table 1; Bilby 1984). Changes of these types may be translated into changes in the species composition and age structure of the fish populations, favoring components preferring fast-water habitats (Bisson et al. 1982, Bisson and Sedell 1984).

Large organic debris also influences sediment movement through streams, which often in turn affects the shape of the channel. The presence of large pieces of wood in the stream creates locations that are very favorable for the deposition of particulate material being carried by the stream (Figure 2). Woody debris held 49 percent of the total amount of sediment stored in seven Idaho streams (Megahan 1982) and 87 percent in a small system in New Hampshire (Bilby 1981). Woody debris in streams is also frequently responsible for the formation of waterfalls, which influence sediment movement by causing a rapid loss in the potential energy of the stream (elevation) with no opportunity to erode material from the bed or bank (Heede 1972). Removal of woody debris from a section of stream in New Hampshire resulted in a reduction in the number of waterfalls of over 50 percent (Figure 2) and a seven-fold increase in the export of particulate matter from the watershed (Bilby 1979).

**Table 1. Relative proportions of pools and riffles before and after removal of woody debris from a section of stream (from Bilby 1984).**

| | Before | After |
|---|---|---|
| Percent of pools formed by wood | 86 | 77 |
| Pools | | |
| Percent of surface area | 50 | 32 |
| Percent of stream volume | 72 | 46 |
| Riffles | | |
| Percent of surface area | 50 | 68 |
| Percent of stream volume | 28 | 54 |

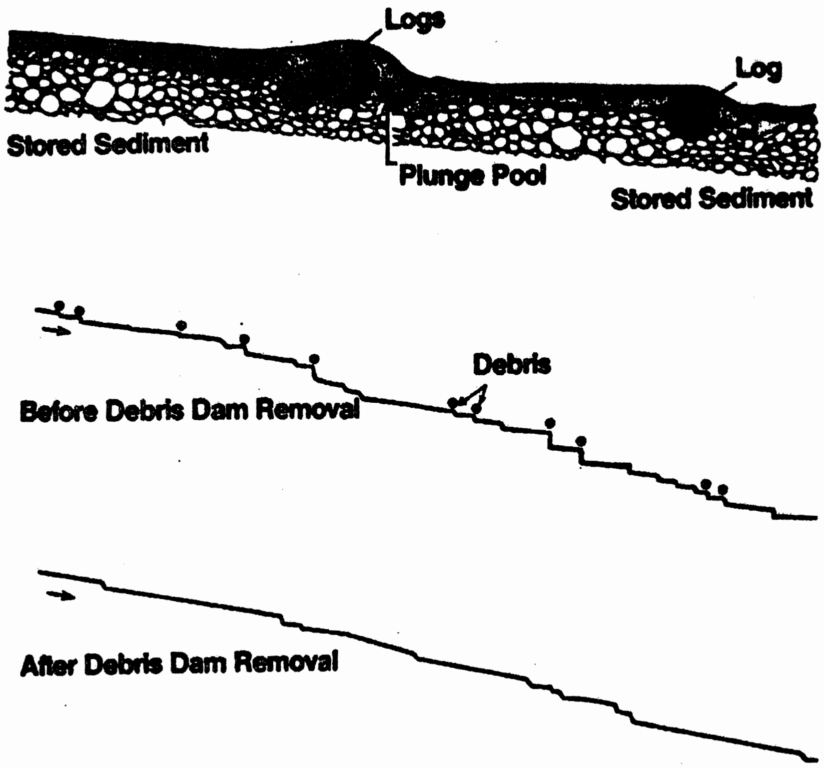


**Figure 2. Schematic representation of the role played by woody debris in sediment retention and waterfall formation in streams. In addition, figure shows the change in the longitudinal profile of a stream section as the result of removal of large organic debris. Falls formed by woody debris prior to removal are indicated by "•" (from Bisson et al. 1987, Bilby 1979).**

Creation of sediment terraces behind pieces of woody debris may also serve to increase the size of the riparian area by forming wide, flat areas adjacent to the channel. In stream systems bordered by steep terrain, these debris-formed terraces may compose a significant proportion of the area displaying riparian characteristics. This process is notable in that it entails the terrestrial system impacting the aquatic in terms of input of the woody debris and then, as a result of the debris input, the aquatic system influences the terrestrial through the formation of an area with soil and water availability characteristics distinct from upland sites.

## Aquatic/Terrestrial Interactions Influencing System Functions

Aquatic systems influence streamside areas by increasing the amount of water in the riparian soil. The increase in water availability is due to both the presence of water in the stream and the migration of groundwater into the rooting zone of the riparian vegetation as it percolates toward the channel (Figure 3). Nutrients carried by the groundwater below the roots of upland vegetation also become available to the riparian plants in this manner (Lowrance et al. 1984).

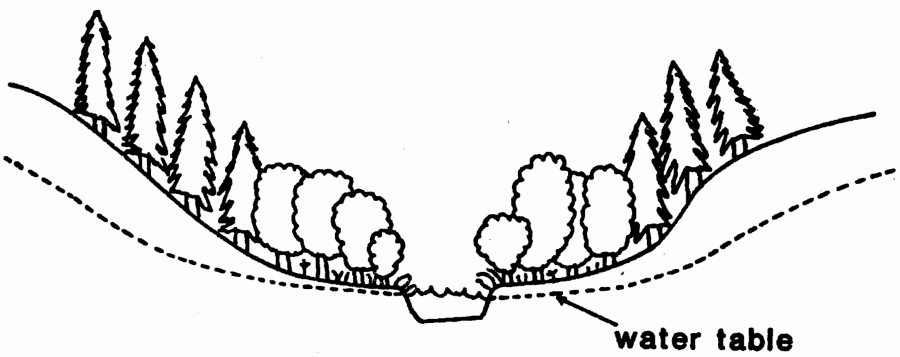


**Figure 3. Illustration of the location of the water table in a forested watershed. As the water moves towards the stream, the table migrates nearer to the soil surface and may be available for uptake by the riparian vegetation.**

Certain chemical properties of the riparian zone are influenced by the aquatic system. As noted above, decomposition of organic matter is accelerated at some locations within the riparian zone (Bell et al. 1978). This is due to both high moisture content in the soil and the easily decomposable litter produced by many riparian plants. As a result of the rapid decomposition rate, nutrients are released rapidly to the riparian soils (Edmonds 1980). Materials associated with the sediment deposited by the stream in the streamside area during floods may also influence the nutrient capital of the soil (Bilby 1979). In addition, in those systems with substantial runs of Pacific salmon, fish carcass decomposition may contribute significant amounts of nutrients (Richey et al. 1975).

The chemical characteristics of the riparian soil can also be influenced by the aquatic system through its influence on the composition of the riparian vegetation (Figure 3). Red alder is a species of tree commonly occurring in riparian zones of Pacific Northwest streams. This tree has the ability to transform atmospheric nitrogen into an organic form, a process known as nitrogen fixation. Levels of nitrogen in the litter stratum below a red alder stand in western Washington were found to be 1.5- to 3-fold higher than in western hemlock, Douglas-fir, or Pacific silver fir stands (Edmonds 1980). In addition, the red alder litter was found to release approximately 33 percent of its nitrogen over a two-year period as compared with 12 percent for Douglas-fir litter (Edmonds 1980). Thus, the red alder stand not only produced litter initially higher in nitrogen, it released a higher proportion of this nutrient to the soil. These processes have been seen to produce higher nitrogen levels in riparian soils than in nearby upland sites (Bollen and Lu 1968).

Increased concentrations of nitrogen in the streamside soils also have the potential to influence stream water chemistry through release of this element to the aquatic system (Figure 4). The nitrogen could be released from the riparian zone either through decomposition of organic matter in the streamside zone (Edmonds 1980) and transport of the material to the stream in groundwater, or by decomposition of leaf litter in the channel (McDiffet and Jordan 1978).

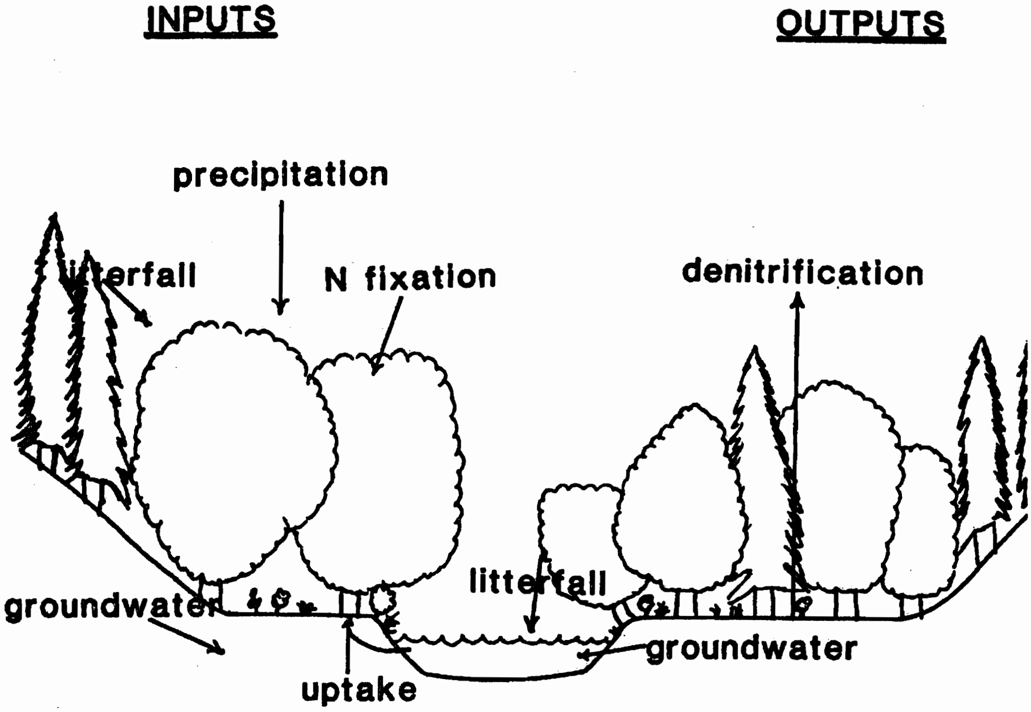


**Figure 4. Representation of the pathways of nutrient movement into and out of a riparian zone. Input vectors to the area are illustrated on the left while outputs are shown on the right. Patterns of nutrient flux and cycling in the riparian area may play a major role in determining stream water chemistry.**

Increased nitrogen levels in stream water may influence the aquatic biota. Litter with high nitrogen content has been shown to be colonized and decomposed rapidly by stream microbes (Kaushik and Hynes 1971). Therefore, this material should provide a superior food source for stream invertebrates since nutritional quality depends upon microbial conditioning of the litter (Barlocher and Kendrick 1973). In addition, low nitrogen levels limit the growth of aquatic plants in many Northwest streams (Thut and Haydu 1971). Thus, enrichment with this material can stimulate primary production in the aquatic system.

Denitrification, the reduction of nitrogenous compounds to gaseous form, is another process peculiar to the nitrogen cycle that has the potential to occur at very high rates in riparian areas. Riparian zones are favorable locations for this process, due primarily to the presence of a high water table, which may produce the anoxic conditions requisite for denitrification to occur (Delwiche and Bryan 1976). Substantial amounts of nitrogen input to the riparian zone may be exported from the system by this pathway. Lowrance et al. (1984) reported a net loss of nitrogen from the riparian zone due to denitrification of 31.5 kg/ha/yr as compared with only 13.0 kg/ha/yr exported by the stream system. Thus, this process has the potential to substantially influence both the chemical composition of the riparian soil and the stream water. Potentially, the elevated rates of denitrification in the riparian zone may offset the higher rates at which this element is input to this area by the processes described earlier. Characteristics of the zone will dictate the rate of each of these processes and thus play a large role in determining the nitrogen dynamics of the site and the concentration of this element in the stream water.

Aspects of the chemical composition of stream water other than nitrogen are also greatly influenced by the vegetation of the watershed (Likens et al. 1977). Certain elements tend to be taken up rapidly and conserved tightly by the terrestrial ecosystem. Thus, the concentration of these constituents in stream water tends to be very low throughout the year (Figure 5). Other components occur at relatively high concentrations in stream water and exhibit little seasonal variability (Figure 6). Many of the elements displaying this pattern of concentration are those that are either not required or that occur in quantities far greater than are necessary for plant growth. However, the level of these materials in stream water may still be affected by the terrestrial vegetation as a result of concentration due to transpiration of water from the soil. A third group of elements ex-

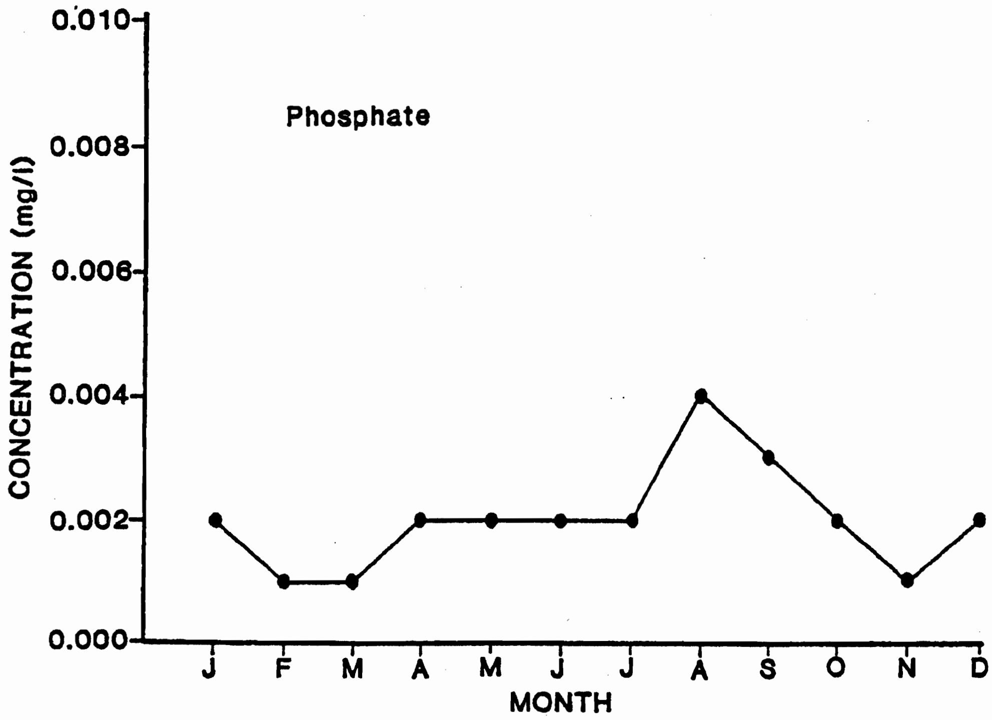


**Figure 5. Mean monthly concentrations of phosphate in stream water from the Hubbard Brook Experimental Forest, New Hampshire. Values are based on samples collected from 1972 through 1974 (Likens et al. 1977).**

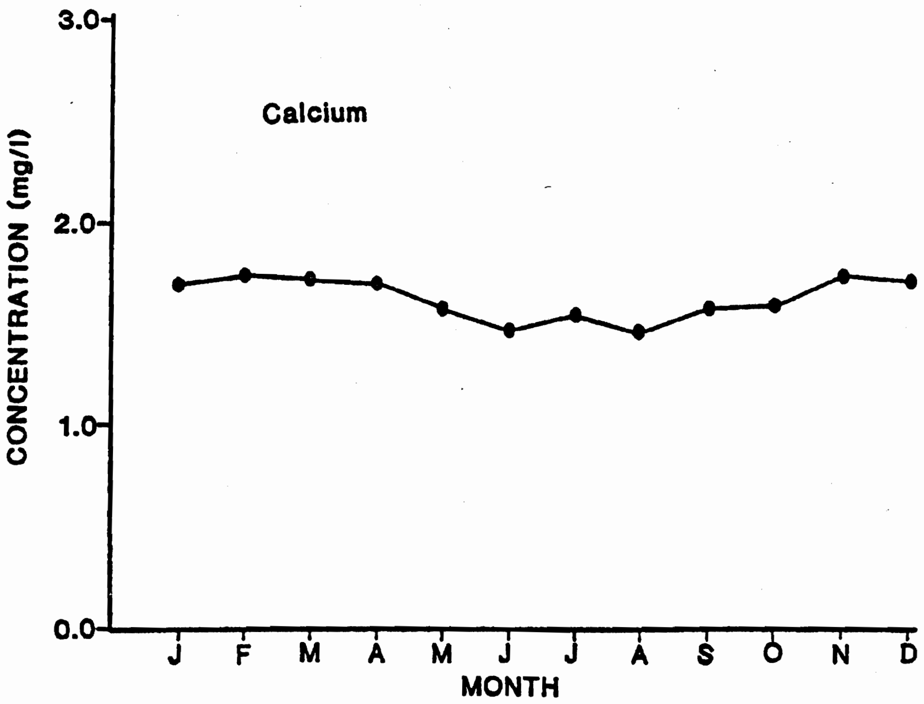


**Figure 6.** Mean monthly concentrations of calcium in stream water from the Hubbard Brook Experimental Forest, New Hampshire. Values are based on samples collected from 1963 through 1974 (Likens et al. 1977).

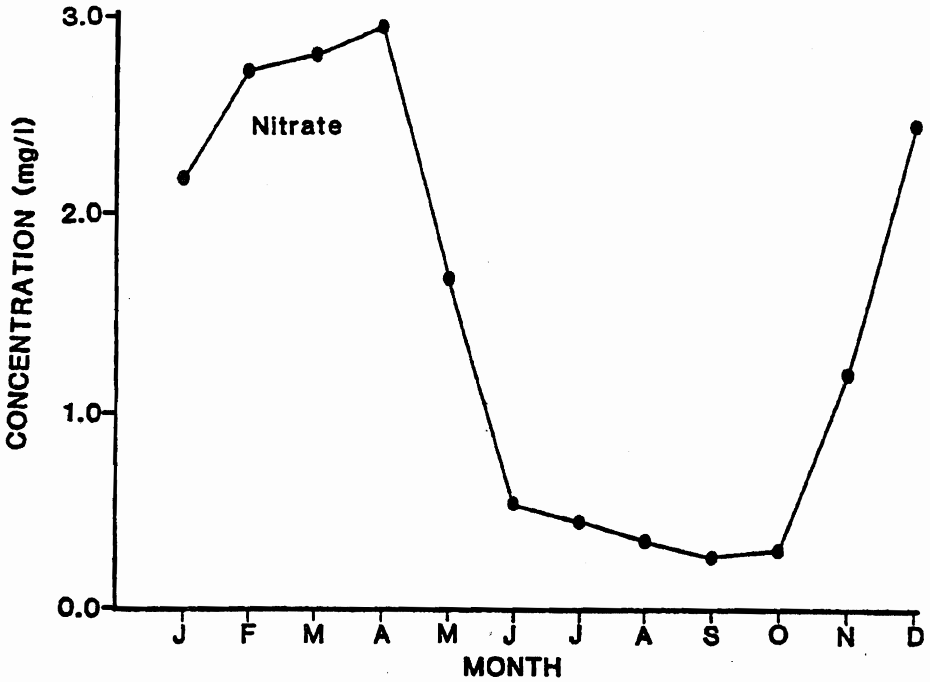


**Figure 7.** Mean monthly concentrations of nitrate in stream water from the Hubbard Brook Experimental Forest, New Hampshire. Values are based on samples collected from 1964 through 1974 (Likens et al. 1977).

hibits seasonal changes in concentration in stream water, with low levels during that period of the year when terrestrial vegetation is actively growing and much higher levels during times of dormancy (Figure 7). These seasonal changes in concentration emphasize the impact terrestrial vegetation can have on the chemistry of stream water.

Even a fairly narrow strip of vegetation along a channel can influence the chemistry of the aquatic system. Table 2 shows the proportions of a series of dissolved materials input to a forested riparian zone that ultimately were carried to the stream (Lowrance et al. 1984). This stream drained an agricultural watershed, and inputs of many dissolved components to the riparian zone tended to be high. Yet fairly substantial proportions of some of the input materials, especially nitrogen, were retained within the streamside forest.

**Table 2. Annual inputs and outputs in stream water of various elements to a riparian zone in an agricultural watershed and the proportion of the input exported by the stream (from Lowrance et al. 1984).**

| | Stream water | | |
|---|---|---|---|
| Element | Input (kg/ha/yr) | Output (kg/ha/yr) | Percent delivered to the stream |
| N | 51.8 | 13.0 | 25 |
| P | 5.6 | 3.9 | 70 |
| Ca | 52.6 | 31.8 | 60 |
| Mg | 19.5 | 15.0 | 77 |
| K | 23.4 | 22.2 | 95 |
| Cl | 104.9 | 97.0 | 92 |

Vegetation in the riparian zone is responsible for shading streams and thus influences the water temperature regime (Figure 8). The degree of temperature control exerted by riparian vegetation has been demonstrated by the elevation in summer water temperatures that occurs following the removal of streamside vegetation (Levno and Rothacher 1967, Brown and Krygier 1970, Brown et al. 1971). The extent to which riparian vegetation controls stream temperature in summer depends upon a variety of factors, including stream flow, elevation, aspect, and availability of alternate shading structures (Brown 1969, 1971, Brown et al. 1971). Streamside vegetation may also form an insulating layer over the stream, thereby slowing the rate of cooling at night (Bilby and Bisson 1987).

In many smaller streams in forested areas, the growth of algae or plants within the stream is limited by low light levels due to shading of the channel by riparian vegetation (Gregory 1980). Thus, terrestrial organic matter supplies by far the greatest proportion of the energy available in these systems (Table 3). This material is used as a food source by invertebrates in the aquatic system that, in turn, provide a food resource for higher trophic levels in the stream and in the nearby terrestrial system. The inver-

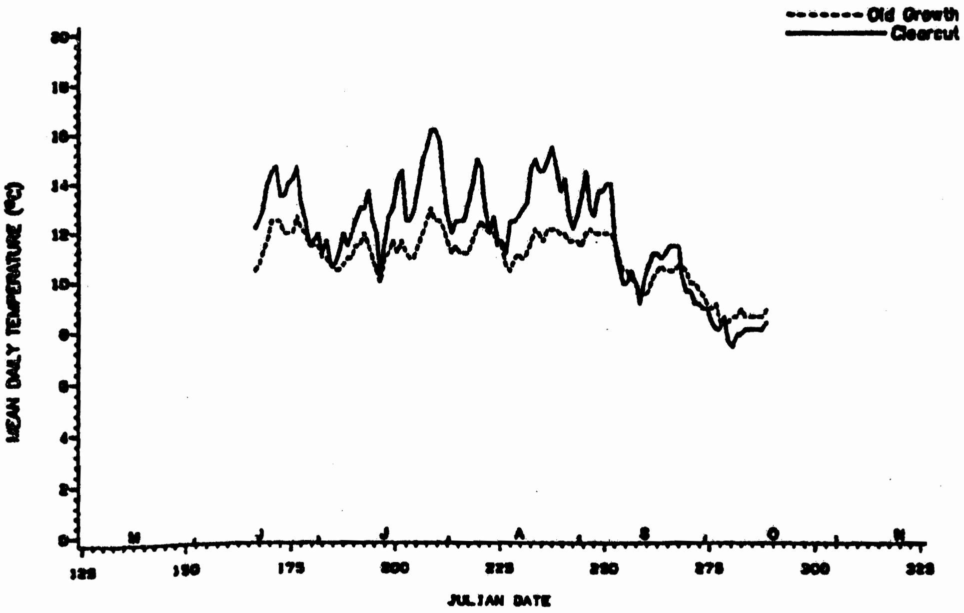


Figure 8. Comparison of mean daily water temperatures during summer in a stream draining a clear-cut watershed with one flowing through a nearby basin forested with old-growth timber (Bilby and Bisson 1987).

Table 3. Comparison of carbon sources and amounts for two small and one intermediate-sized stream system.

| | | Carbon source | | | |
|---|---|---|---|---|---|
| | | Terrestrial | | In-stream | |
| Location | Stream order | ($g/m^2/yr$) | Percent of total | ($g/m^2/yr$) | Percent of total |
| Bear Brook, N.H.[1] | 2nd | 555.0 | 99.6 | 2.1 | 0.4 |
| WS10, Andrews Forest, Or.[2] | 1st | 477.0 | 98.9 | 5.3 | 1.1 |
| Fort River, Mass.[3] | 4th | 384.0 | 38.6 | 609.0 | 61.4 |

[1]From Fisher and Likens 1973.
[2]From Sedell et al. 1973.
[3]From Fisher 1977.

tebrate community of the stream is greatly influenced by the form of the available organic matter, and many species display adaptations for utilizing terrestrial organic matter as a primary food source (Cummins 1974).

Input of terrestrial invertebrates to the stream from the riparian zone may be substantial at certain times of year (Mason and MacDonald 1982). In a study done on cutthroat trout populations in an Olympic Peninsula stream, terrestrial invertebrates falling into the stream were found to form a majority of the food items taken by these fish during late summer (Martin 1984). Availability of this resource to the fish may be quite important in view of the fact that numbers and biomass of aquatic insects tend to be low at this time of year (Hynes 1970).

Conversely, aquatic invertebrates may provide an important food resource for terrestrial predators. At certain times of the year, emergence of aquatic insects from stream or river systems can be profuse and these may be used heavily by terrestrial insectivores. In addition, animals such as herons, kingfishers, otters, eagles, and bears use fish, crustaceans, and other aquatic animals as food sources (Oakley et al. 1985). Many scavengers also feed on salmon carcasses when they are available (Cederholm and Peterson 1985).

## Influence of Stream Size on Terrestrial/Aquatic Interactions

Interactions between aquatic and terrestrial systems are greatly influenced by the size of the aquatic system. Stream size, along with topography of the site, is one of the primary determinants of the size of the riparian zone (Leopold et al. 1964). Many small streams in the Pacific Northwest, especially those in forested areas, drain steep watersheds, limiting the potential for the development of riparian areas. Topography tends to be gentler along larger rivers, and wide floodplains are commonly associated with these systems. However, even in areas of low relief, small streams will produce smaller riparian zones than will larger systems simply because the smaller systems carry much less water and, as a result, do not influence as broad an area as can a system containing a much higher volume of water. Thus, as stream size increases, the aquatic system is able to influence a progressively larger area adjacent to the stream.

Conversely, the influence the terrestrial system has on the aquatic decreases with stream size. As noted earlier, in small stream systems large organic debris plays a key role in determining channel morphology and in controlling sediment and particulate organic matter moving through the system. However, progressively larger pieces of wood are required to form stable accumulations in the channel as stream size increases (Figure 9). These larger pieces are produced by the streamside forest less frequently than are smaller pieces capable of remaining in place in smaller streams. Therefore more woody debris accumulations are typically found in smaller streams than in larger ones (Figure 10), and the impact of this material on stream system structure and function is likewise reduced in the larger streams (Bilby and Ward 1987).

The influence of streamside vegetation on stream temperature also decreases as size of the system increases. Riparian vegetation along small streams completely shades the water from sunlight. For this reason these systems typically display stable, cool temperatures throughout the year. In larger streams, due to their width, the canopy cannot shade the entire channel, so sunlight reaches the water's surface. These larger systems still display a relatively stable temperature, due to the large volume of water in the channel slowing the rate of heating (Brown 1969). However, shade from streamside terrestrial vegetation has little effect on the thermal characteristics of the system.

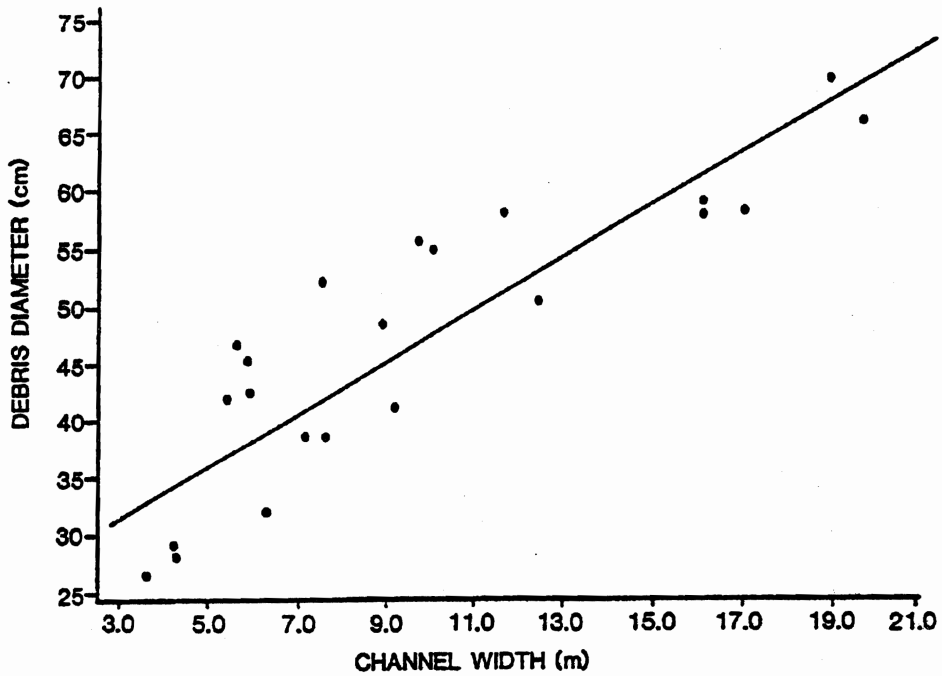


**Figure 9. Relationship between stream channel width and geometric mean diameter of pieces of woody debris for 22 streams flowing through old-growth timber in southwestern Washington (Bilby and Ward 1987).**

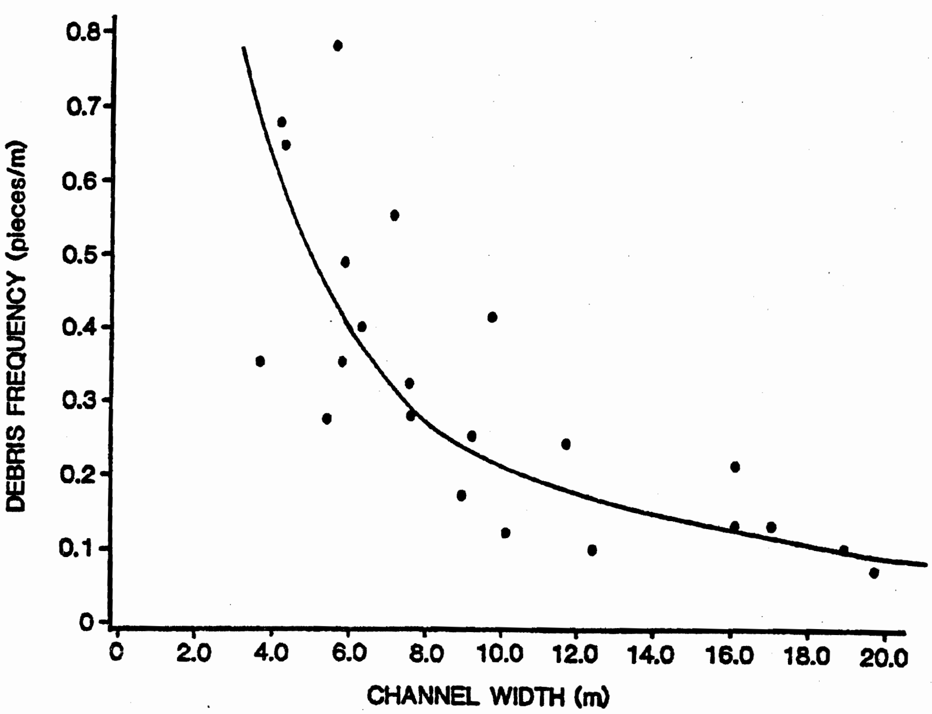


**Figure 10. Change in the frequency of occurrence of pieces of woody debris with changing stream channel width for 22 systems in southwestern Washington (Bilby and Ward 1987).**

Alterations in the predominant form of available energy also occur as stream size increases (Cummins 1975). In headwater systems, which are entirely shaded by streamside vegetation, input of terrestrial organic matter is the primary energy source (Table 3). The availability of this material dictates the composition of the biotic community of the stream (Cummins 1974). As streams increase in size, they become too wide to be completely shaded and in-stream production of organic matter through the growth of algae and other aquatic plants provides a significant proportion of the system's energy (Table 3). In general, the larger the system the less important the contribution of terrestrial organic matter to the carbon budget of the stream. The structure of the stream invertebrate community changes in response to the change in the form of available organic matter. Invertebrate communities in larger systems are dominated by species adapted to the use of the plant material growing in the stream, while in small streams a large proportion of the invertebrates depend upon terrestrial organic matter as a primary energy source (Cummins 1975).

In small watersheds, then, the terrestrial ecosystem plays a major role in determining many of the characteristics of the aquatic system. The influence of the aquatic system on the adjacent terrestrial system is likely to be limited due to the small size of the stream and possibly also to steep topography, common along many Pacific Northwest headwater streams. As a result, the riparian area is likely to be small. As the aquatic system increases in size, however, its potential to impact the terrestrial system also increases, often creating an extensive riparian zone. The influence of the terrestrial system on physical and biological features of the stream is reduced in these larger systems. Therefore, in many cases, the type and magnitude of interactions between a stream and the surrounding landscape depends upon the size of the aquatic system.

Understanding the influence stream size has on the interactions between terrestrial and aquatic systems provides some insight as to how these relationships will alter in response to disturbance of the riparian vegetation. As noted above, small streams tend to be dominated by the terrestrial system. As a result, alterations of adjacent areas tend to have a more pronounced impact on these streams than on larger waterways. For example, removal of riparian vegetation from along small streams significantly alters the way in which they function. Reduction in the riparian vegetation changes the primary source of available organic matter from terrestrial litter to material fixed within the channel (Table 3). This alteration in the form of available organic matter causes a change in the composition of the invertebrate community, favoring those species adapted to the use of organic matter produced within the stream (Wallace and Gurtz 1986). Due to the higher nutritional value of algae, this change often yields higher invertebrate production (Behmer and Hawkins 1986, Wallace and Gurtz 1986). The changes in invertebrate community structure and production may be expressed at higher trophic levels in terms of increased productivity of predators (Murphy et al. 1981, Hawkins et al. 1983).

Removal of streamside vegetation would also affect a small stream through reduction in the thermal control exerted over the stream by the riparian area and reduction in the input of large organic debris to the channel. Thermal control over the stream by the riparian vegetation will return as soon as the channel is fully shaded. Input of woody debris to the stream will remain depressed until the vegetation has regrown sufficiently to provide material of a size able to maintain its position in the channel.

Removal of riparian vegetation from along larger aquatic systems does not produce changes nearly as pronounced as those seen in smaller streams. Since the streamside vegetation cannot shade the entire channel, it plays a minor role in determining water temperature, and only minimal increases in primary production within the channel would be expected as a result of removal of the riparian vegetation. The role performed by woody debris in these larger systems is also reduced, so that an interruption in the input of this material to the system would probably have less of an impact on stream system structure and function than it would along smaller channels. However, woody debris provides cover for fish along channel margins and in backwaters of larger streams and rivers (Sedell et al. 1984). Reducing the input of this material to larger systems may reduce fish habitat quality.

Thus, alterations to the terrestrial vegetation along small streams reduce riparian control over many physical and functional features of the aquatic ecosystem, enabling the stream to assume some characteristics more common in larger systems. However, the influence of the aquatic system on the adjacent terrestrial areas does not change appreciably as a result of this alteration. Therefore, removal of riparian vegetation changes only the effects of the terrestrial system on the aquatic while having little impact on the ways in which the aquatic system can affect the terrestrial.

In contrast, alteration of the hydrologic regimes of larger rivers, as is commonly done with dams and dikes, has the potential to greatly alter the size and characteristics of the riparian zones along these systems. Release of large volumes of water at times of the year when flows are normally low can influence both vegetation of the riparian zone (Stevens and Waring 1985) and riparian wildlife (Brown and Johnson 1985). In other cases, inundation of these areas may be reduced or precluded by controlling the flow. As a result, soil conditions are altered and water availability may be reduced. The vegetation of these areas may respond to the hydrologic changes by becoming more like upland vegetation (Ohmart et al. 1977). In addition, soil fertility may be influenced by the elimination of the periodic deposition of fresh material. This process was dramatically demonstrated along the Nile River following construction of the Aswan Dam when fertilization of riparian agricultural areas downstream from the dam became necessary as a result of the cessation of annual floods (Moore 1985). Since the size of a stream or river is a key factor in controlling interactions between land and water, the impact that change in either system will have on the other is largely dictated by the characteristics of the aquatic system.

The interactions between aquatic and terrestrial ecosystems must be considered in assessing the potential impacts of a change in either. Although the type and magnitude of the interactions may vary from site to site, the linkages between the two systems are still largely responsible for the physical, chemical, and biotic characteristics of the riparian and aquatic habitats.

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