Managed Riparian Zone Prescription for Newfoundland and Labrador

Buffer Zone Working Group
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Abstract

Riparian regulations in Newfoundland and Labrador state that all watercourses represented on a 1:50,000 topographic map are to be bordered with a 20m treed buffer. Harvesting is not permitted within the riparian zone. All other provinces and territories allow harvesting within riparian buffers but operators must adhere to several regulations to ensure the integrity of the riparian buffer is not compromised. Both forest harvesters and government regulators desire a riparian zone management system that is easy to implement, meets environmental objectives and maximizes the amount of timber available for harvest. Complicated rules and techniques will create as many problems operationally as they attempt to alleviate ecologically. With a complicated riparian management system harvesters will have troubles knowing when to apply different buffer treatments and managers will have difficulties enforcing the rules and regulations. Forest managers recognize the complex nature of forest and all aspects of the local environment will have an impact on the riparian buffer. When implementing a managed buffer regime it is important to include site specific variables such as stand composition, stand age, stand density, windfall potential and many other parameters. This paper reviews each site specific parameter and proposed potential management techniques to allow environmentally-sound forest harvesting within riparian buffers. The proposed prescriptions were developed by reviewing current scientific literature and are consistent with other provinces and territories across Canada.

1.0 Introduction

Canada's forest industry is managed by the provincial and territorial governments therefore many different rules and regulations regarding managing the riparian zone exist. Although there are many differences there are also similarities for working within buffers. With the exception of Ontario, all timber removed from within the buffer is done so by selective harvesting (Decker 2003). Selective harvesting is also known as diameter - limit cutting or high grading because a percentage of the most merchantable trees are removed during a harvest event (Chunko 1998). To properly design a successful management plan for riparian buffers in Newfoundland and Labrador it is important to determine the primarily factors influencing our forest and local environment. As forest harvesting in Newfoundland and Labrador enters a new era of forest management it is essential to understand how current management practices evolved in this province.

Prior to 1975 there was very little mention of riparian zone management or sustainable forest management in Newfoundland and Labrador. Since that time there have been great strides in both of these concepts allowing more responsible forest management practices within this province. Sustainable Forest Management can be defined as, "Management to maintain and enhance the long-term health of forest ecosystems, while providing ecological, economic, social and cultural opportunities for the benefit of present and future generations." (Von Mirbach 1999). Newfoundland and Labrador is covered by 22.5 million hectares of forest which comprises 5.4% of Canada's forests. These forests are predominantly softwoods (91%) while mixed woods (8%) and hardwoods (1%) are significantly less abundant (Anon 2001). Newfoundland and Labrador contributes approximately 1.2% to Canada's forest industry and this is directly linked to the pulp and paper industry. Forest rights and forest management practices are designed, implemented and enforced by the provincial governments in association with stakeholders and interest groups.

The primary forest management prior to 1975 was protection from fire and insect damage. This management regime was driven by the economic potential of forested lands. In 1975 a Forest Land Management and Taxation Act was proclaimed which brought changes to how the forests of the Province were managed (Moores 2003). This Act was primarily administrative and required harvesters to create forest management plans for the timber resources they wished to obtain. These management plans evolved through the late 70's and 80's to include activities such as planting and pre-commercial thinning which continue today and are important components of sustainable forest management. Every year in this province replanting and pre-commercial thinning covers approximately 3,600 hectares and 4,700 hectares, respectively (DFRA 2003).

With the creation of the Forestry Act in 1990 there was a major paradigm shift from forest management to ecosystem management. This act was created to ensure that timber was harvested in an environmentally sound manner. Other resources such as fish, wildlife, potable water and aesthetics had to be protected from the adverse effects of forest harvesting as much as possible. This was a major step towards the goal of sustainable forest management. In 1991 the province drafted, "Environmental Protection Guidelines for Timber Management" and this report first introduced the use of riparian buffers to protect the aquatic resources in this province. The guidelines were based on a literature review and set 150 different buffer requirements (Moores 2003). The complexity of these buffer requirements meant that the guidelines were difficult to implement and enforce. For a forest management plan to be implemented in an operational setting it had to be easily interpreted and enforced. From the 1991 guidelines a new report was drafted in

1994, "Environmental Protection Plan for Ecological Based Forest Resources Management". This report drew upon the lessons learned from the 1991 Guidelines and was reviewed by the forest industry, environmental groups, and both the provincial and federal governments. The new report contained two key components that have shaped forest management in the province, the implementation of 5-year operating plans and watercourse buffer zones.

Five-year operating plans are the responsibility of the licensee. Plans are reviewed by the Newfoundland Forest Service for compliance with the provincial guidelines. The provincial government produces its own 20-year operating plans for the province and the operator's 5-year operating plans must be consistent with the management strategies outlined in the 20-year plan (Saunders 2003). The 20-year management plan is based on a timber supply protection for a 160 year period. The 5-year operating plan details on a 1:50,000 topographic map where forest management activities such as harvesting, planting, thinning, and road construction are take place. In association with the 5-year operating plan the licensee also provides an Annual work schedule which details the proposed work for each year on a 1:12,500 scale forest type map (DFRA 2003). Both the 5-year operating plan and the annual work schedule receive input from the stakeholders such as environmental groups, outfitters and the general public.

Watercourse buffers were perhaps the biggest step towards ecosystem management. The 1994 guidelines stated that a strip of land between the cut block and a watercourse remain untouched during a harvesting operation. The buffer zone was to be a 20 m strip around all water bodies represented on a 1:50,000 topographic map. The buffer zone would be larger than 20 m if the slope of the adjacent land was greater than 30% (Scruton et al, 1997). When a slope is greater than 30% the buffer width must be 20 m plus 1.5 times the slope (%) (Table 1). Different land uses associated with forestry operations also required buffers greater than 20 m (Table 2). In Newfoundland and Labrador harvesting within the 20 m buffer is not permitted although most other provinces and territories across Canada do permit some level of selective cutting within their riparian buffers.

Table 1. Recommended minimum buffer strips to protect water bodies during forest harvesting operations. Buffer strip width is equal to 20 m plus 1.5 times the slope (%) where the slope exceeds 30% (reproduced from Scruton et al. 1997).

Slope (%)	**Slope (°)**	**Width (m) of Buffer**
0	0	20
15	8	20
30	17	65
45	24	88
60	31	110

Table 2. A summary of recommended minimum riparian buffer strips for various forestry-related activities (reproduced from Scruton et al. 1997).

Activity	Recommended Buffer Width (m)
Fuelling/Servicing	30m
Fuel Storage	100m
Landings	20m (+1.5 x slope (%) where > 30%)
Skid Trails	20m (+1.5 x slope (%) where > 30%)
Roads	20m (+1.5 x slope (%) where > 30%)
Barrow Pits	100m
Drainage	30m
Pesticide Storage/Mixing	100m (temporary storage)
Herbicide Application	No less than 44m
Insecticide Application	400m from freshwater; 1.6km for coastal areas
Silviculture	20m (+1.5 x slope (%) where > 30%)
Camps/Maintenance Buildings	100m
Primary Processing Facility	100m
Slash Placement	30m
Controlled Burns	20m (+1.5 x slope (%) where > 30%)

Since 1994 there has been some evolution of the watercourse buffer zone guidelines but the fundamental 20m uncut riparian zone is still used. Current guidelines for Newfoundland and Labrador state that a 20m treed buffer is required along all water bodies represented on a 1:50,000 topographic map and any waterway greater than 1 m wide not represented on the 1:50,000 topographic map. Intermittent streams are also subject to the riparian buffer guidelines stated above. Buffer width is measured from the high water mark of all water bodies providing extra protection from the potentially adverse effects of forest harvesting operations (Decker et al. 2003).

Other forest management guidelines in place in Newfoundland and Labrador include prohibitions on equipment entering a watercourse, and no re-fuelling or maintenance of equipment is permitted within 30 m of a watercourse. Silt and debris entering a watercourse should be minimized and immediately mitigated. A 50 m buffer is required around all known Black Bear den sites and an 800 m buffer with no harvesting activity is required around Bald Eagle and Osprey nesting sites. After the nesting season, there is to be no harvesting activity within 200 m of these sites. Hardwoods within 30 m of a watercourse occupied by beavers are not to be removed during the harvest operation. A 150 m buffer is required around all protected municipal water supplies. (Saunders 2003, DFRA 2003).

2.0 Why Do We Have Riparian Buffers

As stated above, riparian buffers were implemented as a step toward ecosystem management. Perhaps the primary reason for maintaining riparian buffers was protection of fish, fish habitat and water quality, but buffers also have a beneficial impact on wildlife that may be affected by forest harvesting operations. Ecologically, poor forest harvesting practices can potentially harm flora and fauna through loss of suitable habitat, blockage of migration routes, decreases in productivity and habitat destruction through increased toxicity. Socially, poor forestry operations can potentially decrease the amount of potable water available for human consumption and create a negative public opinion of forestry by lowering the aesthetic value of a natural setting. Riparian buffers are beneficial to the following parameters;

1) Fish and Fish Habitat
2) Water Quality
3) Wildlife
4) Vegetation
5) Aesthetics

2.1 Fish/Fish Habitat

Forest harvesting operations have the potential to increase the amount of sediment and nutrients entering an aquatic system thereby lowering habitat quality and water quality. Riparian buffers have been theoretically and experimentally proven to lower inputs into aquatic systems through a filtering action. Exposed mineral soils along access roads, skid trails and log landings lead to excess sediments entering neighbouring watercourses. The primary sources of increased sediment and silt in streams and ponds adjacent to cutting operations is from access roads (Elliot et al. 1999, Clarke at al. 1997). This is mainly related to soil compaction, surface erosion and mass failures. Sediment-laden water flowing from roads and cut areas must flow through the buffer prior to reaching a watercourse, it is in the buffer that the majority of sediment is removed. The structural complexity of surface vegetation and the duff layer in the buffer causes run-off to slow down and deposit much of the sediment suspended in the flow (Barden 2001, France 1997). Riparian vegetation also absorbs any excess nutrients that are present in run-off before they reach the aquatic system and disrupt the productivity.

Excess sediment within a stream can increase turbidity therefore reducing visibility and lowering success rates of fish catching prey (Berkman and Rabeni 1987). Sedimentation can destroy important fish habitat by filling pools and can destroy spawning grounds by limiting the amount of oxygen available to developing fish eggs and alevins in redds (Newcombe and MacDonald 1991, Lisle 1989). Other detrimental impacts of increased sediment within watercourses include irritation to fish gills leading to increased stress, infection, disease and potentially death (Goose et al. 1998). High amounts of suspended solids within a watercourse may increase water temperature because suspended solids have the ability to absorb solar radiation thereby raising the temperature of the water column. Increased nutrients within a watercourse can severely alter productivity by eutrophication or algal blooms. This occurs when biologically limited nutrients such as nitrogen and phosphorus are washed into a stream or pond from a cut area. The excess nutrients potentially lead to a rapid increase in algal populations. When these populations die high amounts of oxygen are used for decomposition leading to anoxic conditions within the watercourse. Anoxic conditions can cause large fish kills and lead to an unproductive system (Rosen et al. 1995, Jewett et al. 1995, Horne and Goldman 1994).

2.2 Water Quality

Water quality is a big issue around the world because as the human population continues to increase so does the demand of potable water supplies. Buffers are important for maintaining clean water during periods of municipal expansion and increased demands on forest resources. After the Walkerton, Ontario tragedy there has been an increase in the public's concern over clean, potable water. As forest companies require more timber to sustain their operations, municipalities are evermore cautious of harvesting within water supply areas. Treed buffers may be the key to satisfy both needs. Currently Newfoundland and Labrador requires a 150 m treed buffer around all protected water supplies (Saunders 2003).

Perhaps the most visible impact of forest harvesting on water quality is turbidity. Excess silt and sediment can cause water supplies to be dirty or cloudy and unfit for human consumption. As described in Section 2.1 Fish/Fish Habitat, a vegetated buffer acts as a filter to remove the majority of suspended solids prior to reaching the watercourse. Other than filtering runoff off, vegetated buffers will absorb water flowing over the surface through roots therefore potential pathogens and viruses, which may be present in the water from a contaminated site, may be taken up by buffer vegetation prior to reaching the watercourse. For buffers to be successful at mitigating any potential impacts of forest harvesting it is important for operators to adhere to all provincial guidelines regarding timber harvesting near watercourses.

2.3 Wildlife

Extensive work has been conducted on the impacts of forest harvesting operations on wildlife populations across North America and other parts of the world. The major impact of forest harvesting operations is loss of usable habitat through the removal of trees. Trees and interior forest provide sheltered habitat for many terrestrial organisms. Riparian buffers have been known to act as corridors for wildlife to use as sheltered habitat and migration routes between different habitat types. Most terrestrial organisms do not utilize cut areas since shelter from predators is limited (Rodewald and Brittingham 2001). As forests are harvested, wildlife tends to seek out areas with forest cover. Also, there is limited movement across cut blocks to other forested areas therefore wildlife populations may become isolated from other populations (Meffe et al. 1997). This can possibly lead to decreased survival success of the population because of limited genetic diversity caused by inbreeding. Riparian buffers help minimize these impacts by providing cover and migration paths for wildlife (Doucet 2003). Potentially, buffers may increase species diversity because of increased structural diversity created at the edge of the buffer.

2.4 Vegetation

Riparian buffers are essential for vegetation because they provide a seed source to replenish vegetation that was removed during the harvesting activity. Trees and herbaceous shrubs within the buffer provide enough seed to begin forest succession within the cut block (Anon 1999). Riparian vegetation also provides stability to stream banks and reduces the risk of mass erosion events. Roots add structural complexity to the soil therefore providing strength to the stream banks during periods of high runoff, peak flows, storm events and spring flows thereby limiting mass wasting and major inputs of sediment into the adjacent water column.

Riparian buffer vegetation also helps maintain normal streamflow. After a harvest event streamflow tends to increase because of the reduction in evapotranspiration (Twery and Hornbeck 2001). Lowered evapotranspiration rates may cause an increase in the amount of water within soils and this may lead to a "watering-up" of neighbouring watercourses. Many studies have shown significant increases in water yield and peak flow following clear-cuts and this is directly related to the loss of trees and its impacts on the hydrological cycle (Jones and Grant 1996, Lynch et al. 1972, Douglass and Swank 1972, Dunford and Fletcher 1947). Larger watersheds are less susceptible to increased water levels than smaller watersheds.

2.5 Aesthetics

Riparian buffers are important socially because they can maintain the appearance of a natural setting near a harvested area. Buffers along highways and roads, around communities and in cabin areas limit the view of the footprint left by forest harvesting operations. The public is less likely to oppose forest harvesting if it is not visible to them from their homes and communities. Retention of buffers around watercourses also demonstrates to the public that the operator is attempting environmentally sound harvesting techniques to maintain healthy and productive ecosystem. People enjoy nature and the retention of buffers allows people to experience it with relative ease.

3.0 Riparian Buffers

As discussed above, riparian buffers are an important component of forest management and forest harvesting. What exactly is a riparian buffer? A riparian buffer is a narrow strip of land bordering aquatic systems that has direct interactions with both the aquatic environment and the terrestrial environment (Decker 2003). Gregory et al. (1991) defined riparian buffers as the functional three-dimensional zones of direct interactions between terrestrial and aquatic ecosystems. The description of buffers as three-dimensional is very important because riparian buffer operate on all three axes, vertical, horizontal and spatial. Vertically buffers provide shade to watercourses, canopy cover and habitat for terrestrial organisms. Horizontally buffers provide protective shelter to organisms and protect watercourses from potentially harmful inputs from cut blocks. Spatially riparian buffers provide a seed source to the cut area allowing regeneration over time.

The major uncertainty facing resource managers in Newfoundland and Labrador is whether a 20 m riparian buffer is sufficient to mitigate impacts to both aquatic and terrestrial ecosystems.

Currently, the width of the buffer changes to reflect slope and land-use. Some provinces in Canada use a stream classification system to determine the width of a riparian buffer. Primarily the width is based upon the size of the adjacent watercourse. Manitoba, Saskatchewan, and Alberta classify streams depending on size. Manitoba has Class I and Class II streams. Class I streams drain an area greater than 50 km^2 and contain commercial and/or sport fish while a Class II stream drain an area less than 50 km^2 and lack commercial and sport fish. Ponds and wetlands each have there own classification. A 100 m buffer is required on all classes but a smaller buffer may be approved by the provincial government on smaller watercourses such as Class II streams and small ponds (MNR 1996a, MNR 1996b).

Saskatchewan has three riparian widths, 15 m, 30 m, and 90 m, which are applied to different watercourse classes. Class I streams are 3rd order or less and drain less than 50 km^2. Class II streams are greater than 3rd order and drain greater than 50 km^2. Lakes and ponds are a separate classification. A 15 m buffer is required adjacent to all Class I streams, a 30 m buffer is required on all Class II streams and Lakes lacking commercial fish populations, and a 90 m buffer must be retained on all Class II streams and Lakes containing commercial fish populations (Barten 2001). Alberta's buffers range from 30 m to 100 m. A 100 m buffer is required around all lakes and ponds. A 30 m buffer borders streams with a river valley less than 400 m across and a 60 m buffer is required along streams with a river valley greater than 400 m across. River valley refers to the entire stream area under the same contour level (Anon 1994, Anon 2002).

British Columbia also classifies streams, lakes and wetlands by size and each size class receives a different buffer treatment. This system is very complicated because the differences between each size class require a pre-harvest assessment. The main difference between British Columbia and the rest of Canada is that BC has Riparian Management Areas (RMA) that are divided into two zones, the reserve zone and the management zone. As the name suggests the reserve zone is the inner zone of the RMA where forest harvesting is not permitted. The management zone is the outer zone and selective harvesting is permitted (Anon 1995, McCleary and Mowat 2002). The RMA, the reserve and the management zone have varying widths depending on watercourse classification. The below tables summarize British Columbia's stream, lake and wetland riparian classification systems.

Table 3. British Columbia's stream classification system with corresponding Riparian Management Area (RMA) widths (extracted from Anon 1995).

Riparian Class	Average channel width (m)	Reserve zone width (m)	Management zone width (m)	Total RMA width (m)
S1 large rivers	> 100	0	100	100
S1	> 20	50	20	70
S2	$> 5 \leq 20$	30	20	50
S3	$1.5 \leq 5$	20	20	40
S4	< 1.5	0	30	30
S5	> 3	0	30	30
S6	≤ 3	0	20	20

Table 4. British Columbia's lake classification system with corresponding Riparian Management Area (RMA) widths (extracted from Anon 1995).

Riparian Class	Reserve zone width (m)	Management zone width (m)	Total RMA width (m)
L1*	10	0	10
L2	10	20	30
L3	0	30	30
L4	0	30	30

* L1 lakes > 1000 ha require only a 10m management zone, not a 10m reserve.

Table 5. British Columbia's wetland classification system with corresponding Riparian Management Area (RMA) widths (extracted from Anon 1995).

Riparian Class	Reserve zone width (m)	Management zone width (m)	Total RMA width (m)
W1	10	40	50
W2	10	20	30
W3	0	30	30
W4	0	30	30
W5	10	40	50

If Newfoundland and Labrador is to have a management strategy system with varying buffer widths a simple, easily implemented classification system has to be defined. As seen in British Columbia there can be a great degree of variability but this comes with a cost. A system similar to B.C.'s would be very hard to implement because it requires much education, cooperation and enforcement. Obviously the 20 m buffer approach currently used in Newfoundland and Labrador is not suitable for all situations encountered while harvesting therefore a stream classification system specific to this province needs to be developed. A slope classification has been determined for Newfoundland and Labrador but there are other site specific options to consider.

The size of the watercourse is perhaps the most logical basis for a stream classification system. However, it need not be as complex as the system in British Columbia. Larger stream systems are more able to absorb the stresses incurred from forest harvesting with little change whereas smaller systems are not as resilient (Garman and Moring 1991). Potentially, this is where a riparian classification system with reserve zones and management zones would be beneficial. A reserve zone of 10 m around all headwater streams and low order streams ($\leq 3^{rd}$ order) and then a 10 m or greater management zone would prove sustainable ecologically and operationally. Larger systems would be bordered with buffers greater than 20 m but the entire buffer could be managed through selective harvesting. The critical elements for selecting a site-specific riparian zone prescription will be discussed in greater detail in a later section.

4.0 Managed Buffers of Eastern Canada

Although the boreal forest does not extend to all provinces of eastern Canada there are management regimes allowing harvesting within riparian buffers which may be relevant to Newfoundland and Labrador. This section summarizes riparian zone management from each of these provinces beginning with Nova Scotia and working west as far as Quebec. Similar to Newfoundland and Labrador, Nova Scotia regulations stipulate a 20 m buffer, referred to as a Special Management Zone (SMZ), is required on all water courses represented on a 1:50,000 topographic map including streams, lakes, ponds, marshes with permanent water openings and all salt water bodies (NSNR 1997). Streams less than 50 cm wide can be harvested to the stream bank providing machinery does not travel within 5 m of the stream. The SMZ is managed and selective harvesting is permitted within the 20 m zone but there are a number of guidelines operators must follow. These guidelines states that no more than 40% of the merchantable timber in the SMZ can be harvested in one event and at least 20 m^2 of basal area per hectare must be left standing. Canopy opening can be no greater than 15 m across and machinery is not permitted to travel within 7 m of the stream bank (DNR 1997, Duke 1997). Also, all snags within the SMZ are not to be harvested because they provide important habitat to approximately 1/3 of Nova Scotia's terrestrial organisms. An interesting point regarding forest management regulations in Nova Scotia is the retention of forest clumps within the cut block. These clumps must have at least 30 trees and are to be no farther than 200 m apart to maintain wildlife connectivity and migration routes.

Prince Edward Island is a small province dominated by farm land, but it also has riparian regulations requiring the use of buffers around all watercourses. Riparian buffers are referred to as Forested Riparian Zones (FRZ) and are 20 m or 30 m depending on slopes greater or less than 9%, the larger FRZ required along slopes greater than 9%. PEI allows selective harvesting within the FRZ and regulations detailing harvesting practices are outlined by the provincial government. Only 1/3 of live trees from two different size classes (10 - 30 cm and greater than 30 cm at the base) can be removed in a 10-year period (DAF Undated). Harvesting in these two size classes will produce a uneven-aged stand which is structurally diverse. Trees can be harvested in patches but these patches cannot be greater than 0.2 hectares in size.

In New Brunswick riparian buffers are referred to as Watercourse Buffer Zones (WBZ) and are 30 m along all watercourses draining greater than 600 hectares and 15 m along all watercourses draining less than 600 hectares (DNRE 1999, MacLauchlan 1994). Within the WBZ, 30% of the basal area can be selectively harvested in a 10-year period creating an uneven-aged forest that is structurally diverse. Canopy openings must not exceed 10 m and the operator must retain at least 50% of pre-harvest canopy cover. Machinery is not permitted within the WBZ therefore timber is removed by alternant methods such as cable logging.

In Quebec riparian buffers are considered a portion of the provinces protected areas and buffer width is 20 m along all watercourses (MRN 2002). Harvesting within the riparian zone is permitted provided the operator follows provincial guidelines that will help maintain the ecological functioning of the buffer. Within the buffer 30% of the merchantable timber can be removed although machinery is not permitted within the buffer therefore timber is manually cut and felled perpendicular to the watercourse (Hamilton 2003). This allows for easy extraction of the harvested logs with winching cables. Limiting machinery from entering the buffer minimizes the potential for soil compaction and erosion thereby reducing sedimentation into adjacent waterways.

As shown in the above examples managed buffers can be implemented for Newfoundland and Labrador but it is important to ensure that the management regime used will work here without adversely impacting the environment. Two of the eastern provinces allow machinery within the buffers while the other two do not. Newfoundland will have to determine whether or to allow machinery within our buffers. Also, how much timber can be removed from the buffer without altering its ecological functioning must be addressed. These are some issues that must be considered before a final decision can be made on a new buffer system for the province.

5.0 Objective of Riparian Zone Prescription

It is clear from the above discussion that natural forest systems are much too complex for a single buffer prescription to meet all our objectives of riparian zone management. In reality a 20 m buffer can provide too much protection to some aquatic systems and not enough protection to others. Recent research conducted in the boreal forest illustrates that a single buffer prescription is not adequate for all situations

Ecologically, a riparian zone management system that can protect all environmental components including soil, sensitive wildlife areas, and sensitive fish habitats from the adverse impacts of forest harvesting operations is necessary. The unfortunate problem with this approach is that so many different situations occur in the forest that it will be impractical to create a management plan for each specific situation. The key is to develop a riparian management system that can be effectively implemented and that mitigates the adverse impacts of forest harvesting operations in most situations. With three pulp and paper mills currently operating on the island portion of the province and a growing sawmill industry, there is an increased demand on forest resources. Therefore any new regulations must be easily implemented across the board.

Both forest harvesters and government regulators desire a riparian zone management system that is easy to implement, meets environmental objectives and maximizes the amount of timber available for harvest. The regulation and guidelines for harvesting within the riparian zone must protect the environmental integrity at a variety of different sites and allow forest harvesters to easily access timber. Complicated rules and techniques will create as many problems operationally as they attempt to alleviate ecologically. With a complicated riparian management system harvesters will have troubles knowing when to apply different buffer treatments and managers will have difficulties enforcing the rules and regulations.

Based on the above discussion of riparian areas and how they are managed in this province and in other areas of the country, we can consider a new system for Newfoundland and Labrador. Two questions need to be addressed: 1) What type of classification system is appropriate for this province and on what basis will we determine the width of riparian zones? and 2) How will we determine the type and amount of timber of timber harvesting allowed within the riparian zone?

6.0 Site Specific Riparian Zone Prescription

Forest harvesting within riparian zones is a management regime that is practiced in all other provinces of Canada. To properly implement such management in Newfoundland and Labrador all site specific aspects must be researched and understood so that harvesting within the riparian zone can be done effectively and efficiently with minimal impacts to the surrounding environment. Each area within the natural environment is different therefore all site-specific aspects should be incorporated to ensure environmentally sound harvesting techniques. All aspects and recommendations below are based on a 30% basal area removal from the riparian zone to be consistent with other riparian management regimes across Canada. Basal area (m^2/ha) is the cross sectional area, measured at breast height, of all stems within a stand. Stand volume is more difficult to determine than basal area because it is a function of tree height, basal area and tree shape. Removing 30% of basal area from a riparian zone will minimize canopy openings, retain seed trees, and limit impacts to the forest floor and residual stand. The remaining stand will provide structural integrity to protect the regenerating trees.

Most of the Best Management Practices (BMP) developed for forest harvesting states that all cut blocks, roads, skid trail, log landings, and skid trails should be determined prior to harvesting. This is completed using topographic maps, soil survey maps, and aerial photographs. Currently in Newfoundland and Labrador harvesters must submit a 5-year operating plan to the provincial government for approval. These plans include 1:12,500 topographic maps detailing the operators intentions. Managing riparian buffers can be completed using the same process and presented in the 5-year operating plans.

Currently, there is a policy for Newfoundland and Labrador that regulates the width of buffers and the Newfoundland and Labrador Forest Service (NLFS) incorporates the objectives of the policy into the planning process. Aerial photographs are used by the NLFS to determined species composition and stand density using canopy closure. This information, in conjunction with detailed topographic maps, allows the NLFS to pre-determine widths of riparian buffers. Prior to harvesting the operator can determine the amount of each species that can be removed from the riparian zone. Soil survey maps can be used to determine the type of equipment and felling can be used in and around the riparian zone. Wind is another issue that could be addressed prior to harvesting. Pre-dominated winds in Newfoundland and Labrador are westerly but there are many alterations caused by topography and geographic location. The majority of the riparian prescription should be designed prior to harvesting so that operators comprehend the undertaking before harvesting begins. Below is a detailed summary of each parameter which has to be considered when considering harvesting timber from riparian zones.

6.1 Species Composition

Newfoundland and Labrador is covered by 22.5 million hectares of forest comprised predominantly of softwoods (91%), mixed stands (8%) and hardwoods (1%) (Anon 2002). Softwood species are primarily Balsam Fir (*Abies Balsamea*) and Black Spruce (*Picea mariana*) with pines and other species of spruce present at lesser amounts. Black spruce and balsam fir can form pure stands or mixed stands depending on size characteristics and forest succession. Birch can also a common species dispersed within mixed forest stands in Newfoundland and Labrador. Pure stands tend to be even aged while mixed stands can vary between even and uneven aged forests. The question challenging forest managers is whether to use the same harvesting technique for each type of stand or develop a slightly different technique for each condition.

Pure stands are desirable for the harvesters because all trees are of uniform size, condition and age allowing for easy harvesting. The main problem is pure stands are less resistant to disease, insect damage, and other natural impacts such as winds. Insect damage is a major issue with pure stands because epidemics which target one particular species can cause severe damage to a pure stand of the target species. Currently, the provincial government of Newfoundland and Labrador participates in the Canadian Forest Service insect control programs to limit the populations of hemlock looper and the balsam fir sawfly. These two insects have caused severe defoliation of balsam fir and black spruce in the past.

Recent studies in western Canada have suggested that forest harvesting should been managed with the underlying goal of mimicking natural disturbance in the boreal forest (Work et al. 2004, York et al. 2004). In most instances natural disturbances do not lead to complete removal of all trees in a stand therefore forest management should strive to produce the same conditions. When natural disturbance such as an insect epidemics, fire and wind influence an area it leads to mixed stands because all different species are impacted therefore biodiversity is maintained. In the boreal, balsam fir has a high vulnerability to causes of mortality such as defoliators and wind and as a results is less resilient than black spruce (Pham et al. 2004). It stands to reason that mixed stands of balsam fir and black spruce will withstand natural disturbances better than a pure stand of balsam fir. Wang et al (2002) found that root structure is increased in mixed stands therefore mixed stands are more resistant to wind event than are pure stands.

In mixed species forest there is reduced competition within the stand because each species differs slightly in their needs for survival. This leads to a more productive forest because all species are thriving. Forest policies in British Columbia recommend that harvested areas are replanted with a mixture of tree species regardless of the initial stand composition because mixed stands have greater biodiversity therefore greater productivity (Chen et al. 2003, Chen et al. 2002). Pham et al. (2004) found that in mixed stands of balsam fir and black spruce the removal of a balsam fir tree leads to the regeneration of a black spruce and vice versa therefore maintaining biodiversity of the stand. In a single species stand a removed tree is replaced by the same species.
Riparian zones can be pure stands or mixed stands so if Newfoundland and Labrador is going to implement a managed buffer harvesting regime it is important to develop a environmentally sound harvesting technique. Newfoundland and Labrador is dominated by evened-aged forest therefore harvesting within riparian zone should create uneven-aged stands. A series of selective harvesting within riparian zones would create a two-aged or three-aged structure which is the definition of an uneven-aged stand (Smith and Exine, 2002). Uneven-aged stand are produced by small-scale natural disturbances or selective harvesting and are the most forgiving stands ecologically (Raunikar et al. 2000).

In Newfoundland and Labrador's boreal forest mixed forest are dominated by balsam fir and black spruce with other species distributed throughout. In mixed buffers removal of older trees that are a risk to wind or insect damage should be removed during harvesting regardless of species. Leaving all healthy trees will maintain buffer integrity. As stated above Pham et al (2004) found that in mixed forest of black spruce and balsam fir the remove of one species leads to the regeneration of the other species. Harvesting will alter the composition of the stand but will maintain stand diversity.

In Newfoundland and Labrador balsam fir and black spruce are the most economical species because they are used for paper production. Other species present in the riparian zone, such as birch should remain uncut. Leaving these species uncut will maintain canopy cover thereby increasing regeneration potential of balsam fir and black spruce because these are shade tolerant species (Hosie 1990).

6.2 Stand Age

Even-aged and uneven-aged stands can be treated similar to pure and mixed stands. Even-aged stands are often the product of large scale natural disturbances or clear-cut harvesting (Tappeiner et al. 1997). Harvesting should be performed to replicate small-scale natural disturbance events such as windfall especially in riparian zones and other environmentally sensitive areas. Even-aged riparian zones are easily managed by simply removing 30% of living trees. This will create canopy opening which will lead to the regeneration of shade tolerant saplings present in the understorey.

Uneven-aged riparian zones do require a management technique to ensure sustainability of the stand after a harvest event. To harvest trees from an uneven-aged riparian zone a classification of trees could be used. The easiest system to implement is a size classification because the size of the tree is positively correlated to tree age. Using diameter at breast height (dbh) or basal diameter are two classification methods that can be used to determine which trees to cut. Within the uneven-aged stands young trees should not be harvested because these will replace the mature trees removed by harvesting.

In Prince Edward Island riparian management states that 1/3 of live trees from two different size classes can be removed from the riparian zone during a harvest event (Decker 2003). The two size classes are 10 - 30cm and greater than 30cm at the base. Unfortunately, this method would be difficult to implement in Newfoundland and Labrador since selective harvesting will only be conducted along the outer portion of the riparian buffer. Removal of large, older trees that are more susceptible to windfall will protect buffer integrity and will maintain age structure within the riparian zone.

6.3 Stand Density

Stand density is an important variable among stands because it can determine the health and viability of trees. Mortality of an individual within a stand is often caused by the competition for available light, water and nutrients. Theoretically, stand density is limited by these parameters regardless of available crown space (Barnes et al. 1998). There is a strong relationship between stand density and the tree size. For example, Makinen (1999) found that the number of branches per tree increases as stand density decreases. Larger trees occupy more space therefore there are fewer stems present in a stand and vice versa for smaller trees. As a stand develops, competition and mortality increases leading to a decrease in stand density. Although stand density decreases the tree volume increases because larger trees are present within the stand.

In Newfoundland and Labrador forest management practices have addressed stand density through pre-commercial thinning practices. Saplings grow very fast in dense populations due to the protection provided by neighbouring saplings. After approximately 8-10 years the growth rate steeply declines therefore thinning the number of trees per stand as a young age will lead to larger trees because of reduced competition (Woodruff et al. 2002). A possible management perspective for riparian zones with a high stand density dominated by smaller diameter stems is removal of more trees than in a low density stand with larger diameter trees. The removal of small trees in the high-density stand will reduce competition and mortality potentially leading to increased growth within the stand. Small trees have fewer branches and crown therefore removal will also limit canopy openings. Maintaining a 30% removal in riparian zones would mimic pre-commercial thinning or "self-thinning" thereby leading to increase growth of remaining stems. Self thinning is a natural process where less competitive stems die off and allow the more resilient species to prosper (Woodruff et al. 2002).

In low density riparian zones there are fewer stems with large crowns and these areas should be treated differently to ensure viability of the riparian zone. Removing fewer stems in a low-density stand should be considered to limit canopy openings to less than $10m^2$. When one tree is harvested a large canopy opening is produced thereby changing the integrity of the stand. The potentially large opening produced when trees are removed from a low density stand may also lead to increased wind damage. Large trees have greater roots structures (Wang et al. 2002) which greatly increase the soil stability therefore a high removal harvest in a low density riparian zone could potentially lead to mass wasting and excessive sedimentation within the watercourse.

Table 6. Alternating riparian prescriptions for increasing stand density.

Stand Density	**Riparian Prescription**
Low Density (fewer large stems)	Selectively harvest that creates canopy openings no greater than $10m^2$.
Medium Density	Selective harvest until 30% of basal area is removed or canopy opening of $10m^2$ are produced, whichever comes first.
High Density (many small stems)	Removal of 30% of basal area from riparian zone to mimic self-thinning. Selectively cut less competitive stems allowing healthy stems to flourish.

After trial operations occur a more precise system could be determined so that as stand density increases so does the permitted harvest rate within the riparian zone. If a stand is very dense with small diameter stems then the harvest rate could be as high as 40% while in low density sites with relatively fewer large stems the harvest rates would be much lower at 10%. Measuring stand density would become a part of developing annual operating plans (AOP) as part of forest management in Newfoundland and Labrador.

6.4 Wind Damage

Wind causes considerable damage to residual stands after a harvest event. Riparian zones bordered by clear-cuts are particularly susceptible to wind damage because edges have no protection from winds. Root and butt rot is usually the causal factor leading to windfall and mortality of residual stands (English and Warren 1999) therefore older stands have more instances of windfall (Whitney et al. 2002). Older trees often become uprooted by the wind thereby increasing the amount of exposed soil that may enter into neighbouring watercourses (MNR 1996b). There are many parameters that influence windfall other than stand age. Tree species, pre-dominant wind, and topography all play role influencing windfall.

Of boreal species, balsam fir is the most susceptible to wind because of its shallow roots (Pham et al. 2004, Ruel et al. 2001). In 20 m unthinned riparian buffers, Ruel et al (2001) found windfall mortality in balsam fir reached 19.6% of the number of stems followed by black spruce, white spruce and paper birch at 11.1%, 5.3% and 4.0%, respectively. The same study revealed that there was no significant difference between thinned and unthinned buffers. Also, buffer width was not considered at factor for reducing windfall percentages. Observations in Newfoundland and Labrador suggest that the majority of windfall occurs along the outer edge of the riparian buffer (Decker et al. 2003).

Topography is a definite factor influencing the amount of windfall which occurs in any given area. The majority of windfalls occur at the top of hill while valleys are often protected from strong winds although wind speeds can increase significantly if they run parallel with the valley. This forms a wind tunnel thus topographic can strongly increased by the pre-dominant winds. After a clear-cut harvest the edge of the riparian buffers form very abrupt solid bodies that forces airflow upwards thereby increasing wind loading. Healthy trees are uprooted while older trees often crack at the stem where butt rot has weakened the stem.

Although topography and winds do influence windfall tree species is perhaps the key factor to apply a riparian zone prescription. Early hypothesis suggested windthrow would decrease with increasing buffer zones but Steinblums (1978) study found that up to 78% of a residual stand blew down regardless of buffer strip. However, managing buffers should not disregard winds and topography. Riparian buffers which are perpendicular to predominant winds should be managed differently that buffers which are parallel to predominant winds. Perhaps removal of only 15% should be permitted within buffers perpendicular to predominant winds. Also, older trees should be removed from these buffers because they are the most susceptible to windfall because of root and butt rot. Older trees which fall due to winds have the potential to damage or fell neighbouring trees thereby further reducing the number of standing stems within the riparian zone. If harvesting does occur in riparian zones it is essential that the operator does so to limit the amount of residual stand damage.

Wind damage is of particular interest in Newfoundland and Labrador because the province is dominated by balsam fir which is very susceptible to wind due to shallow roots (Pham et al. 2004). This is where riparian zone management will play the biggest role in reducing windfall. Riparian zones dominated by pure stands of balsam fir should be managed differently than pure stands of black spruce or mixed stands. Spruce is less susceptible to windfall because it is associated with wetter soils which act as a better anchor for roots (Huggard et al. 1999, Hosie 1990). In stands dominated by balsam fir the removal rate should be between 15% and 20% to retain enough trees to maintain wind stability (Stathers et al. 1994). In evenly mixed stands or pure stands of black spruce, 30% of the basal area can be removed during a harvest event as long as the harvest is consistent with other aspects mentioned above. Excessive thinning should be prohibited because it increases the roughness of the crown thereby increasing the potential for windfall.

Managing the buffer edge to absorb and deflect wind will increase the wind tolerance of the riparian zone (Stathers et al. 1994). Wind absorption at the buffer edge is achieved by producing feathered edges, uneven-aged stands and removing all trees with visiable stem and root decay. Also, the operator should avoid producing large canopy gaps within the buffer which will increase canopy roughness. This will create a strong, healthy buffer that is able to filter and absorb high winds. Deflecting winds over the top of the buffer will also increase wind tolerance. Maintaining understory along the edge of the buffer will deflect winds upwards and away from interior trees. The canopy should be smooth and arc-shaped to allow wind to travel over the buffer with few obstructions. Large trees at the edge of the buffer should be removed to achieve this goal. In Newfoundland and Labrador, spruce are more wind tolerant than balsam fir therefore the edge should be managed to selectively harvest more balsam fir from the buffer edge. The key is to maintain as many wind-firm trees within the riparian zone.

6.5 Site Condition

There are many site specific limitations which occur when managing a forested area. Often slopes are too steep or rough for machinery to travel and safely harvest therefore the riparian zone is much wider than the prescribed 20m. Slope and soil type are the most important parameters that limit harvesting. Currently in Newfoundland and Labrador buffer width is to be increased if the slope exceeds 30%. In this situation the formula used to determine the buffer width is 20m plus 1.5 times the slope (%) (Table 1). The buffer width is increased as the slope increases to protect the adjacent watercourse from excess sedimentation that may potentially occur on slopes when soil stability is altered due to removal of vegetation. Maintaining this system and not managing buffers with slopes greater than 30% will protect water resources in this province. Any timber removed from the riparian zone will increase the potential for increased sedimentation. Grosse (1989) reported that sedimentation rates increased 30 to 300-fold once an area is roaded and harvested. This sedimentation increases proportionality with increasing slopes. France (1997) found greater soil loss from experimental harvest blocks as slope increased. The control site (no harvest) had the least soil losses while clear-cuts had the greatest proportion of soil loss. Soil losses for partial harvest site averaged between the clear-cut site and control site.

Riparian areas dominated by dry soils will have to managed differently from areas dominated by wet soils. Wet soils are more prone to compaction and rutting by heavy machinery which alters the drainage and seepage of the area (OMNR 1991). This may lead to increased sedimentation into neighbouring watercourses. Riparian zones dominated by wet soils should not be harvested. Dry and rough soils are less susceptible to compaction and rutting than are wet soils therefore using heavy equipment to remove timber would be acceptable. Many management plans from central and western Canada states that harvesting operations can occur in riparian zones on dry or frozen soils. A major obstacle with implementing this in Newfoundland is frost often does not extend deep enough into the soil to support the weight of heavy machinery.

Table 7. Guide for assessing site susceptibility to soil erosion (modified from DNRE 1999).

Item Affecting Soil Erosion Hazard	**Site Susceptibility to Soil Erosion**				
Texture	Gravel 0	Sand/Loam 1	Loam/Sand/ Clay 3	Silt & Clay 5	Silt & Fines 6
Depth to Impermeable Layer	> 100cm 0	70 - 100cm 1	50 - 70cm 2	30 - 50cm 4	< 30cm 7
Slope	0 - 15% 0	16 - 30% 3	31 - 45% 6	46 - 70% 10	> 70% 15
Drainage	Rapidly Drained 0	Well Drained 1	Moderate Drainage 2	Imperfectly Drained 3	Poorly Drained 4

Table 3 was developed and implemented by the New Brunswick Department of Natural Resources and Energy in 1989. Point values for the above table are related to compaction and erosion hazards, the higher the points value the greater potential for soil erosion. A value 0-2 is a very low hazard, 3-5 is a low hazard, 6-11 is a moderate hazard, 12-19 is a high hazard and 20-32 is a very high hazard. These values could possibly be determined prior to harvesting without a site assessment using information available from previous geological surveys. A value could be set for each area and the management regime implemented to suit the site conditions. Moderate, high and very high values could mean the riparian zone should be managed using the reach-in method or with manual felling and cable winching timber out of the buffer zone. Very low and low value sites could allow inserting machinery into the buffer to allow easy access to merchantable timber.

6.6 Harvest Season

Forest harvesting in Newfoundland and Labrador occur year round but there are some restrictions due to the winter season. Excessive snow depths tend to limit forest harvesting machinery during the winter months. However, harvesting during the winter months limit potential soil compaction and rutting caused by harvesting equipment. Unfortunately, winter harvesting does increase stump height because trees are harvested at the snow height rather than ground level. Fall and spring months tend to be the wettest periods of the year and can potentially increase the adverse effects of forest harvesting such as soil compaction, soil rutting, and sedimentation and siltation to neighbouring watercourses. All these aspects will play a role in the management of riparian zones.

Managing riparian buffers will require alternate treatments for different seasonal conditions. It is important to maintain the ecological functioning of the riparian zone so that the natural environment is protected from the potential impacts of forest harvesting. Harvesting within riparian zones during the summer months can be performed using a reach-in method or the insert method. In this method the wheels of the harvester remain outside the riparian buffer while the cutting arm reaches in and selects a tree from the riparian zone. The arm can reach between 6 - 8m in the buffer. Trees can be removed from the remainder of the buffer using manual felling and cable winching. This is a more labour intensive method but it will protect the buffer zone from the adverse impacts of heavy equipment. The insert method allows equipment to enter the buffer via shallow openings (< 5m). This method can be employed during the summer months in areas dominated by larger stems with good soil conditions. It is also important to protect the residual stand from being damaged during the harvest event. Residual stand damage may be most severe during the period of peak sap flow because this is when bark is most easily removed. The operator should strive to minimize residual stand damage to less than 5%.

During the winter months a more direct approach to managing riparian buffers can be employed. When the ground is snow covered the operator can create a shallow opening (< 5m) into the edge of the buffer and insert the harvester into the opening. This will allow the mechanical harvester arm to reach further into the buffer and treat the majority of the 20m riparian zone. The harvesting equipment will not cause soil compaction or rutting because it will occur on top of the snow therefore there is less potential for sedimentation or siltation entering the watercourse during spring runoffs.

Potential adverse affects caused by forest harvesting may be elevated during spring and fall months because these are the wettest periods of the year. Avoiding all disturbances within the riparian zone during these months will decrease the likelihood of excessive soil compaction and sedimentation associated with forest harvesting operations (Archibald et al. 1997). In late fall there is the potential to harvest the riparian zone prior to snowfall. Harvesting could occur when the ground is frozen so that there is limit damage incurred to the soil and forest floor. Many other provinces in Canada allow harvesting within riparian zones on frozen soils but a major problem implementing on the island portion of the province is the soil rarely freezes prior to snowfall. The surface soils tend to freeze but the frost does not extend deep enough to support the heavy equipment used during a harvest operation. To ensure this riparian prescription can be easily adapted to forest harvesting operations it may be best to avoid harvesting within riparian zones when climatic conditions have increased soil wetness such as spring melt and heavy fall rains.

6.7 Variable Buffer Width

The majority of the above prescriptions have been for a 20m riparian buffer which is regulation in Newfoundland and Labrador but in reality riparian buffers often vary up to 100m and greater in some areas due to other factors. Different levels of management can be applied to varying buffer widths. For buffers measuring 20m, following the above prescriptions where applicable should allow a compromise between obtaining merchantable timber resources and protection of the natural environment.

For riparian buffers with widths between 20m and 60m a different level of management can be used to remove timber while maintaining the integrity of the buffer. Inserting machinery into the riparian zone can help access the timber within these larger buffers. The machinery tires should not travel within 20m of the watercourse and timber can be removed with the harvester and with the aid of cable winching. Brush matting should be used for the machinery to travel over in areas with wet soils that can easily be compacted and rutted. The inserts will also mimic feathered edges and potentially increase wind firmness of the stand.

Creating a narrow skid trail or "ghost" trail parallel to the watercourses with buffer widths greater than 60m would allow the operator access to merchantable timber with minimal impact to the riparian zone. All ghost trails should be at least 30m from the watercourse. Timber within the riparian zone could be cut by manual fellers and cable winched to the ghost trail. Brush matting would be required on wet soils to limit potential impacts.

6.8 On-site Harvesting Equipment

The development of the above riparian prescriptions incorporates the use of on-site equipment to allow for easy implementation of the proposed prescriptions. In Newfoundland and Labrador, the majority of forest harvesting is conducted using single-grip harvesters and, to a lesser extent, feller bunchers. In most instances the above prescriptions have been developed to harvest timber using the reach-in method or the insert methods. Both of these harvesting techniques can be achieved using either the single-grip harvest or feller buncher. When using the insert method to harvest a buffer, the operator should insert equipment on brush matting to limit soil compaction and potential erosion from the riparian zone. In buffers greater than 60m a ghost trail can be created for timber removal. In this situation a narrow skidder or forwarder could be used to extract harvested timber. Ghost trails should not travel within 30m of watercourse. Careful handling of equipment will limit the amount of residual stand damage which should be less than 5% after a harvest event. If available, machinery equipped with dual tires or wide (or high flotation) tires should be used to help displace the weight of the machinery thereby limiting disturbance to the ground (Blinn and Dahlman 1995).

All harvesting within the riparian buffer should be performed during the initial harvest event to reduce the number of times heavy equipment is required to travel over the cut block. Manual felling toward the watercourse and cable winching the timber out of the riparian zone using synthetic fibre mainlines will limit the amount of soil and residual stand damage and is perhaps the most ecologically sound manner to remove timber from the riparian zone. Keim and Schoenholtz (1999) found that cable logging in riparian buffer is effective at controlling Total Suspended Solids (TSS) entering neighbouring watercourses. Unfortunately, manual felling operations are less safe because the operator has less control on the felling direction of the tree.

6.9 Multi-Use Values

Careful forest harvesting within riparian zones should maintain important habitat features to accommodate terrestrial wildlife. Managed riparian buffers will continue to function as wildlife corridors for dispersal, provide sheltered habitat, and provide a food source for terrestrial organisms. Potentially harvesting within riparian buffers may increase productivity of flora by increasing canopy openings. Many plant species present in the riparian zone have little opportunity to flourish because they are shade intolerant. Once a tree is removed and a canopy opening is produced plants in the understorey has the opportunity to fill in the gap (Canham et al. 2001). This increases the structural diversity of the riparian zones.

In theory increased structural diversity leads to increased biodiversity. A study from Labrador showed that there was an increase in avifauna species in areas impacted by 30% removal from old growth forest because there was enough old growth forest and canopy openings to support both interior birds and birds depended on early successional forest conditions (Simon et al. 2000).

Unfortunately, other than avifauna, little work has been conducted in the boreal forest to quantify the use of riparian buffers as habitat and corridors for terrestrial organisms.

Riparian buffers can potentially become an ecological trap for terrestrial organisms. When forest are removed many interior species seek refuge in riparian zones therefore it becomes good hunting grounds for predators (Vander Haegan and DeGraaf 1996). A riparian zone that is 60m width and 1.7km long is equivalent to 10 hectares of forest therefore there is little space for displaced terrestrial species (Potvin et al. 1999). Many studies have suggested that wider buffers will support more species (Hannon et al. 2002, Metzger et al. 1997) but the buffer still acts as an ecological trap for species.

Managing riparian buffers will require some knowledge of sensitive or unique habitat requirements for species. Interior species do not utilize cut block therefore it is important not to create large openings within the riparian zone. The proposed prescriptions, if followed, will limit the size of the openings therefore accommodating species more suited for interior forest. Forest harvesting will have an impact on terrestrial organisms because it removes habitat but attempting to minimize the impact is crucial. For example, limiting the size of clear-cuts and increasing the number of clumps maintained in cut blocks may facilitate terrestrial organisms if harvesting within riparian zones is approved. Also, not harvesting in key habitat for endangered or threatened species such as pine marten may help maintain these populations.

7.0 Summary of Riparian Prescriptions

Below is a table of summary points that should be considered prior to implementing a management plan for riparian buffers in Newfoundland and Labrador. Some of these points reflect current management regimes being used in other parts of Canada while others are based purely on scientific literature. The majority of the issues below can be assessed prior to harvesting and can be included in the annual operating plans. Operators harvesting within riparian buffers should adhere to the following;

Table 8. Summary of prescriptions developed for harvesting within riparian zones in Newfoundland and Labrador.

Site-Specific Characteristics	Fir	Spruce	Mixed Stands
All Areas	30% removal of basal area (BA) unless otherwise specified.		
	Residual strand damage should be less than 5%.		
	Canopy openings less than 10m^2.		
	Machinery not permitted within 5m of watercourse.		

Site-Specific Characteristics	**Fir**	**Spruce**	**Mixed Stands**
Dry Sites	30% removal of BA using reach-in or insert method.	30% removal of BA using reach-in or insert method.	30% removal of BA using reach-in or insert method. Remove older, balsam fir trees first due to susceptibility to wind.
Wet/Sensitive Sites	Limited harvesting using either reach-in method or manual felling with cable winches. Harvesting during winter months will limit soil damage. See Table 4.		
Wind Influenced Areas	Removal 15-20% of older, less wind-firm trees.	Removal of 30% of BA producing feathered edges.	Removal of 30% of BA maintaining all wind-firm trees such as healthy spruce.
Age	Remove oldest, less wind-firm trees. Snags remain standing due to their importance as habitat.		Remove older, balsam fir trees first due to susceptibility to wind. Snags remain standing due to their importance as habitat.
Slope	No harvesting permitted on slopes greater than 30%. Operators should adhere to current provincial guidelines which determine increasing buffer width with increasing slope.		
High Density Stands	30% removal of BA using reach-in or insert method. Mimic pre-commercial thinning operations.		30% removal of BA using reach-in or insert method. Remove older, balsam fir trees first due to susceptibility to wind.
Low Density Stands	Harvest rate should be reduced to limit canopy openings to less than $10m^2$.		Harvest rate should be reduced to limit canopy openings to less than $10m^2$. Remove older, balsam fir trees first due to susceptibility to wind.
Buffers 20 - 60m	Harvesting equipment can enter buffer via narrow inserts perpendicular to watercourse. Equipment not permitted within 20m of watercourse.		

Site-Specific Characteristics	Fir	Spruce	Mixed Stands
Buffer 60m +	Narrow skid trails or "ghost trails" parallel to watercourse will allow harvester to access timber. Ghost trails should be 30m from watercourse and brush matting should be used on wet, easily compacted soils.		
Equipment	On-site harvesting equipment such as single-grip harvesters and feller bunchers can be used for both the reach-in method and insert method to access timber. Inserted machinery should be on brush matting to limit potential soil compaction and erosion. In sensitive areas, manual harvesting with cable winching should employed. Machinery not permitted with 5m of watercourse.		

8.0 Post Harvest Monitoring

Post harvest monitoring should be considered for the first couple of years after harvesting riparian zones is implemented. This will ensure the proposed prescriptions were followed by the operator and the area is left in reasonable condition with little residual stand damage within the riparian zone. Also, post harvest monitoring would ensure managed buffers are protecting the integrity of the riparian zone and terrestrial and aquatic ecosystems. Post harvesting monitoring could include amount of windfall, sedimentation rates within watercourses, and condition of the remaining stand. An assessment of regeneration within the managed buffer could also be included in a post harvest monitoring program.

9.0 Conclusion

The removal rate of 30% from the riparian zone was chosen to be consistent with other provinces and territories across Canada. This is a precautionary approach that should be used in Newfoundland and Labrador until further studies can suggests a more appropriate harvest rate. Due to the variability within the natural environment it is difficult to protect systems from the potentially adverse effects of forest harvesting with the one riparian regulation which presently exists in Newfoundland and Labrador. Therefore all aspects of an area must be incorporated into a managed riparian prescription. The prescriptions presented above can be determined prior to harvesting and therefore should allow implementation of the prescriptions with relative ease. The main goal of the above prescriptions is maintain adequate protection to both the terrestrial and aquatic environments. All stakeholders involved in the process want to maintain the integrity of the natural environment while optimizing the potential of the natural resource.

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