WORKING PAPER

Riparian Management in British Columbia

An Important Step Towards Maintaining Biodiversity

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British Columbia

Ministry of Forests Research Program

Riparian Management in British Columbia:

An Important Step Towards Maintaining Biodiversity

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Province of British Columbia
Ministry of Forests Research Program
Ministry of Environment, Lands and Parks
Habitat Protection Branch

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FOREWORD

British Columbia, Canada's most westerly province, has a bounty of biological diversity. Its mountains, lakes and rivers, rain forests, wetlands and arid grasslands, and long rugged coast provide habitats for more species of living organisms than are found anywhere else in Canada. However, this very diversity means that there is much to be discovered about these organisms–their distribution, abundance, habitat requirements, and interrelationships with their environments. Increasing our knowledge of this biodiversity will help us with the complex task of sustainably managing our lands and waters.

In 1992, the Provincial Government initiated a co-operative biodiversity research program with funding from the Corporate Resource Inventory Initiative; the British Columbia Ministries of Forests (Research Branch), Environment, Lands and Parks (Wildlife and Habitat Protection Branches), and Tourism and Culture, (Royal British Columbia Museum); and the Forest Resource Development Agreement (FRDA II). One goal of this research program is to extend information to scientists, resource managers, and the public through biodiversity publications. These publications are intended to increase awareness and understanding of biodiversity, promote the concepts and importance of conserving biodiversity, and communicate provincial government initiatives related to biodiversity. We hope that they will be used as tools for the conservation of British Columbia's rich, living legacy.

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Most helpful in the photographic department were Trudy Chatwin of MOELP who gave us access to the biodiversity slide show, and the staff at the Sierra Club office who allowed us unrestricted use of their slide files. A special thanks to the photographers who were very co-operative. They are identified by page numbers below, (letters refer to vertical order on page).

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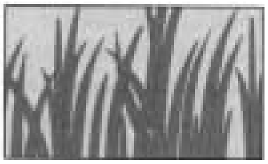


INTRODUCTION AND DEFINITION

The word "riparian" comes from the Latin *ripa* meaning bank or shore. Ecologically, riparian refers to the *area adjacent to streams, lakes and wetlands that is wet enough or inundated frequently enough to develop and support natural vegetative cover distinct from the vegetation in neighbouring freely drained upland sites.* In this document, "riparian area" and "riparian ecosystem" will be used interchangeably.

Riparian areas cover a small percentage of the land in British Columbia, but they are of vital importance to the wildlife, fisheries, and people of the province. They are used by wildlife and humans far more than one would predict, based on the land area they occupy. Because of their relatively small size and their location at the base of slopes, riparian areas are particularly vulnerable to severe alterations. Riparian areas are also important because of their distinct plant and animal communities.

The integrity of a riparian ecosystem depends on and is influenced by the adjoining upland area. The concept of the **Riparian Management Area (RMA)** recognizes the importance of this relationship and has been developed as the basis for developing strategies and guidelines for managing and maintaining different types of riparian ecosystems. The RMA encompasses the ecological continuum, from water (stream, lake, pond, wetland, etc.) through the riparian area and into the adjacent upland that buffers the riparian ecosystem and provides habitat for wildlife. (Figure 1).

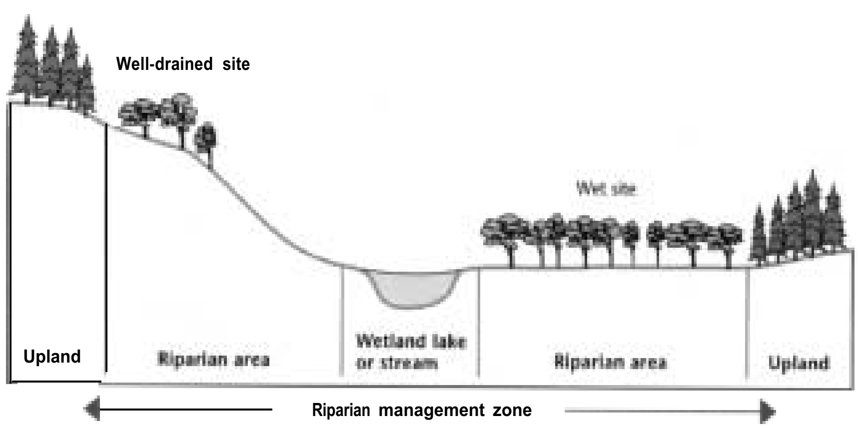


FIGURE 1 *Riparian management zone.*

The purpose of this document is twofold: to explore the importance of riparian ecosystems to the broader landscape, and to outline a management strategy to sustain the biological functioning of riparian areas and still provide for other essential human needs. It can be argued that the most essential human need is for fully functional ecosystems. This document will also discuss resource extraction, range and agriculture, recreation and aesthetics, energy, and water quality.

The basic premise of the management strategy outlined here is that the *goal of riparian management in British Columbia is to maintain the ecological processes of riparian ecosystems*. This approach aims to maintain **biodiversity** by means of habitat protection and restoration, and therefore to avoid expensive, time-consuming species-by-species recovery projects.

***Biodiversity** is the diversity of life in all its forms and levels of organization, including genes, species, ecosystems, and the evolutionary and functional processes that link them. To maintain all the visible and invisible levels described in this definition requires maintaining all the pieces of a diverse and connected habitat with enough integrity that nature can continue to evolve to meet ever-changing conditions.*

WATER! THE KEY TO RECOGNIZING RIPARIAN ECOSYSTEMS

Riparian ecosystems vary considerably in their size, vegetation, species abundance, and diversity. However, they share one common denominator—water. Whether it is associated with a major river system, a mountain stream, an interior dryland lake, or the smallest bog or seep, a riparian area can be recognized by the presence of water-loving vegetation, or simply by its position adjacent to water. Figure 2 illustrates a generalized progression of vegetation types from the water to the upland zone. This progression parallels the decrease in soil moisture and emphasizes the transitional nature of these areas. **Edges** are an important structural component resulting from the moisture gradient. The transition between riparian and upland areas is usually identified by a gradual change in plant composition, relative plant abundance, and a decrease in soil moisture. The influence of water, along with the characteristic plant types, creates a microclimate that is both distinct from and generally more productive than the drier surrounding areas. Humidity, transpiration, shade, and air movement are all elevated relative to the surrounding environment.

***Edges** are transitional areas between two different vegetation types. Because of their greater plant species diversity, edge zones provide a wide variety of habitat niches for wildlife. Because of the moisture gradient, riparian areas tend to have high edge-to-area ratios, and are therefore important for biological diversity.*

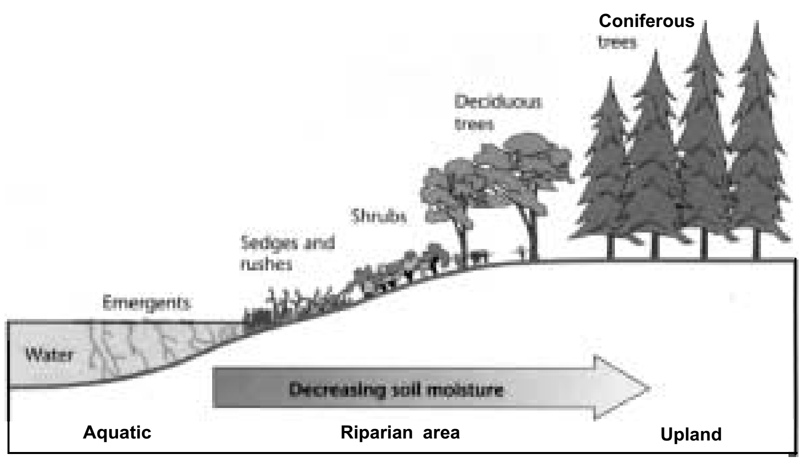


FIGURE 2 *One example of a riparian ecosystem showing the transition from aquatic to upland habitat.*

(Note: **Bold** type refers to information in side bar.)

Small but Critical

Riparian ecosystems are biologically important for many reasons. Even though they make up a small proportion of the overall landscape, the presence of water, the layers of variability, and the high edge-to-area ratio make riparian habitats a critical source of biodiversity.

Plant Diversity

Some Common Riparian and Wetland Plants
skunk cabbage, yellow water-lily coltsfoot, cat-tail, lady-fern, rushes, sedges, willow, devil's club, western redcedar, water-parsley, black cottonwood salmonberry, red alder, vine maple, Sitka spruce, bigleaf maple, Douglas-fir

Riparian vegetation is typically diverse in its structure. From the water's edge to the upland boundary there is often a series of different "layers": emergent plants, herbaceous plants and low shrubs, taller shrubs, and trees (Figure 2). The presence of water increases the production of plant biomass and provides suitable conditions for a wide range of plant species unable to grow in drier soils. These factors increase the diversity of plant species and the structural complexity of the community, providing many different habitats within a relatively small area. Note, however, that some riparian areas have little or no distinct vegetation, although they are still unique ecosystems because of their proximity to water.

Skunk cabbage

Wildlife Habitat

Riparian ecosystems are highly productive for wildlife. The presence of free-flowing or standing water is part of the attraction, but the associated plant communities are equally important.

Birds, mammals, amphibians, reptiles, and an assortment of invertebrates use riparian areas for foraging, watering, breeding, raising their young, hiding, resting, and travelling. Most temperate species exhibit some degree of dependency on

riparian areas. Some aquatic and amphibious species, such as the beaver and the Pacific giant salamander, depend entirely on riparian habitat. Others choose riparian areas as preferred habitat for one or more activities, such as feeding or reproduction.

Riparian areas offer a wide range of feeding possibilities. Succulent water plants, berry-producing shrubs, fish, and aquatic insects are only a few of the many food sources. Drinking water is also important, especially during the dry summer months. Predators and scavengers are attracted in turn by the high concentration of prey species.

Riparian vegetation is generally dense and therefore favoured for cover and shelter. Large mammals often hide in the thick bushes. Small mammals create runs through the undergrowth, avoiding carnivorous mammals and raptorial birds. Numerous birds are associated with riparian habitat. The diversity of shrubs and trees, the multi-layered canopy and understorey, and the presence of snags provide ideal habitat for perching, feeding, and nesting. Many small birds nest in riparian thickets or use them as stopovers during migration. Most waterfowl build their nests on floating vegetation or banks, while some ducks nest in tree cavities close to the water. Waterfowl also depend on shoreline vegetation to hide their young and for refuge during stormy weather.

Riparian vegetation moderates local climate by providing "thermal cover" throughout the year. In summer, riparian areas are cooler and moister. In winter, they may be warmer and often have less snow. Some riparian areas are dominated by deciduous plants that shed their leaves in the fall and winter months, and provide a variety of seasonal habitats.

Homes for Fish

Of note in British Columbia are the many species of fish that live and spawn in the rivers and lakes for all or part of the year. Riparian vegetation is as important to fish as to terrestrial animals. Root systems function to stabilize banks. Leaf litter and branches of all sizes contribute small and **large organic debris** (LOD) to lakes and streams. These provide food for fish and other aquatic organisms as well as structure for habitat.

All salmonids need freshwater spawning areas where water flows continuously over a gravel bottom. There, they excavate nests, known as redds, and deposit their eggs. If silt settles on the eggs during incubation, the embryos may suffocate. Riparian vegetation helps keep banks from eroding and prevents the deposition of sediments in the water.

Leaves, conifer needles, and insects that fall into the water are part of the food chain providing fish plenty of aquatic invertebrates to eat. Branches and twigs trap leaves and sediments; invertebrates feed on these, and in turn, nourish the fish.

Large organic debris provides food and shelter

Large Organic Debris
*In riparian areas, large pieces of wood, branches, fallen trees, and root material, known as **large organic debris** (LOD), often find their way into the watercourse. Small coastal streams may contain as much as 500–1700 tonnes/ha of such material. LOD plays several important roles in the aquatic ecosystem. It increases aquatic habitat diversity by forming pools and protected backwater areas, provides nutrients and substrate for biological activity, dissipates energy of flowing water, and traps sediment. It is essential for creating rearing habitat for salmonid fishes. Stream restabilization after major floods, debris torrents, or massive landslides is aided by LOD in and along the channel. It becomes a home for fungi and wood-boring insects, as well as providing critical habitat for reproduction of reptiles and amphibians such as the Pacific giant salamander. LOD provides a long-term source of nitrogen and other essential nutrients to the aquatic system. However, large woody debris has traditionally been cleared from streams and riparian areas following logging operations. Consequently, many streams lack their natural LOD volume.* "Of all the ecological functions of riparian areas, the process of large organic debris loading into channels, lakes, and floodplains requires the longest time for recovery after logging. Most future riparian functions will be guaranteed if natural abundances and distributions of all sizes of woody debris are maintained in streams, lakes, floodplains, and lower hillslopes." *(Gregory and Ashkenas 1990).*

In streams, adult fish arc most often found in pools, which are sometimes formed when trees fall into the water. Large organic debris also creates sheltered areas along lakeshores. Fish favour these microhabitats because of the slower current and plentiful food. They seek the protective cover provided by overhanging vegetation or by logs in the water. Smaller woody debris enhances the quality of the habitat and deposits organic matter into the aquatic ecosystem.

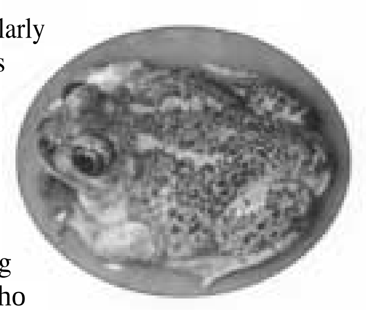
Although in cold water systems increased water temperatures can increase productivity, salmonids become more susceptible to diseases in warmer water. Shrubs and trees that overhang shorelines and narrow channels shade the water, keeping it cool during the height of summer. Small undisturbed headwater streams are often completely screened by foliage. Although they may not be inhabited by any fish, they have an important function in contributing cool water to the downstream system.

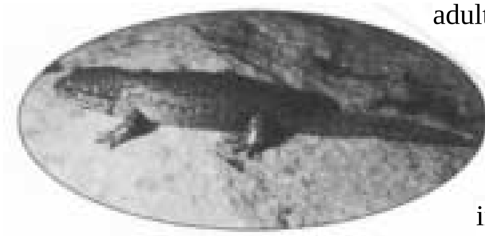
Amphibian Habitat

British Columbia has twenty species of amphibians—frogs, toads, and salamanders—many of which are associated with riparian areas. Most amphibians lay their eggs in water; many spend their adult lives in humid sites adjacent to water.

Seven of British Columbia's riparian-dependent amphibians are on the provincial red or blue lists, which note species at risk. Like other species, their existence is threatencd by the destruction or deterioration of their habitat.

Certain environmental impacts are particularly harmful to amphibians. Like fish fry, the eggs and larvae of aquatic-breeding amphibians are highly sensitive to changes in water temperature, which may be caused by the removal of riparian vegetation. Herbicides, pesticides, and other pollutants that enter water bodies threaten all life stages, including adults who absorb water through their skin. Other impacts include habitat fragmentation, and reduced food supply caused by spraying mosquitoes and other insects with insecticides.





The Pacific giant salamander (left) and the spadefoot toad (right), both species at risk, are dependent on riparian habitat.

Rarely seen and not commercially exploited, amphibians tend to be ignored. Yet they play an important role in fully-functioning riparian ecosystems. In forest streams of the Pacific northwest, for example, amphibians contribute four times as much biomass to the ecosystem as salmonids. Tadpoles and salamander larvae are a critical link in the energy flow through ecosystems. Each spring, a single frog can lay up to 30 000 eggs, many of which will be consumed before they hatch. Those that survive to the tadpole stage eat algae, detritus, and plant material and, in turn, 90% of them become food for other organisms.

Water Quality

Clean water is essential to wildlife, fish, and humans. Abundant and diverse vegetation in riparian areas helps maintain water quality. Riparian vegetation and root systems stabilize banks and slopes, thereby reducing the sediment entering lakes and streams. Plant roots and large organic debris help to dissipate the energy of floodwaters, allowing sediments to settle to the bottom rather than wash downstream. Intact riparian forests along streams can also minimize the impact of debris avalanches, debris torrents, and debris jams (see page 12); they prevent their occurrence and can minimize their effect. This is particularly important in smaller headwater streams that tend to have relatively unstable channels and that, in turn, affect downstream water turbidity and sedimentation.

Riparian vegetation helps ensure clean water

Riparian areas can act as filters and storage sites for water and nutrients. Nitrogen and other nutrients essential to both terrestrial and aquatic organisms can be transformed by many species of riparian vegetation into usable forms. In addition, potentially harmful inputs of nitrogen and phosphorus from fertilizers, as well as chemicals from agricultural pesticides and herbicides, may be filtered from runoff water as it passes through the riparian vegetation.

The Bigger Picture

Riparian areas do not exist in isolation. They are an integral component of the landscape and they help to maintain regional biodiversity in several ways.

By following water courses, riparian areas can link several different wildlife habitats. Strips of forest along streams can connect otherwise isolated forest patches.

Movement Streams and rivers move water, soil, plant seeds, and nutrients to downstream areas. However, riparian habitats also provide ideal corridors for birds and forest-dwelling mammals as they forage, seasonally migrate, or disperse into new territory as a result of population pressures or food and water shortages in their original habitat. They may be especially important as travel corridors in areas of high disturbance or during times of rapid climate change.

Reservoirs Riparian ecosystems that are protected from disturbance may serve as genetic storehouses for plants and animals. Dispersal may take place along riparian travel corridors to upland habitats. Similarly, undisturbed riparian populations help to repopulate or revegetate adjacent areas disturbed by fire, logging, or floods. Riparian areas play a larger role in preserving rare, threatened, and endangered species than their proportion of the landscape would suggest. In British Columbia, 59% of the species at risk use riparian areas for all or part of their habitat needs. Figure 3 shows not only the high percentage of species at risk that use riparian areas, but also how each vertebrate class depends on riparian areas to a different degree. Appendix 1 lists known species at risk in British Columbia that use riparian ecosystems.

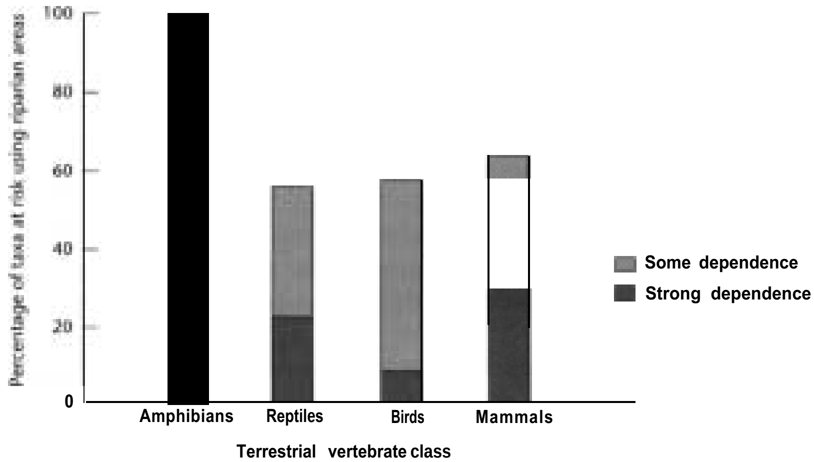


FIGURE 3 *The percentage of species at risk in each terrestrial vertebrate class that use riparian areas. The proportion of the riparian users that are strongly dependent on riparian ecosystems is noted.*

DISTURBANCES

Natural Disturbances

Hydroperiod is the frequency of flooding in a riparian zone and is the most important external influence on the vegetation in a riparian zone. Short hydroperiods usually mean more change and younger successional stages. To maintain the natural diversity of an area, the natural flow regimes should be unaltered. Major changes to the natural hydroperiod, such as fire, damming, water diversion, or logging, usually lower the productivity of an area.

Anything that has an impact on the ecosystem can be called a disturbance. Disturbances can be natural, such as periodic flooding, a tree falling over to expose bare soil, or a catastrophic fire. These events have been shaping riparian areas for thousands of years, and will continue to exert their influence on the riparian environment and ultimately on the genetic systems that evolve to cope with these special areas.

To maintain the integrity of riparian ecosystems, the processes that shape these ecosystems must also be maintained. Many of these processes are subtle and involve interactions of plants, animals, and the substrates on which they live. But major disturbances have played a role in the evolution of these ecosystems and must be part of their successful maintenance.

Natural disturbances, such as flooding, are partially responsible for the increased structural diversity in riparian areas.

Floods Flooding is an important natural phenomenon that significantly shapes riparian ecosystems. The broad floodplains of larger riparian areas are defined by a complex and shifting pattern of gravel bars and islands, back channels and streambeds. The characteristic vegetative structure has adapted to cope with periodic flooding. In areas with less well defined floodplains, floods move debris within a stream channel, change the vegetative features of the bank, or deposit sediments along streamsides.

Landslides Just as flooding is caused by high rainfall and/or snowmelt, landslides result from high soil water coupled with steep slopes. Landslides can significantly alter streambeds, increase sedimentation downstream, and create openings for pioneering species to occupy. These species are important components of the diversity of a riparian ecosystem.

Succesion is the process of community development that begins, usually, with bare ground following a disturbance (such as flooding) and proceeds through early successional species like annuals and grasses to shrubs. If the conditions are appropriate, the shrubs give way to tree species. This process is usually more complicated than a simple linear movement through kinds of species. It involves the modification of a site by the primary species which in turn creates conditions appropriate to another species. Animals as well as plants are important players in this community process. Continuous disturbance can keep a community in an early stage of development.

Wind Wind plays an ongoing role in shaping natural ecosystems. High winds may uproot old trees singly or in large groups. This creates many new opportunities in riparian areas: exposed soil for plant pioneers; openings in the overstorey for increased sunlight; natural bridges across and through streams for wildlife travel or enhanced stream habitat. Windthrow contributes large and small organic debris to water courses, providing nutrients to aquatic organisms and structure for habitat. Fallen trees enrich the riparian soil as they decay. Large pieces of decomposing wood store water and are essential to moisture-dependent amphibians and plant seedlings.

Fire Fires modify habitats by opening the understorey, creating snags, or burning down large sections of riparian vegetation and upslope forests. However, some riparian areas are not as susceptible to fires as are the surrounding uplands because of their wetter conditions. This often results in the oldest plant communities occurring in riparian areas, while the neighbouring uplands have a more recent history of fire.

The Human Factor: Resource Extraction and Other Human Disturbance

Healthy riparian ecosystems are undoubtedly important to plants, wildlife, fish, and the processes that sustain them. As a product of evolution, humans are inextricably tied to these natural processes. We directly benefit from them and are responsible for ensuring that our actions do not interfere with their ongoing and healthy functioning.

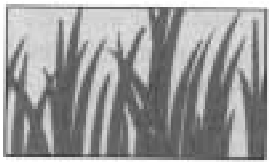
We are attracted to riparian areas for many reasons: as places of beauty and recreation; as sources of water, electricity, and raw materials; and as places to live. However, our growing population and our ability to manipulate the environment to suit our needs increase the potential for negative impacts on the very ecosystems upon which we depend. Native organisms are usually adapted to local natural disturbance regimes, but may not be adapted to disturbances caused by humans. Human activities often cause long-term damage to riparian ecosystems by increasing the frequency or severity of natural events.

Places of beauty and pleasure Humans are attracted to water for aesthetic as well as practical reasons. We are drawn as much to the greenery that lines the banks as to the water itself. Our favourite scenic views usually include water, and we often seek the soothing sounds of "babbling brooks" or waves lapping on a lakeshore. This appreciation of water and the vegetative communities associated with it is not in itself harmful. However, our activities in and around riparian ecosystems are seldom without impact.

Recreation in and on the water Riparian strips along streams and around lakes are usually the most heavily used areas for human recreation. Because recreational activities are tied to the aesthetically appealing surrounding area, campsites, picnic areas, bicycle paths, and hiking trails are most often located near water.

Hunting, fishing, and wildlife viewing are all directly dependent on healthy riparian ecosystems. The severity of the impact of these activities on wildlife and plant communities varies with the type of use and the season. In general, any recreational activity that occurs in wilderness areas increases the probability of conflict with wildlife. Trails, campgrounds, and picnic sites negatively impact riparian habitat through fragmentation, trampling, soil erosion and compaction, and loss of vegetation. Contamination of water by human wastes and intentionally destructive acts are also detrimental.

Timber management Riparian ecosystems are not always the most productive timber-producing areas. While plentiful water and fertile floodplains contribute to growing some very large individual trees, riparian areas also include many sites that are unsuitable for production of commercial timber because of poorly developed soils, periodic inundation of the rooting zone, and damage by water and floating debris during floods. However, logging operations frequently occur in riparian ecosystems.



Studies such as the 20-year Carnation Creek Experimental Watershed on Vancouver Island have helped elucidate the interactions between forestry and riparian ecosystems. Results show that while not all forestry practices have negative impacts, logging in or near riparian areas tends to be detrimental to wildlife and fish habitat, and water quantity and quality. The magnitude of impacts varies with the type of harvesting system (selection versus clearcut), the type of equipment, and the proximity of operations to the water's edge.

In terms of their effect on riparian ecosystems, forestry operations can be divided into three main categories: harvesting and silvicultural activities adjacent to or upslope from riparian areas; harvesting and silvicultural activities within riparian areas; and road building. Some adverse effects are related to one category only, while others result from all three. Negative impacts in the higher reaches of stream systems often become cumulative and more severe downstream. Riparian areas downslope from harvested areas, particularly clearcuts, are frequently subject to alterations in water flow. Without the moisture-retaining forest vegetation, spring flows are increased and summer flows decreased. Greater run-off in the spring may result in damaging **debris avalanches** and **torrents**.

*Rapid landslides that occur on hillslopes (and may or may not be delivered to a stream channel) are called **debris avalanches.** A **debris torrent** involves rapid movement of material including sediment and woody debris within a stream channel. Debris torrents frequently begin as debris avalanches on adjacent hillslopes. An accumulation of woody debris within the stream channel that often extends onto the banks is termed a **debris jam.** Debris jams, torrents, and avalanches may be naturally occurring or the result of poor management, and they may result in disturbance to riparian and in-stream habitat.*

Logging is often responsible for large inputs of organic debris from waste wood into streams and rivers. Although some LOD is important in riparian systems, too much can increase sedimentation, reduce dissolved oxygen concentration, damage banks, and block channels.

Some herbicides and pesticides used in silvicultural operations are harmful to animals living in riparian areas, especially fish and amphibians. Those not actually applied in riparian areas may still enter the system through groundwater and surface run-off. Certain chemicals are directly toxic to non-target organisms. Others are detrimental because they alter the chemical composition of water or reduce the availability of food items, such as aquatic insects or riparian plants that are important as forage.

All of the impacts described above are intensified when harvesting takes place within riparian areas. In addition, removing riparian vegetation reduces shading, usually resulting in increased water temperature. Loss of riparian vegetation also means direct loss of habitat for many species. Partial cutting is less damaging than clearcutting, but structural diversity and long-term supply of LOD are still decreased when all or most of the large, commercially valuable trees are removed. Wildlife trees that provide critical wildlife habitat must also be felled before harvesting can be undertaken. Operations within riparian areas carry with them the risks of soil erosion and/or compaction, and damage to banks and channels.

*A **wildlife tree** is a tree that provides present or future critical habitat for the maintenance or enhancement of wildlife. Wildlife trees are important contributors to biodiversity. They provide homes and food for birds, mammals, amphibians, and insects. By supplying nest cavities and platforms, nurseries, dens, roosts, hunting perches, foraging sites, and display stations, wildlife trees aid in maintaining healthy forest ecosystems.*

Roads associated with forestry operations often have the most severe long-term effects on riparian ecosystems, especially where they follow or cross over streams or rivers. As with any activity involving the use of heavy machinery, soil compaction and degradation of banks and channels can be a problem. Poorly engineered or maintained roads uphill from riparian areas may cause slope failure resulting in landslides and debris torrents. Noise and activity during road construction (as well as during other forestry operations) displace wildlife and decrease the habitat value of adjacent habitat.

Roads are also a concern because of their presence long after the activities they were built for have been completed. By facilitating the entry of people into remote areas, logging roads increase human/wildlife contacts, improve accessibility to wildlife for hunters and poachers, and isolate species that are unwilling or unable to traverse roads. Roads through riparian areas may eliminate habitat directly, or indirectly by fragmentation, altering vegetative structure and microclimate, or reducing water quality. This is true of roads built for any purpose.

Mining Riparian areas are often impacted by mining development because the presence of water is required for some operations, and road building frequently occurs along streams.

In terms of volume, gravel extraction is the most important mining activity in British Columbia. Where sand and gravel are scarce, they are often extracted directly from streambeds. The mining of gravel and sand from streambanks is convenient and inexpensive, but can greatly alter the stream and streamside vegetation. Streambed gravel removal is only allowed with a permit from Crown Lands after approval under Section 7 of the *Water Act.*

Gold mining by hydraulic (placer) methods generally uses large quantities of water and takes place in riparian environments. Most placer mining in British Columbia occurs near Prince George, Quesnel, and Kamloops. Placer mining removes vegetation and creates unstable piles of large rock and rubble, often leaving sites unproductive for many years.

Metal extraction can lead to chemical pollution and nutrient loading of the water source. Changes in the extent and frequency of flooding, greater fluctuation in groundwater tables, and increases in sedimentation, are particularly associated with coal strip mines.

About 30% of currently active mines in British Columbia produce acid drainage. Other concerns associated with metal extraction are metal leaching, cyanide release, and nutrient loading. The most damaging pollutant may be high siltation and turbidity originating from erosion of the tailing banks. Water withdrawals, stream blockage, and stream diversion may be the most irrevocable impact to the riparian ecosystem. The Mine Development Review Process assesses environmental impact prior to granting development approval.

On the range Domestic livestock are drawn to riparian areas for the same reasons as wildlife: abundance of lush vegetation; availability of water; thermal cover; and gentle topography for ease of movement. In British Columbia, livestock grazing occurs primarily east of the Coast Range in the drier interior. Heavy, continuous grazing in riparian areas and wetlands can reduce, alter, or eliminate vegetation. Poorly managed grazing can lead to a complete change of vegetative structure, as some plant species are prevented from reproducing through over-consumption, trampling, or lowering of the water table.

Prolonged heavy grazing can cause excessive erosion when the root structure of the riparian vegetation deteriorates and overhanging streambanks cannot bear the weight of cattle. As a result, flooding has a greater impact on stream morphology. Floods increase stream width, and change the meander pattern and stream depth. Reduced water quality occurs through fecal contamination and increased nutrient input. These types of habitat degradation have a negative effect on wildlife populations and diversity.

Water to grow our food Livestock grazing is not the only agricultural practice that affects riparian areas. Where rainfall during the growing season is scarce or unpredictable, irrigation water taken from lakes and rivers is usually the key to agricultural success. The orchards and vineyards of the Okanagan region are a prime example. Fertile floodplains, such as those of the Fraser Valley, are often converted from natural vegetation to croplands.

Changes to riparian vegetation through soil management practices, vegetation clearance for crops, channelization of streams, and irrigation significantly reduce wildlife habitat and biodiversity. Sedimentation and instream habitat degradation may also occur.

Agriculture is a major source of non-point source pollution. Pesticides and chemical and natural fertilizers run off into aquatic systems or percolate into ground water sources. Pesticide residues can have direct and sometimes lethal effects on fish and other organisms. Increased nutrient loading of nitrogen and phosphorus from fertilizers can lead to algal blooms, phytoplankton growth, oxygen depletion, and fish kill.

Bio-accumulation *refers to the tendency of certain chemicals, such as pesticides and herbicides used in agricultural and forestry applications, to accumulate at increasingly higher concentrations in the fatty tissues of organisms over time. As these organisms are eaten by their predators, the toxins can magnify in concentration in the predator's tissues. This increase in concentration at higher trophic levels is called bio-magnification, and can have detrimental and even lethal effects on wildlife and humans. Riparian vegetation plays an important role in filtering some harmful chemicals from groundwater before it reaches the water source.*

Energy British Columbia has an extensive hydroelectric generation system. Small hydro developments (those that generate less than 20 MW) often do not stop or divert waterways. Instead they pipe portions of it through a turbine. Large hydro developments, on the other hand, involve massive manipulation of the environment.

Building dams for generating electricity is often devastating to riparian areas and the wildlife that use them. Those areas located directly upstream of a dam are virtually eliminated by flooding. Wildlife migration routes may be disrupted. The riparian areas created alongside reservoirs are generally unproductive because of water level fluctuations. Frequently changing conditions make it difficult for either water-loving or drought-resistant plant species to adapt. These nearly barren zones become a source of windblown dust.

Natural processes of erosion and deposition may be affected downstream from dams by frequent and abnormal alterations in stream discharge patterns. The possible consequences of these changes in flow include the loss of aquatic and riparian organisms, an increase in dissolved materials, a decrease in particulate matter, elevation of biomass, and reduction of biodiversity.

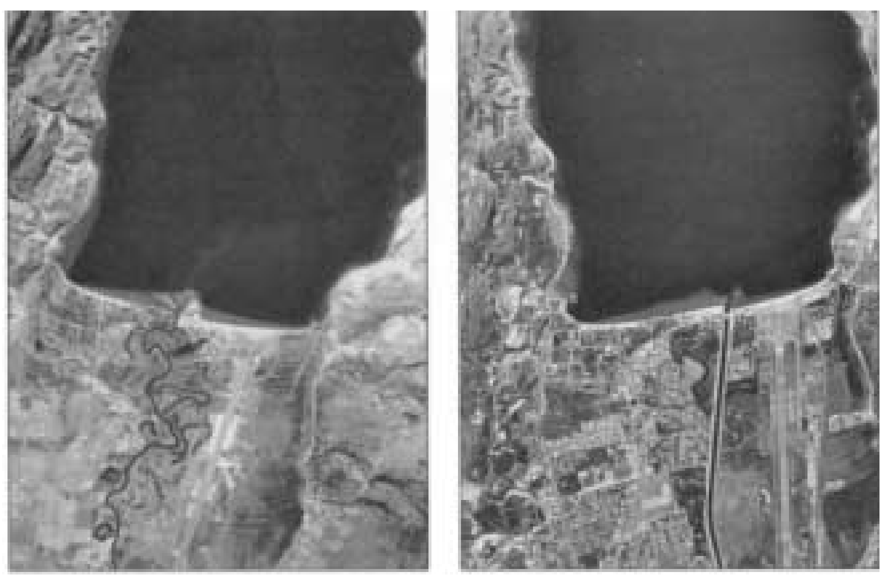
Other energy projects, such as oil and gas exploration, increase access to riparian areas and carry with them associated impacts of road building, clearing, and wildlife/human contacts.

Urban development Riparian areas are attractive to humans not only for their resource development potential, but also because they are ideal places to live. Large areas of riparian habitat in British Columbia have been taken over by urbanization. The impacts are many and varied.

Until recently, most Canadians took for granted an unlimited supply of clear, unpolluted drinking water. Now, there are many lakes or rivers that are unsafe to drink from. Increased nutrient loading from storm runoff, sewage treatment plants and septic fields, nutrients from fertilizers, and toxic domestic and industrial wastes are all sources of water pollution.

Channelization and damming associated with flood control or water reservoirs in urban areas reduce the structural diversity of riparian habitat and thereby decrease species diversity. Elevated water temperatures from industrial processes and thermal power plants can displace native species, favouring others adapted to warm water. Primary productivity may be reduced in response to an increase in water turbidity and a decrease in photosynthesis.

The construction of houses and other buildings on or near wetlands, riverbanks, and lakeshores reduces riparian habitat available for wildlife.



Increasing channelization with urban development at the south end of Okanagan Lake. Maps-B.C., MOELP 1922 (left) and 1982 (right).

Conflicts over the use of riparian areas may well be a result of misunderstanding. The responsibility of humans to maintain the natural world is now widely accepted. How large a role the small land area represented by riparian ecosystems plays in this fundaniental goal is less well understood.

The relative importance of the riparian ecosystem to potential users has been well illustrated by biologists in the Willamette National Forest on the western slopes of Oregon's Cascade Mountains. The following illustration (Figure 4) shows that, although only 6% of the total forested area in this region is classified as riparian, it is used by a very large proportion of birds, mammals, and recreationists.

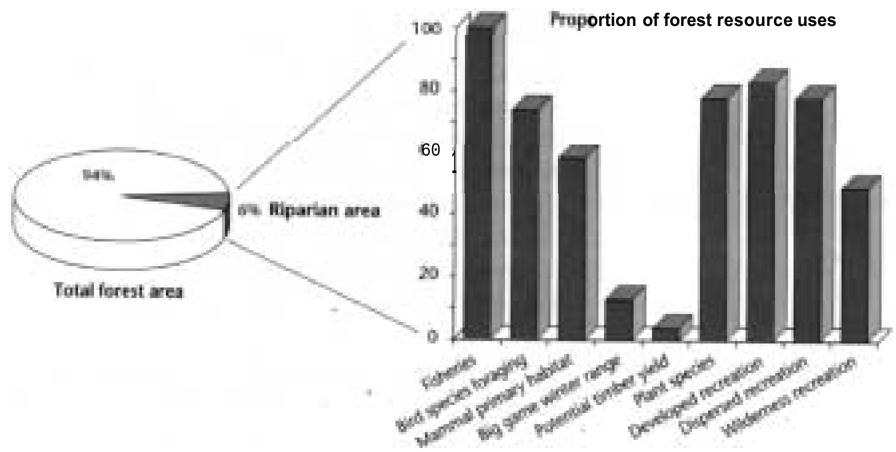


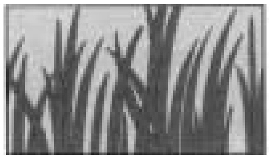
FIGURE 4 *Proportion of selected forest resource uses found in the riparian areas of the Willamette National Forest in Oregon State. Note that percentages are approximate. (Modified from Gregory and Ashkenas 1990.)*

Similarly, in British Columbia, the elements that have so often driven decision making in the past, such as timber resources, have the smallest proportion of their value in riparian areas. An increased understanding of riparian areas and their importance to all elements of the ecosystem will help managers make informed decisions.

LEGAL PROTECTION AND EXISTING GUIDELINES FOR RIPARIAN AREAS

Provincial government objectives include environmental quality, water quality, fisheries and wildlife management, and the maintenance of biodiversity and natural areas. Legal protection for riparian areas in British Columbia is provided for under two separate ministries, the Ministry of Forests and the Ministry of Environment, Lands and Parks.

Legislation



British Columbia Environmental Assessment Act The *British Columbia Environmental Assessment Act* consolidates all measures related to provincial environmental impact assessment in B.C. It combines the current assessment processes into one integrated system. Of particular concern is the scope and application of environmental assessment for all activities and developments with significant environmental impacts. Care will also be taken to ensure co-operation and efficiency among jurisdictions.

Forest Practices Code The recently enacted Forest Practices Code provides the legal basis for regulation of forest practices on Crown lands in British Columbia. The code provides protection for riparian areas consistent with the scope and application of environmental impact assessment. It consists of four parts: the *Forest Practices Code of B.C. Act,* Regulations, Standards, and Guidebooks.

Regulations under the Code lay out the universal and fundamental forest practices that apply province-wide at all times. Within the restrictions and limits set by the Code, Guidebooks provide information with which to make site-specific interpretations and modifications. The *Operational Planning Regulation* and the *Riparian Management Area Guidebook,* in particular, address riparian concerns with respect to forest practices and are based on the experiences gained from the former *Community Watershed Guidelines, Coastal Fisheries/Forestry Guidelines,* the *Okanagan Timber Supply Area Integrated Resource Management Timber Harvesting Guidelines,* and the draft *Interior Fish Forestry Wildlife Guidelines.*

The defined area in which riparian management is carried out is called the Riparian Management Area (RMA). As specified by the *Operational Planning Regulation* of the Forest Practices Code, RMAs are required along both sides of a stream and around all lakes and wetlands. Minimum widths for the RMA along streams vary depending on channel width, stream gradient, community watershed use, and fish presence, (Tables 1 and 2). Wetland and lake RMAs depend on wetland or lake size and rarity on the landscape. Overall RMA objectives are to:

1. minimize or prevent impacts of forest and range uses on stream channel dynamics, aquatic ecosystems, and water quality of all streams, lakes, and wetlands; and

2. minimize or prevent impacts of forest and range use on the diversity, productivity, and sustainability of wildlife habitat and vegetation adjacent to streams, lakes, and wetlands with reserve zones, or where high wildlife values are present.

The RMA has two parts—a reserve zone, where required by regulation, and a management zone. The reserve zone is inviolate except where access roads cannot avoid stream crossings. The management zone is established adjacent to the reserve zone and directly adjacent to those waterbodies that do not require a reserve zone. Forest practices within the management zone must be modified to ensure they meet the objectives of the RMA. Appropriate measures must be taken to reduce windthrow within the management zone and to maintain key riparian attributes such as large organic debris, wildlife trees, coarse woody debris, (CWD), and understorey vegetation. In general, tree removal within the management zone is restricted to partial-cut harvesting systems, and must maintain mature streamside trees required for streambank or channel stability, and ensure water quality for fish habitat and domestic consumption.

TABLE 1 *Definition of riparian classes*

Class	Definition
Streams or portions of streams in community watersheds, which are also fish streams	
S1 (Large rivers)	>100 m wide
S1	>20 m wide
S2	>5–20 m wide
S3	1.5–5 m wide
S4	<1.5 m wide
Streams outside of community watersheds, which are not fish streams	
S5	≥3 m wide
S6	< 3 m wide
Wetlands	
W1	>5 ha in area
W 2	between 1 and 5 ha in the PP, BG, IDF (very dry subzones), CDF, CWH (very dry maritime, dry maritime, or dry submaritime subzones)
W 3	between 1 and 5 ha in any biogeoclimatic unit other than above
W 4	between 0.25 and 1 ha in PP, BG or IDF (very dry subzones), or between 0.5 and 1 ha in CDF or CWH (very dry maritime, dry maritime, or dry submaritime)
W 5	2 or more individual wetlands with a combined size of 5 ha or larger, having overlapping riparian management areas
Lakes	
L1	>5 ha or designated by the forest district manager
L2	between 1 and 5 ha and in the PP, BG, IDF (very dry subzones), CDF, CWH (very dry maritime, dry maritime, or dry submaritime)
L3	between 1 and 5 ha and in any other biogeoclimatic unit than above
L4	between 0.25 and 1 ha and in PP, BG or IDF (very dry subzones) or between 0.5 and 1 ha and in CDF or CWH (very dry maritime, dry maritime or dry submaritime)

TABLE 2 *Management widths for riparian classes*

Class	Riparian Reserve Zone (m)	Riparian Management Zone (m)	Riparian Management Area (m)
S1 (large rivers)	0	100	100
S1	50	20	70
S2	30	20	50
S3	20	20	40
S4/S5	0	30	30
S6	0	20	20
W1/W5	10	40	50
W 2	10	20	30
W3/W4	0	30	30
L1	10	established by forest district manager	established by forest district manager
L2	10	20	30
L3/L4	0	30	30

Ministry of Forests (MOF) Although providing no explicit protection to riparian ecosystems, the provincial *Forest Act* requires the Chief Forester to assess land for:

- growing trees continuously
- providing forest for wilderness-oriented recreation
- producing forage for livestock and wildlife
- conserving wilderness
- accommodating other forest uses

In addition, Section 4(c) requires the Ministry to manage for multiple timber and non-timber values in consultation and co-operation with other government agencies and the private sector.

Ministry of Environment, Lands and Parks (MOELP) MOELP carries out government objectives through several pieces of legislation. Those providing the most protection to riparian ecosystems are the *Waste Management Act* and the *Water Act,* both of which address water quality concerns and can limit riparian development.

The Department of Fisheries and Oceans (DFO) Protection is afforded to riparian areas by means of Section 35 of the federal *Fisheries Act,* which prohibits the harmful alteration, disruption, or destruction of fish habitat unless authorized by the Minister. Under Section 36, the *Fisheries Act* also protects fish and fish habitat from the discharge of deleterious substances.

The DFO "Policy for the Management of Fish Habitat" (1986) has as its long-term objective a net gain in the productive capacity of fish habitat on a national scale. On a project-specific basis DFO pursues a "no net loss" policy.

Proposed Legislation

The B.C. government is currently considering several proposed acts and/or amendments that may affect the protection and management of riparian areas and wetlands. Public discussion papers and other information regarding the following proposed legislation may be obtained from the Ministry of Environment, Lands and Parks.

__Anadromous fish__ are those species that migrate up rivers to spawn in the shallow waters near the source. In British Columbia, they include the salmonids and steelhead trout. They require spawning areas where unpolluted, silt-free, cool water flows continuously over gravel bottoms.

The British Columbia Environmental Protection Bill will be the major environmental protection act of the Ministry. It aims to group together the provisions that apply to all environmental legislation and to establish the legislative basis for programs related to pollution prevention and control, air quality, water quality, pesticides, and waste management.

The Wildlife, Fish, and Endangered Species Bill is expected to encompass all programs concerned with managing and enhancing wildlife, fish, habitat, and endangered species. This proposed act will be a major environmental statute. It will provide for many new approaches and programs on species protection, biodiversity, and wildlife enhancement.

The British Columbia Water Management Bill is proposed to consolidate all provisions dealing with the effective management of water. This will include groundwater protection, instream flow protection, water management planning, and water export.

Water quality criteria and objectives Criteria have been set by the Ministry of Environment, Lands and Parks for particulate matter, nutrients and algae, phosphorous, molybdenum, nitrogen, cyanide, copper, lead, aluminum, mercury, chlorine, fluoride, and microbial indicators. The levels suggested are considered by the provincial government to be safe for fish, wildlife, livestock, and humans.

Environment Canada has published water quality guidelines that set acceptable levels of chemical and organic compounds for water to be used by aquatic life, and by humans for drinking, recreation, aesthetic endeavours, industry, and agriculture.

__Ecological reserves__ are permanent sanctuaries established in British Columbia for:

- *scientific research and educational use:*
- *preservation of representative examples of plant and animal communities;*
- *preservation of unique or rare natural phenomena;*
- *protection of rare and endangered plants and animals in their natural habitat; and*
- *perpetuation of important genetic resources.*

Of the 133 reserves established since 1971, more than 30% and over 20 000 ha involve riparian areas and wetlands. Further information can be obtained from B.C. Parks.

Mining Placer mining guidelines apply to aquatic fish habitat. No work is to be done in streams with high fisheries values. A general prescription for mining by the Ministry of Environment, Lands and Parks is for riparian disturbance to be kept to a minimum and streamside logging avoided during testing.

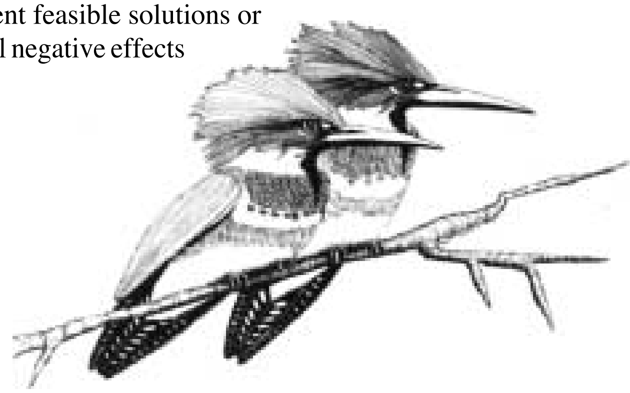
The *British Columbia Guidelines for Mineral Exploration* summarize approval requirements of the Ministry of Energy, Mines, and Petroleum Resources and the *Mines Act* .

Land Development Guidelines for the Protection of Aquatic Habitat The purpose of these guidelines is to protect fish populations and their habitat from the damaging effects of land development activities. Each land development project is subject to the following guideline objectives:

- provision and protection of leave strips adjacent to watercourses;
- control of soil erosion and sediment in run-off water;
- control of rates of water run-off to minimize impacts on watercourses;
- control of instream work, construction, and diversion on watercourses;
- maintenance of fish passage in watercourses for all salmonid life stages;
- prevention of the discharge of deleterious substances into watercourses.

The second goal of these guidelines is to encourage the provision of environmental assessment/impact information to DFO and MOELP. These guidelines are intended to assist land developers to identify problems prior to development and to present feasible solutions or measures to prevent potential negative effects on fish and fish habitat.

Wildlife Various formal wildlife guidelines exist in British Columbia but are not widely used. Most prescriptions are developed on site-specific bases.



Within the framework of the biological system and legal regulations, there is room for well-considered human activity. *The underlying principle of any management strategy should be that in the absence of scientific data, all management decisions will maintain options by protecting the ecosystem composition, structures, and function.*

Because of the linear nature of riparian ecosystems, it is especially important to consider two levels of planning — the site and the landscape levels. Disturbances at the site level can have far reaching effects downstream and can disrupt the continuity of the riparian ecosystem.

At the landscape level, managers must recognize the connective nature of riparian habitats. Management activities in the headwaters affect the floodplain. Organisms use the riparian corridor for dispersal, seasonal movements, and possibly for escape from catastrophic events such as fire. A riparian corridor can link one watershed to the next by joining headwaters on a ridge. Because of their built-in linearity and connectivity, riparian systems are a critical component of the **Forest Ecosystem Network** (FEN) outlined in the *Biodiversity Guidebook* of the Forest Practices Code. A network is most effective if its corridors are wide enough to serve as habitat as well as travel routes.

*A **Forest Ecosystem Network** is a planned landscape zone that serves to maintain or restore the natural connectivity within a landscape unit. It consists of a variety of fully protected areas, sensitive areas, classified areas, and old-growth management areas.*

At the site or stand level, riparian areas provide for a myriad of organisms: soil microflora and fauna, invertebrates and vertebrates, vascular and non-vascular plants. Riparian habitat must be managed to maintain the existing structures and functions essential to all species and their interrelationships. Riparian sites also have important functions in terms of maintaining stream integrity. Water quality, temperature, velocity, and turbidity may all be affected by human activities in riparian areas.

Riparian Classification System

Effective riparian management requires a classification system that:

- considers both the aquatic and terrestrial components of riparian ecosystems;
- is comprehensive but not complex;
- can be understood and employed by non-biologists working in forestry, agriculture, mining, or any other field that might have an impact on riparian areas; and
- is broad enough that initial classification can be done in the office, although on-site verification may be necessary.

Classification must recognize both the perspectives spelled out here.

The stream's perspective A stream and the organisms it nourishes and supports need the protection of riparian guidelines or codes. Without protection, the stream ecosystem will be degraded and provincial and global biodiversity will be degraded. Most streams need:

- large organic debris from the adjacent or upstream forest to provide diversity of stream habitats and to control flow;
- fine litter-fall in the form of leaves, twigs, mosses, lichens, and the arthropods associated with them to add organic material to the stream as a primary food source for its inhabitants;
- root systems in the stream banks to add stability to overhanging banks and to protect banks from flooding events;
- the moderating influence of overhanging vegetation on stream temperatures and light levels; and
- healthy streamside vegetation to act as filters from potentially harmful agricultural chemicals and as storage sites for water and nutrients (see page 8).

Generally these requirements are found within one tree height from the edge of the channel (Figure 5).

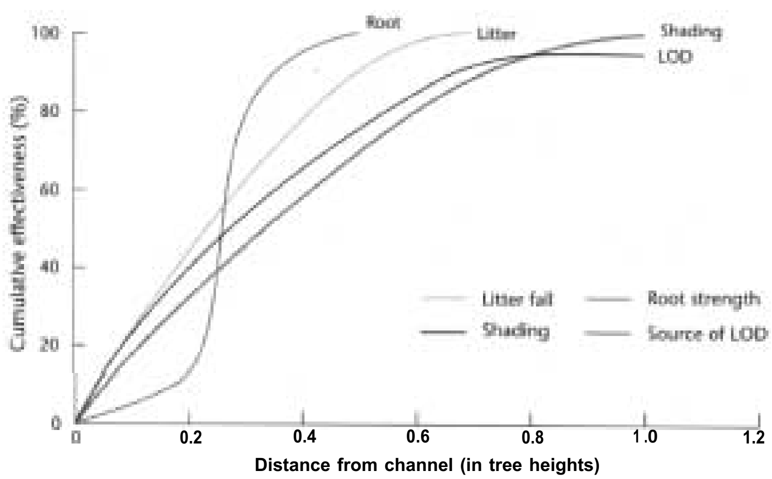


FIGURE 5 *Riparian forest effect on streams as a function of buffer width.*

Upland riparian habitat perspective The upland portion of a riparian zone is the area not immediately adjacent to the stream channel or lakeshore but influenced by its proximity to such areas. To maintain the ecosystem functions of these upland portions of riparian areas, careful consideration should be given to:

- maintaining the distinct microclimate of upland areas (characterized by differences in soil moisture and temperature, air temperature, radiation, wind speed, and relative humidity);
- a variety of cover types for vertebrate fauna (riparian areas are important as primary habitat, seasonal habitat and as corridors);

• maintaining current CWD and future supplies;
• maintaining current wildlife trees and future supplies; and
• the relatively high diversity of plant species in these areas (caused by the combination of upland and stream disturbance processes that influence them).

The effects of the riparian buffer on the microclimate of a forest stand bordering a lake or stream are gradually reduced, until by three tree-heights from the edge of the water the effects are nil (Figure 6).

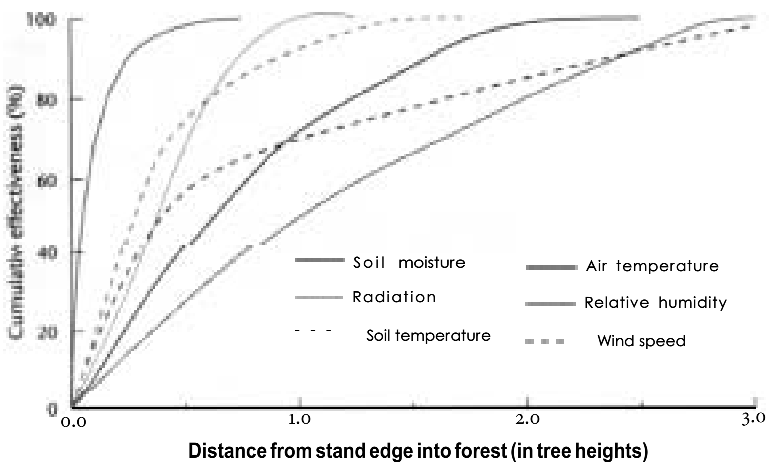


FIGURE 6 *Riparian buffer effects on microclimate.*

Riparian Management Areas

Considering the stream and upland viewpoints together is accomplished in the overall objectives of riparian management areas (RMA). These are, to retain:

• water quality (i.e., sediments and nutrients) that provides for stable and productive ecosystems;
• stream channel integrity and channel processes under which the ecosystem developed, such as timing, volume and character of sediment, and LOD input and transport;
• riparian vegetation, including understorey and non-commercial species;
• instream flows to support desired riparian and aquatic habitats;
• natural timing and variability of the water table elevation in meadows and wetlands:
• diversity and productivity of fish, wildlife, and riparian ecosystems;
• current suitable wildlife trees and a source of future wildlife trees;
• amount and distribution of coarse woody debris characteristic of natural riparian and aquatic ecosystems;
• riparian and aquatic habitats for unique genetic stocks within specific biogeoclimatic subzones;
• ecological linkages across forest landscapes; and
• associated forest and social values.

Strategies and Guidelines

Specific guidelines are most effective and appropriate when designed and agreed to by all those with a genuine interest in a watershed. Non-humans cannot be present at the table and must be represented, fairly, by human proxy.

The following principles should be adhered to in developing guidelines:

- When supporting data are not available, decisions should be made which do not alter the structure and function of ecosystems.
- The entire floodplain is critical to sustaining a properly functioning riparian system. Floodplains were formed by both high-and low-level flooding events and their vegetation is important to future soil integrity.
- Upland vegetation adjacent to riparian areas forms an integral part of the ecosystem.
- The effects of headwater activities are compounded in downstream areas.
- Rehabilitation may be a viable option where past practices have disrupted function or structure of riparian ecosystems.
- Every development activity that has an impact on the riparian environment (timber harvesting and silviculture, livestock grazing, urban and rural development, mining, construction of roads, pipelines, and railways) should have specific guidelines or be covered by comprehensive guidelines.

APPENDIX 1 Riparian species at risk in British Columbia

The terrestrial species at risk in British Columbia that use riparian ecosystems for all or part of their habitat needs (endangered or threatened = red (R), vulnerable or sensitive = blue (B)).

Common name	Scientific name	Status
Amphibians		
Tiger salamander	*Ambystoma tigrinum*	R
Pacific giant salamander	*Dicamptodon tenebrosus*	R
Coeur d'Alene salamander	*Plethodon idahoensis*	R
Great Basin spadefoot toad	*Scaphiopus intermontanus*	B
Leopard frog	*Rana pipiens*	R
Reptiles		
Painted turtle	*Chrysemys picta*	B
Rubber boa	*Charina bottae*	B
Night snake	*Hypsiglena torquata*	R
Birds		
Western grebe	*Aechmophorus occidentalis*	R
American bittern	*Botaurus lentiginosus*	B
Tundra swan	*Cygnus columbianus*	B
Trumpeter swan	*Cygnus buccinator*	B
Oldsquaw	*Clangula hyemalis*	B
Surf scoter	*Melanitta perspicillata*	B
Turkey vulture	*Cathartes aura*	B
Northern goshawk subsp. *laingi*	*Accipiter gentilis laingi*	R
Ferruginous hawk	*Buteo regalis*	R
White-tailed ptarmigan subsp. *saxatilis*	*Lagopus leucurus saxatilis*	B
Sage grouse	*Centrocercus urophasianus*	R
Sharp-tailed grouse subsp. *columbianus*	*Tympanuchus phasianellus columbianus*	B
Sandhill crane	*Grus canadensis*	B
Upland sandpiper	*Bartramia longicauda*	R
Red-necked phalarope	*Phalaropus lobatus*	B
Common murre	*Uria aalge*	R
Marbled murrelet	*Brachyramphus marmoratus*	B
Horned puffin	*Fratercula corniculata*	R
Barn owl	*Tyto alba*	B
Western screech owl subsp. *kennicottii*	*Otus kennicottii kennicottii*	B
Western screech owl subsp. *macfarlanei*	*Otus kennicottii macfarlanei*	B
Northern pygmy owl subsp. *swarthi*	*Glaucidium gnoma swarthi*	B
Northern saw-whet owl subsp. *brooksi*	*Aegolius acadicus brooksi*	B
Williamson's sapsucker subsp. *thyroideus*	*Sphyrapicus thyroideus thyroideus*	B
Williamson's sapsucker subsp. *nataliae*	*Sphyrapicus thyroideus nataliae*	R
Hairy Woodpecker subsp. *picoideus*	*Picoides villosus picoideus*	B
White-headed woodpecker	*Picoides albolarvatus*	R
Horned lark subsp. *strigata*	*Eremophila alpestris strigata*	R
Purple martin	*Progne subis*	R
Steller's jay subsp. *carlottae*	*Cyanocitta stelleri carlottae*	B
Canyon wren	*Catherpes mexicanus*	B
Sage thrasher	*Oreoscoptes montanus*	R
Hutton's vireo	*Vireo huttoni*	B

Cape May warbler	*Dendroica tigrina*	R
Palm warbler	*Dendroica palmarum*	B
Bay-breasted warbler	*Dendroica castanea*	R
Connecticut warbler	*Oporornis agilis*	R
Yellow-breasted chat	*Icteria virens*	R
Brewer's sparrow subsp. *breweri*	*Spizella breweri breweri*	R
Vesper sparrow subsp. *affinis*	*Pooecetes gramineus affinis*	R
Grasshopper sparrow	*Ammodramus savannarum*	R
Sharp-tailed sparrow	*Ammodramus caudacutus*	R
Pine grosbeak subsp. *carlottae*	*Pinicola enucleator carlottae*	B

Mammals

Black-backed shrew	*Sorex arcticus*	B
Pacific water shrew	*Sorex bendirii*	R
Water shrew subsp. *brooksi*	*Sorex palustrus brooksi*	R
Tundra shrew	*Sorex tundrensis*	R
Townsend's mole	*Scapanus townsendii*	R
Pallid bat	*Antrozous pallidus*	R
Western red bat	*Lasiurus blossevilli*	R
Keen's long-eared myotis	*Myotis keenii*	R
Northern long-eared myotis	*Myotis septentrionalis*	R
Fringed myotis	*Myotis thysanodes*	B
Townsend's big-eared bat	*Plecotus townsendii*	B
Snowshoe hare subsp. *washingtonii*	*Lepus americanus washingtonii*	R
Mountain beaver subsp. *rufa*	*Aplodontia rufa rufa*	R
Mountain beaver subsp. *rainieri*	*Aplodontia rufa rainieri*	B
Southern red-backed vole subsp. *occidentalis*	*Clethrionomys gapperi occidentalis*	R
Southern red-backed vole subsp. *galei*	*Clethrionomys gapperi galei*	B
Townsend's vole subsp. *cowani*	*Microtus townsendii cowani*	R
Northern Bog lemming subsp. *borealis*	*Synaptomys borealis borealis*	B
Northern Bog Lemming subsp. *artemisiae*	*Synaptomys borealis artemisiae*	R
Northern pocket gopher subsp. *segregatus*	*Thomomys talpoides segregatus*	R
Cascade mantled ground squirrel	*Spermophilus saturatus*	B
Red-tailed chipmunk subsp. *simulans*	*Tamias ruficaudus simulans*	R
Red-tailed chipmunk subsp. *ruficaudus*	*Tamias ruficaudus ruficaudus*	R
Meadow jumping mouse subsp. *alascensis*	*Zapus hudsonius alascensis*	B
Wolverine subsp. *luscus*	*Gulo gulo luscus*	B
Wolverine subsp. *vancouverensis*	*Gulo gulo vancouverensis*	R
Ermine subsp. *haidarum*	*Mustela erminea haidarum*	R
Ermine subsp. *anguinae*	*Mustela erminea anguinae*	B
Lang-tailed weasel subsp. *altifrontalis*	*Mustela frenata altifrontalis*	R
Black bear subsp. *emmonsii*	*Ursus americanus emmonsii*	B
Grizzly bear	*Ursus arctos*	B
Elk subsp. *roosevelti*	*Cervus elaphus roosevelti*	B
Caribou (southeastern populations)	*Rangifer tarandus*	B

Backhouse, F. and J.D. Lousier. 1991. Wildlife tree problem analysis. Prepared for B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks. B.C. Wild. Tree Comm., Integrated Manage. Br., B.C. Min. Environ., Lands and Parks, Victoria, B.C.

Important components of riparian areas, wildlife trees are vital habitat for birds, mammals, and amphibians, Produced jointly for the Ministry of Environment, Lands and Parks and the Ministry of Forests by the Wildlife Tree Committee, this publication discusses the qualities and classification of wildlife trees in B.C. and makes recommendations for their management in relation to forestry and the maintenance of biodiversity. The problem analysis and its accompanying publication, *Wildlife Tree Management in British Columbia* (1993), are available through the Wildlife Tree Committee.

Bunnell, P., S. Rautio, C. Fletcher, and A. Van Woudenberg. 1991. Problem analysis for integrated resource management of riparian ecosystems. Prepared for Ministry of Forests and Ministry of Environment: ESSA Ltd., Vancouver, B.C. 126 pp.

Produced jointly for the Ministry of Environment, Lands and Parks and the Ministry of Forests, this problem analysis formed the basis for the publication, *Riparian Management in British Columbian Important Step Twards Maintaining Biodiversity*. It includes recommendations for policy and guidelines, classification, research, management, extension and education, legislation and support, as well as an extensive bibliography on riparian-related topics. In addition, the problem analysis involved the construction of two riparian bibliographic databases. RIPBIB and RIPPER are available along with a user's guide from the Ministry of Forests, Research Branch, Victoria.

Chamberlain, T.W. (editor). 1987. Applying 15 years of Carnation Creek results: Proceedings of the workshop, January 13-15, 1987, Nanaimo, B.C. Carnation Creek Steering Committee, Pacific Biological Station, Nanaimo, B.C.

The Carnation Creek Experimental Watershed was established in 1970 by the federal Department of Fisheries and Oceans in partnership with the B.C. Forest Service, B.C. Ministry of Environment, Canadian Forest Service, Environment Canada, B.C. Universities, Council of Forest Industries, and MacMillan Bloedel Ltd. It has served to elucidate forestry–fisheries interactions in coastal watersheds in British Columbia. This publication summarizes the experimental results between 1970 and 1985, which are being applied to forest management practices in the province.

Douglas, D.J. 1984. The river why. Bantam Books, New York, N.Y.

Set along a coastal river in the Pacific Northwest, this beautifully written novel touches poignantly on the recreational, aesthetic, and spiritual values of riparian habitat. Suitable to a wide range of readers.

Gregory, S. and L. Ashkenas. 1990. Riparian management guide: Willamette National Forest. Dep. Fish. and Wild., Oregon State Univer. 120 p.

"The primary goal of riparian management is to provide self-sustaining streamside forests that will ensure the desired conditions of riparian resources for the future." With this goal as its basis, this publication provides an overview of the values and characteristics of riparian areas. It presents a detailed and progressive example of forestry-related guidelines for riparian management.

Harris, L.D. 1984 The fragmented forest. The University of Chicago Press, Chicago, Ill. pp. 127–165.

Larry D. Harris, professor at the School of Forest Resources and Conservation, University of Florida, and curator of ecology in the Florida State Museum, describes riparian areas as critical components for preserving biodiversity through landscape-level management. Important as natural travel corridors between forest islands, riparian strips are recognized as superior wildlife habitat and ideal linkages in a regional network of forest types.

Johnson, R.R., C.D. Ziebell, D.R. Patton, P.F. Ffolliott, and R.H. Hamre. 1985. Riparian ecosystems and their management: Reconciling conflicting uses. First North American Riparian Conference, April 16–18, Tucson, Arizona, USDA Forest Service, Gen. Tec. Rep RM–120, 523 pp.

The proceedings from this 1985 conference address the issues of conflict over riparian and wetland resource use from both a socio-economic and biological perspective. It includes special sections on specific areas of potential conflict such as recreation, agriculture, wildlife, livestock, and fisheries. The premise of the discussion is that reconciliation of conflicts and balanced use, rather than preservation of each area in its entirety, is the only way to salvage riparian ecosystems.

Lousier, J.D. and N. Taylor (editors). 1990. The role and value of riparian resources in coastal forests of British Columbia: A workbook, Victoria, B.C. Unpublished.

This is a compilation of information and readings to accompany workshops on the management of riparian ecosystems in coastal British Columbia. The workshops were developed as part of the FRDA extension program for coastal British Columbia.

Morgan, K.H. and M.A. Lashmar (editors). 1995. Riparian habitat management and research. Proceedings of a workshop, May 4–5, 1993, Kamloops, B.C. A Special Publication of the Fraser River Action Plan. Environment Canada and the British Columbia Forestry Continuing Studies Network. 139 pp.

This workshop proceedings reviews the current state of knowledge of the biology and management of riparian habitats in B.C., with special emphasis on the Fraser River Basin. The ten papers and two abstracts are organized by the following categories: The Value of Riparian Habitats; Riparian Habitats; Riparian Wildlife; and Management and Research in Riparian Habitats. Topics include the importance of riparian habitats to fish, bats, and small mammals; the use of riparian areas by fishers; vegetation dynamics and classification on alluvial floodplain; livestock impacts on grassland riparian ecosystems; alternative timber harvesting to maintain grizzly bear habitat; and a summary of the riparian habitat problem analysis.

Oakley, A.L., J.A. Collins, L.B. Everson, D.A. Heller, J.C. Howerton, and R.E. Vincent. 1985. Riparian zones and freshwater wetlands. *In* Management of wildlife and fish habitats in forests of Western Oregon and Washington, pp. 58–80 E.R. Brown, (tech. editor). USDA For. Serv. Pub. No. R6–F&WL–192–1985. 332 pp.

This chapter provides an excellent overview of riparian and wetland characteristics and their importance in relation to wildlife and fish habitat. It contains a comprehensive section on management considerations for timber, livestock grazing, mining operations, recreation, energy development, wood fuels, and rehabilitation and enhancement.

National Wetlands Working Group, Canada Committee on Ecological Land Classification. 1987. The Canadian wetland classification system. Can. Wild. Serv. Environ. Can. Ecological Land Classification Ser. No. 21. 18 pp.

The Canadian Wetland Classification System represents a synthesis of existing regional classification systems. This document describes five wetland classes (bog, fen, marsh, swamp, and shallow water) and 70 wetland forms found in Canada. It provides keys for identifying the different forms.

Raedeke, K.J. (editor). 1988. Streamside management: Riparian wildlife and forestry interactions. Coll. For. Resour., Univ. Wash., Seattle, Wash. Contrib. No. 59. 277 pp.

A compilation of papers presented at the second University of Washington symposium on streamside management in forests of the Pacific Northwest, this volume considers the special relationships that some terrestrial organisms have to streams and streamside zones. The submissions are divided into five sections, which include riparian characteristics, ecological relationships with associated uplands, comparisons of managed and unmanaged systems, current management practices and policies, and social and economic influences on management decisions.

Runka, G.G. and T. Lewis. 1981. Preliminary wetland managers manual: Cariboo Resource Management Region. B.C. Min. Environ. APD Technical Paper 5. 113 pp.

Developed originally for use within the Cariboo Resource Management Region, this working manual outlines a wetland classification system detailed at four levels: class, subclass, variant, and plant association. A second section discusses wetland use and management considerations for each use presented in both text and table form. A comprehensive glossary is included.

Sedell, J.R, P.A. Bisson, F.J. Swanson, and S.V. Gregory. 1988. What we know about large trees that fall into streams and rivers. *In* From the forest to the sea: a story of fallen trees, pp. 47–81 C. Maser, R.F. Tarrant, J.M. Trappe, and J.F. Franklin (editors). USDA For. Serv. Gen. Tech. Rep. PNW-GTR-229. 153 pp.

Fallen trees and the resulting large organic debris are considered vital to the productivity of salmonid fish habitat in small streams associated with mature and old-growth coniferous forests. A detailed examination of the historical perspective and present knowledge about fallen trees in riparian areas, this chapter emphasizes the need for management considerations.

The integrated watershed management approach exemplifies the importance of looking at multiple uses of watershed resources, rather than simply the hydrology. It attempts to balance human and environmental needs, while simultaneously guarding ecosystem services and biodiversity (Bakker 2012). Managing watersheds in this manner allows the needs of society and the environment to be accounted for, even with increasing population pressures and demand for higher productivity and multiple uses of forests and related landscapes (Dortignac 1967). integrated resource management of riparian areas in British Columbia. B.C. Min. For. and.Â Stevens, V., F. Backhouse, and A. Eriksson. 1995. Riparian management in British. Columbia: an important step towards maintaining biodiversity. Province of British Columbia, Ministry of Forests Research Program. Working Paper 13/1995, 30 p. Wondering why you should contribute your bit towards biodiversity conservation? Here are some good enough reasons for you to do so!Â The very existence of life on planet Earth is in severe crisis, and lack of awareness about the importance of biodiversity is one of the key problems which needs to be looked into. Wondering why you should contribute your bit towards biodiversity conservation? Here are some good enough reasons for you to do so!