Centre technologique des résidus industriels

Impact of Forest Practices on Fish Habitat

STUDY REPORT PREPARED FOR THE WASWANIPI CREE MODEL FOREST

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ABSTRACT

Fishing is a key element in the lifestyle of the Waswanipi Crees. Given the extent of forest activities in the territory, assessing their impact on fish habitat and suggesting conservation-minded management strategies have become a necessity. The fish species that are aimed specifically in this study are: walleye, lake sturgeon, northern pike, lake whitefish and brook trout.

Cree fishermen were met in order to gather information on observed forestry impacts on the territory. It appears from this consultation that forest operations significantly disrupt fish habitat and the lifestyle of Cree fishermen: direct disturbances (water crossing structures, logging operations near watercourses, impairment of water quality) and indirect disturbances (increase in access and fish-catching).

A summary of scientific knowledge on the effects of forest activities on fish stocks points out the same impacts. The main element of disturbance for the aquatic ecosystem is the forest road network. The construction, maintenance and degradation of forest roads and water crossing structures are detrimental to the free mobility of fish populations, and destroy fish habitat and spawning areas. They also provide easier access to the resources, thus resulting in a stronger pressure on fish stocks, whose habitat is disrupted already. Maintenance of riparian forest buffer areas proves an essential component of fish habitat preservation. It contributes to the retention of the physicochemical quality of water, and provides shelter and structure to fish habitat in watercourses and lakes. Windthrow in riparian buffer strips is a serious problem that land managers must tackle. Other major impacts of forest operations arise where logging is carried out in a large portion of a watershed: water flow regime changes and peak flows increase, thus causing erosion; water quality changes, the aquatic fauna and flora may alter with environmental changes, thus affecting fish populations, which feed on those aquatic organisms. Finally mercury concentration in fish exceeds that in lakes where the watershed has undergone extensive logging operations compared to lakes where the watershed has not.

The territory of the Waswanipi Crees does not escape from forestry-caused disturbances. An analysis of maps have allowed to highlight the high density of the road network in the southern part of the territory under study; the roads are designed with many water crossing structures that may have led to the degradation of fish habitat and hindered fish mobility. Furthermore extensive harvesting operations have taken place in that very same sector; those activities have possibly affected the physicochemical quality of water and increased the mercury level in fish caught by the Crees. Finally it is possible that a very significant increase in access to fishing territories have resulted in a stronger pressure on fish stocks and caused a reduction in fish populations.

The *Draft directives on the protection and management of wildlife habitats on the territory of the Agreement concerning a new relationship between le gouvernement du Québec and the Crees of Québec* suggest fine recommendations for the protection of fish habitat. The directives chiefly recommend protecting the spawning areas, widening sloped riparian strips, and applying sound practices with respect to choice and construction of water crossing structures. To these are added the following recommendations to preserve or restore fish habitat:

- Roads:
  - Plan the road network in such manner as to keep water crossing structures and water access to a minimum;
  - Consult the tallymen concerned and make sure there is no spawning area prior to proceeding with the installation of any water crossing structure;
  - Repair damaged or obsolete structures to prevent habitat disturbances.

- Riparian areas:
  - Protect the riparian areas of small permanent streams better; do not harvest in the 10 m zone adjacent to these watercourses;
  - Keep windthrow in riparian strips to a minimum, in particular near spawning areas (some means are proposed).

- Harvesting
  - To preserve water quality, avoid peak flow increases, and keep mercury accumulation in fish to a minimum; make sure the deforested area never exceeds 50% of the equivalent cutting area (ECA) of the watershed and sub-watersheds.
  - Keep rutting to a minimum, and apply corrective measures in case of rutting occurrences;
  - Avoid disturbances in wetlands.

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The first part of this document reports on the results of the workshop attended by a few Cree trappers. The workshop aimed to learn more about forestry impacts on fish habitat. The Cree trappers voiced their observations about fish habitat changes related to forestry operations. The second part of the document completes the portrait of the situation by consolidating scientific knowledge about forestry and fish. The third part briefly examines the territory of the Waswanipi Crees and identifies major threats to fish populations in the region concerned. The last part of the document lists recommendations elaborated to improve forestry practices and preserve fish populations and habitat.

CREE KNOWLEDGE ABOUT FORESTRY IMPACTS ON FISH POPULATIONS

1 MEETINGS

Several meetings were held in Waswanipi with a view to hear the concerns of Cree fishermen and tallymen about fish and forestry. Informal discussions with the Forestry Department and the Cree Trappers Association provided basic information. A subsequent workshop on fish habitat highlighted a series of forestry impacts on fish. Four Cree trappers participated in the workshop, which was directed by the researcher and a co-researcher of the Waswanipi Cree Model Forest.

2 DATA GATHERED

Fish is a key element in the Cree way of life. It is used all year long, chiefly in the summertime. Besides being a food commodity, fish is used as a trapping bait or lure.

The impacts raised in the meetings can be classified by themes. No statistical study was conducted after the meetings. The following text gives a review of the impacts raised at the meetings.

2.1 Forest road network

Water crossing structures stand out by being very disturbing to fish habitat for their direct and indirect impacts in many different ways.

2.1.1 Direct destruction of habitat

It is essential to mention that water crossing structures are often built where essential fish habitats are situated. They are intentionally erected at the narrowest points of water bodies and streams. Where streams are concerned, the narrowest points correspond to areas where water flows fastest and important spawning areas for walleye, sturgeon and brook trout are located. As regards lakes, the narrowest points often correspond to holes or deepwater spots, where fish gather. Of course those fishing spots are of great interest to the Crees. The tallyman should be contacted so as to ensure there is no spawning area or any other important habitat at planned water crossing sites.

2.1.2 Erosion- and sedimentation-related habitat disturbance

Installation, maintenance and abandonment of culverts cause sedimentation in water streams. Significant sediment increase adversely affects spawning areas downstream from watercourses. Sediment can smother spawning areas and other fish habitat. Culvert destruction due to washout or other causes may bring streambed to slide on either side from its original position, thus affecting fish populations and their predators. In spring, debris obstruct poorly designed culvert pipes and ultimately cause floods.

The passage of cars and heavy vehicles produces fine sediment accumulation (dust) in stream, which are suspected to affect fish.

2.1.3 Barriers to fish migration and mobility

Culverts often hinder fish mobility by blocking their way to habitat (lakes, rivers, spawning areas) located on the other side of water crossing structures. Sometimes the culvert pipes become completely blocked (e.g. beaver dams); sometimes if poorly designed, fish can't swim across the culvert because the water level is either too low or too high.

Water crossing structures can also cause spawning area displacement. Spawning areas upstream from culverts and no longer accessible to fish populations can lead them to spawn in proximity to water crossing structures. There are many negative aspects associated with such situations: 1) unsure sustainability of the new spawning area (culvert instability); and 2) direct access of fishermen (Native or non-Native) using new forest roads to new spawning areas. Fish therefore become vulnerable and, as matter of fact, more prone to hook injuries.

2.1.4 Fishing intensity and disturbance increase

Road network development gives rise to fishing intensity increase. Easier access fosters fishing in lakes, streams and rivers near water crossing structures or in boat facilities. Fish populations in such areas are smaller and hook injury prone.

Enhanced access to lakes and rivers draws a larger number of boats. Sometimes people who simply want to ride their boat for fun actually disturb fish in a significant period of their lifecycle (e.g.: spawning period).

Water crossing structures near spawning areas disturb fish spawn. Heavy vehicle noise disturbs fish in the spawning period. Lake sturgeon is very sensitive to noise.

Forest operations are noisy. The Crees interviewed think that forest operations near spawning areas should not be allowed in the spawning period. Riparian buffer strips are too narrow to ensure water tranquility.

With the laws presently in force, the Crees are unable to control access to their trapping territories.

2.1.5 Mobility of Cree people

Culverts cause prejudice to the Crees, for they cannot operate their boat freely on water streams and need to carry them to the other side of culverts. Culverts made of huge pipes but crossable by boat are not as harmful. Bridges and arched culverts are more acceptable and not as much a barrier to fish and Cree mobility. Temporary bridges to be removed after logging operations prove an interesting solution that satisfy some tallymen because they limit access to trapping territories. Other tallymen however prefer having access to new roads brought about by permanent structures.

2.1.6 Water regime

Forest roads can be detrimental to water quality and quantity as a result of changes in drainage patterns. Forest roads can modify groundwater flows and dry wetlands.

Areas where logging has recently taken place may show a difference in water regime, with snowmelt and water discharge no longer matching in time and manner with nearby areas.

2.2 Riparian buffer strips

Riparian buffer strips are a major concern to the Crees. Consultations conducted by the Waswanipi Forestry Department reveal that all riparian buffer strips should be at least 70 m to 1.66 km wide along large navigable lakes and streams, and 40 to 60 m wide along creeks and small streams.

It is important to prevent windthrow in buffer zones. Presently wind causes windthrow in riparian buffer strips. In the long term, most trees left standing will end up on the ground.

Windthrow in riparian buffer strips have direct and indirect impacts. First, windthrow prevents Cree trappers from riding their boat on rivers. Riparian buffer strips along navigable streams should be much wider (from 70 to 100 m wide) so as to prevent windthrow occurrences. In addition, windthrow can affect adversely fish habitat with debris drawn into the water (increase in). Also, windthrow may also hinder fish mobility. Finally, windthrow can destroy spawning areas.

Clear cutting should not be carried out in riparian buffer strips. This residual forest should be left intact so that it can provide habitat and protection.

Leaving treed edges such as riparian buffer strips in large clear cutting areas opens a path to sunburned trees, a situation that leads to a reduction in insect abundance. Since several fish species feed on insects (e.g. brook trout), this situation results in a reduction in food supply.

Windthrow can have indirect impacts. Example was given of a beaver abandoning its territory after windthrow in riparian strips upstream from its dam. The trees were barriers to the beaver mobility. Now that the beaver has abandoned the dam, it will eventually deteriorate (no maintenance) with the following consequences on fish habitat: brook trout populations living upstream from the beaver dam are safe from predation by pike populations, which presently cannot swim upstream because of the presence of the dam. If the dam disappears, brook trout will be threatened by heavier predation.

2.3 Large-scale logging operations

Water quality deteriorates when the watershed of a given body of water is affected significantly by logging operations. The Crees interviewed have stopped drinking water originating from those areas, and fish from those areas no longer taste the same. Even the water has changed in color.

In large clearcut areas, rain causes more damage to the environment and soil: no trees to slow down the rainfall, more soil erosion (particularly in slopes) and irrecoverable site damages.

2.4 Rutting

In areas of intense harvesting, machinery can cause rutting of the soil. Rutting hinders the mobility of Cree trappers and probably has an impact on water movement.

2.5 Pollutants

The Crees interviewed expressed concern about water pollution due to forest machinery operation. For instance, they mentioned that oil can run off from logging areas to watercourses via intermittent creeks. They also suspect calcium discharge into water courses when maintenance vehicles spread abrasives on the roads and near water crossing structures. Ice bridges, which are no longer allowed in the Waswanipi Cree territory, also cause pollutants (oil and other wastes) to fall into watercourses.

2.6 Conclusion

As regards to impacts on fish, there is a big difference between areas undergoing or not undergoing logging. Forestry operations have major impacts on fish and fish habitat. In certain areas, the Crees interviewed no longer find fish. In most areas, now that forestry operations have begun, fish are very small and no longer taste the same.

FORESTRY AND FISH: SUMMARY OF SCIENTIFIC KNOWLEDGE

3 FISH BIOLOGY

This brief overview presents the biological aspects of the fish species targeted in this study. It serves to highlight their needs in terms of habitat and ultimately the impacts of forestry on them.

In order to meet their habitat requirements, fish must find the following five elements in their environment:

1. Spawning areas
2. Sources of food supply that can satisfy their needs at every stage of development
3. Shelters and rest areas
4. Quality water in sufficient quantity
5. Free access to the above

The following table outlines items of scientific knowledge on habitat requirements for six species covered by this study.

Table 1. Fish Biology – Summary Table

Species	Habitat	Spawning Period	Food	Movement	Threats
Lake Sturgeon (*Acipenser fulvescens*, Esturgeon jaune) (Scott and Crossman 1974; Moisan and Laflamme 1999)	Ground fish, lives in very productive areas of large lake and river shoals. Fresh- and cold-water fish species.	May or June. Water temperature ranging from 11 to 18° C. Spawning areas in rivers, rapids or areas of strong water currents. Depth: from 0.6 to 4.5 m. Hard substrate, from pea gravel to bedrock. Uses same spawning area.	Finds food in muddy bottoms or muddy/gravel bottoms, at depths exceeding 5 to 10 m, depending on food availability. Mature: mostly insect larva, mollusks and shellfish; fish, eggs, plants or seeds occasionally.	Significantly during the spawning period (about 130 km).	Exploitation and loss of habitat, particularly spawning areas, concentration zones for mature lake sturgeon and culture areas. Barriers to mobility are the main causes of habitat loss. Late sexual maturity (more than 20 yrs) and reproduction cycle (every 4 to 6 years for female) make lake sturgeon sensitive to exploitation. Given its longevity, lake sturgeon is highly prone to bioaccumulation (e.g. mercury).
Walleye (*Sander vitreus*, Doré jaune) (Scott and Crossman 1974, Hazel and Fortin 1986)	Preference: large shallow turbid lakes Photophobous fish: seeks turbid waters, deep waters or shelters. Freshwater fish.	Shortly after lake ice breaks up, at temperatures below 5°C, north of its distribution area (P.-P. Dupont, personal communication). Spawning areas in rivers, near bedrock, high flow streams. Also on wind-exposed sandy/gravel beaches. Substratum: generally clean gravel. Uses same spawning area. Depth: 20 to 180 cm.	Uses same summer feeding site. Feeds in mid-water zones. Prefers fish, but also insects, shellfish, amphibians and, small mammals.	Access to spawning areas, in rivers, is an essential condition to its preservation. Can swim up to 300 km between two spawning events (Dupont and Bernatchez, writing underway).	Spawning areas can be destroyed, deteriorated or become inaccessible due to construction of dams, excessive water level fluctuations, fine sediment deposit, timber floating wastes, and tailings release. It is important to protect walleye nursery areas; however those sites must be indexed, for they vary depending on lakes. Little tolerance to low dissolved oxygen rates. Given its longevity - more than 20 years - north of its distribution area (P.-P. Dupont, personal communication), walleye is highly prone to bioaccumulation (e.g. mercury).

Species	Habitat	Spawning Period	Food	Movement	Threats
Northern pike (*Esox lucius*, Grand brochet) (Scott and Crossman 1974, Vallières and Fortin 1988)	Clear, warm water areas of low-flow serpentine rivers with heavy vegetation; or vegetated bays of warm lakes. Fresh-water fish. Versatile and relatively tolerant.	After ice melt, in temperatures ranging from 4.4 to 11.1°C. In highly vegetated floodplains of rivers, marshes and big bays of large lakes. In general, spawning areas are located in shallow, low turbidity waters where vegetation abounds and flow is low. Juvenile northern pike stay in shallow waters of spawning areas several weeks after hatching.	Omnivorous/carnivorous. Eats live vertebrates at reach. Prefers fish. Eats in mid-water zones and water surface.	Generally prefers shallow waters in spring and fall, but swims in deep and cooler waters on hot summer days. Generally sedentary.	
Brook trout (*Salvelinus fontinalis*, Omble fontaine) (Scott and Crossman 1974)	Lives in cold and well-oxygenated streams and lakes. Seldom found in lakes of Abitibi-Témiscamingue.	Late in summer or fall, depending on latitude and temperature (3 to 13°C). Gravel bottoms, shallow waters, headstreams, in areas of source water (high-flow and well oxygenated). Depth: 10 to 30 cm. After hatching, brook trout fry remain in gravel nests until vitellus resorbs. Uses same spawning area.	Carnivorous fish. Feeds on a large variety of animals, including soil insects and water insect larva. Water bottoms, mid-water zones and surface.	Brook trout can swim upstream over several kilometers to reach spawning areas. In rivers and streams, brook trout swims downstream to larger water bodies when the temperature rises.	Very sensitive to water temperature rising and introduction of fine sediment into water stream. Very sensitive to dissolved oxygen drops.
Lake whitefish (*Coregonus cupleaformis*, Grand corégone) (Scott and Crossman 1974)	Lake fish. Cold water species.	In the fall. Generally in waters of less than 8 m deep. Often on hard or rocky bottoms, and sometimes on sandy bottoms. Lake shorelines and shoals, and often tributary rivers. Hatching takes place in spring (April or May).	Larva form schools in shallow waters along steep banks and leave in early summer. Mature lake whitefish feed mostly on the bottom; eats a wide variety of benthic insects and small fish. Certain types of lake whitefish feed in mid-water zones.	Leaves deep waters and swims to littoral waters in early spring, but returns to deep waters when water temperature rises. In fall, swims to shallow waters to spawn.	May be sensitive to shortage of dissolved oxygen in hypolimnion.

4 FISH HABITAT MODIFICATIONS

Fish habitat is strongly sensitive to disturbances, particularly in Nord-du-Québec (FAPAQ 2003). Fish populations in northern environments generally have the following characteristics: slow-growth, longevity, late sexual maturity, low fertility, longer reproduction cycle, reduced density possibly associated with lower productivity ecosystems (FAPAQ 2003). In the region, the main disturbances that have affected fish habitat are chiefly related to forest and mining operations and hydroelectricity projects (FAPAQ 2003).

In riparian environments, forest management has some influence on water ecosystems, revealed through mechanisms occurring in watersheds or near streams (Plamondon, 1993, Steedman *et al.* 2003). Logging impacts at both scales differ and their relative significance depends on the type of management and location of activities in the watershed (Plamondon, 1993, Steedman *et al.* 2003). Forest management impacts on fish habitat depend on the extent of the logging operations in the watershed, and planning method for logging operations, road construction, water crossing structure implementation and forest operations in riparian zones (Steedman *et al.* 2003). Penetration into the territory resulting from road network development is an indirect impact likely to cause an increase in fishing pressure (Gunn and Sein, 2000).

Fish habitat can be disturbed by changes in water quality and quantity, aquatic community composition, habitat structure (shelters and rest areas) and mobility barriers.

While related, forestry impacts on streams and lakes differ. While literature about forestry impacts on water streams is more abundant than on lakes, the documents consulted to conduct this study were sufficient to evaluate those impacts globally.

4.1 Watershed disturbance

Watersheds are defined as areas from which waters flow into a given body of water, including rivers, lakes and man-made reservoirs. Any modifications to areas where waters flow into a given lake or stream bring changes to water quality and quantity. Large-scale watershed disturbances due to events such as logging operations, forest fire, windthrow or tree diseases have significant impacts on the water environment.

Steedman et al. (2003) indicate that where watersheds are disturbed, changes in water quality are more important in streams, while shallow lakes with short renewal time give intermediary response and deep lakes with long renewal time give low response.

4.1.1 Water regime

Annual water flow regime can change with the retraction of part of the forest canopy in a watershed. Annual flow increases proportionately with vegetal cover reduction (Plamondon 1993). Plamondon (1993) describes peak flow modifications as changes to the water regime likely to cause heavy impacts. Peak flows are maximum flows generated by localized and short-lasting storms, long lasting precipitations, snowmelt or rain on melting snow. Important peak flows may change the bed of streams and cause erosion and sedimentation. In general, low water flows – a factor that can limit the reproductive rate of fish populations that are extremely low - are not an issue because they tend to increase after logging operations. Change in the water regime may have significant effects on fish habitat; a change in water morphology, for instance, may bring key habitat (spawning and hatchery areas) to move, and changes in peak flows – generally occurring in spring - may affect fish in the spawning period if occurring simultaneously.

Clear cutting over less than 33% of watersheds rarely disturbs the water regime. Over more than 50% of watersheds, however, clear cutting operations are likely to product peak flow increases (St-Onge *et al.* 2001, Plamondon 1993). Steedman *et al.* (2003) indicate that in small watersheds flow regime or peak flow increases cannot be detected until 25 to 50% of the watersheds are disturbed. Therefore disturbance covering 50% of a given watershed is likely to cause water flow changes and peak flow increases. The impact of disturbance on the water regime subsides in time. That is why a method has been developed to calculate the cumulative impacts of logging operations on watersheds: equivalent cutting area (ECA) (Langevin and Plamondon 2004).

Forestry impacts on peak flows are hard to forecast. One may only try to minimize forestry impacts by abiding by certain rules as regards to distribution and layout of clearcut areas in the watersheds. Say logging operations cover 30% of a given watershed: they would have more impact if carried out in the upper part than in the lower part (Eikaas *et al.* 2005). The impacts would also increase proportionately with the size of the compacted area resulting from the development of access roads and skidding trails (St-Onge *et al.* 2001). Rutting can accelerate and accentuate runoff occurrences, give rise to peak flow increases, and foster erosion (St-Onge *et al.* 2001). Rutting often disturbs water runoff patterns and eventually causes water logging. (Jutras 2004).

4.1.2 Water quality

At every watershed scale, extensive forest disturbances bring about significant changes - though temporary - on groundwater and water quality of lakes and streams. Those changes include increase in dissolved substances such as organic carbon, cation (chiefly potassium) and nutrients (phosphorous and nitrogen) (Steedman *et al.* 2003).

4.1.2.1 Nutrients

The nutrient content, particularly nitrate, in streams may increase after forest operations. Increase in nutrients may generate higher primary productivity and changes in invertebrate and fish communities. With regard to lakes, the ratio between the size of a watershed and that of a lake is proportional to the increase in nutrient concentration (St-Onge *et al.* 2001). Carignan *et al.* (2000) note an increase in total phosphorous and total nitrogen that is proportional to the extent of logging operations in the watershed of lakes. Phosphorous concentration is a determining factor in primary productivity of Canadian Shield lakes (Steedman *et al.* 2003). The nitrogen:phosphorous ratio (N:P) can influence the composition of the algae populations (Lamontagne *et al.* 2000). It is possible that an increase in nutrients due to forest operations does not accelerate primary productivity. The effect on productivity can be stopped by other forestry impacts, including water turbidity increase hindering light penetration into water (Planas *et al.* 2000). Time required to return to initial conditions is correlated with the regrowth rate of vegetation in the watershed concerned (Steedman *et al.* 2003).

4.1.2.2 Dissolved organic carbon

Deforestation generates dissolved organic carbon (DOC) increase in water streams and bodies (Carignan *et al.* 2000). Exportation of DOC to water environments is more significant in watersheds where logging operations have been carried out than in watersheds that have not or in fire-affected watersheds (Lamontagne *et al.* 2000). This increase results in an observable change of water color, turning brownish. Darker water reduces the penetration power of light into water, thus causing ecosystem changes: less light penetrating down into water is likely to adversely affect photosynthesis (Carignan *et al.* 2000, Planas *et al.* 2000). In lakes, water limpidity loss can cause thermocline to increase and habitat of species using epilimnion to decrease (Steedman et Kushneriuk, 2000, Steedman *et al.* 2003).

4.1.2.3 Mercury

Mercury is associated with organic substances. It can lixiviate towards bodies of water simultaneously with DOC, and penetrate the food chain (Carignan *et al.* 2000). In a study conducted on Haute-Mauricie lakes, northern pike living in lakes where the watershed had undergone clear cutting operations showed higher mercury concentration rates than lakes with preserved watershed. Mercury concentrations in northern pike flesh exceeded World Health Organization standards (Garcia and Carignan 2000, Garcia 2001). The watersheds had been logged in proportions ranging from 11 to 72% (average of 43%).

4.2 Riparian environments

Disturbances in or near riparian environments can have significant impacts on fish habitat. They include: forest roads, chiefly water crossing structures, riparian forest operations and heavy machinery passage in riparian or aquatic environments.

4.2.1 Riparian forests

The presence of riparian forest helps (Steedman *et al.* 2003):

- Maintaining water temperature
- Ensuring large woody debris input, thus providing shelter to fish
- Ensuring food supplies for fish and organic substance supplies for aquatic environment components (insects and leaves)
- Filtering surface water originating from forest environments (thus preventing excessive sediment and nutrient input from disturbed areas)
- Preventing wood debris input originating from logging areas into water, thus increasing oxygen demand (DBO)
- Stabilizing banks.

While the significant role of riparian forests in preserving streams is acknowledged, its importance in lake preservation is not as widely recognized. That role is not of lesser importance, but is simply different. The shorelines of lakes and streams provide food and shelter to fish, and are very important for spawning and for the early development of many fish species (Zalewski *et al.* 2001). For instance, mature lake whitefish find food in littoral zones in spring, while juvenile lake whitefish live in littoral zones; northern pike spawns and feeds in littoral zone (Table 1).

4.2.1.1 Temperature

Suppression of vegetal cover near streams (chiefly small and slow-flow streams) generates changes in water temperature (rises in summer, drops in winter, significant daily fluctuations) (St-Onge *et al.* 2001) and cause changes in primary production (algae, phytoplankton…) and invertebrates, thus causing changes in food sources. Certain fish species do not tolerate high temperature water. Their sensitivity varies depending on development stages and species. Brook trout, lake whitefish and walleye prefer freshwater (Scott et Crossman 1974). Temperature is a determining factor in fish biology. Fish development and behavior are partly regulated by water temperature (Moyle and Cech 2000).

Preservation of riparian buffer strip apparently fosters preservation of stream water temperature (Plamondon 1993). The role in water temperature preservation of riparian buffer strips along lakes is not as important, particularly large lakes (Steedman *et al.* 2001). It is however essential to preserve the balance of aquatic ecosystems.

4.2.1.2 Windthrow in riparian buffer strips

Windthrow in riparian buffer strips is a chronic problem (Steedman *et al.* 2003). Macdonald *et al.* (2003) observed that windthrow in riparian buffer strips has significant influence on water temperature and that solar impact linked to opening up is related to it.

Kreutweiser et al. (2005) observe that large woody debris in creeks increase in volume where the riparian environment is adjacent to a clearcut area. The Government of Ontario stresses this problematic issue in its forest operations standards for fish habitat (OMNR 1988). It is however difficult to find any scientific reference mentioning the impact of large woody debris input found in significant volume in streams. Are trees found in streams abundant to the extent of blocking the passage of fish? Macdonald et al. (2003) indicate that studies on many British Columbia watersheds have revealed that besides water temperature, windthrow in riparian buffer strips has little major impacts on water streams. However they mention that according to Salo and Cederholm (1981), windthow in riparian buffer strips may cause a loss in bank stability, generate a large quantity of sediments, and significantly increase the volumes of large woody debris.

One question remains: how do we prevent windthrow in riparian buffer strips? Ruel *et al.* (2001) indicate that it is hard, almost impossible to determine the level of risk of windthrow in stands. However they mention that thinned riparian buffer strips are more likely to be windthrow prone (Ruel *et al.* 2001). Rollerson and McGourlick (2001), after conducting a study on windthrow in riparian buffer areas, recommend the following elements to reduce risks of windthrow:

- Enlarging the riparian buffer strip to more than 40 m wide, thinning it progressively from severely on the edge of the clearcut to complete preservation, and removing windthrow prone trees. This method can significantly reduce risks of windthrow. It is

very important not to thin the buffer strip uniformly or to remove all of the big trees for risks of windthrow would increase);
AND/OR

- Cutting only one side of the stream at a time. Risks of windthrow in riparian buffer strips where both sides of the streams are completely logged are much higher than in riparian strips where only one side has been cut.

4.2.1.3 Large woody debris

Large woody debris input plays a key part in riparian forests, hence in riparian buffer strips, by providing shelter and structure to fish. Several studies conducted on Western Canada highly steeped streams reveal the significant role of woody debris in the formation of pools of essential importance for salmonid habitat. There would be a correlation between abundance of salmonid stocks and abundance of large woody debris in water streams. However studies conducted in Eastern Canada - where trees are smaller and streams have softer slopes – found no correlation between abundance of large woody debris in water streams and formation of pools (Kreutzweiser *et al.* 2005) or abundance of brook trout (Clarke *et al.* 1998). That however does not delete the importance of large woody debris input in the water ecosystem. Woody debris provide shelter and food sites to fish in streams and lake littoral zones (Steedman *et al.* 2003).

4.2.1.4 Dissolved oxygen

Oxygen dissolved in water is essential to aquatic life. The tolerance threshold of fish to dissolved oxygen drop varies depending on species. Some are more sensitive, including brook trout, lake whitefish and walleye. A drastic drop in dissolved oxygen can be fatal to them. Dissolved oxygen drop can be caused by the discharge of logging debris in streams (organic sedimentation) or water temperature rise. A combination of both factors can become critical (Roberge, 1996). Protection of riparian forests can prevent temperature change and sedimentation increase, which may bring dissolved oxygen to drop.

4.2.2 Forest roads

Poor road planning and maintenance, and inappropriate water crossing structures can cause fish habitat to degrade. Fish habitat degradation can result from waterbed being destroyed or buried by sediments. Circular culverts disturb waterbeds, and can restrain fish mobility if poorly installed or inappropriate. Abandoned and poorly kept roads can also cause long-term problems to fish habitat. In case of culvert failure or wash out, a very important quantity of sediments is introduced into the water stream. However the use of proper construction and maintenance techniques can reduce significantly the frequency and intensity of erosion and sedimentation (Steedman et al. 2003). Poor territory knowledge may result in the destruction of spawning sites by installing water crossing structures directly on the site.

4.2.2.1 Sedimentation

Increase in sediment input would be the main cause of quality water degradation associated with timber operations (Roberge, 1996). Inorganic sedimentation can come from two main sources: superficial erosion and waterbed and bank erosion.

Sediments are either carried by suspension or bed load. Suspended sediments increase water turbidity - thus reducing light penetration into streams - and reduce fish visibility (St-Onge *et al.* 2001). Bed load can cause significant damage by scouring (reduction of benthic populations). Sediment deposit in pebbles and gravel of spawning areas may be critical for fish reproduction (silting of spawning areas, drop in dissolved oxygen). Such condition is more likely to affect brook trout and walleye, but also lake whitefish and lake sturgeon (Table 1).

According to Delisle *et al.* (2004), a study conducted in the Canadian Shield, north of Québec, demonstrated that fine sediment input is more significant upstream from culverts than downstream. The study covered a period of three years after the construction of the said culverts. Lachance, S. (personal communication) states that sedimentation occurs over distances exceeding 50 m (up to 500 or 1000 m).

4.2.2.2 Barriers to fish migration

Since forest roads often cross water streams, allowing the passage of fish under roads is of the essence (Furniss *et al.* 1991). Poorly designed culverts can hinder passage of fish in many ways. Of course fish swimming capacity varies depending on species and development stage (Furniss *et al.* 1991): attempting to meet the needs of each and every species could be complex. By keeping disturbance of water beds and flow regime to an absolute minimum, the passage of most species could be ensured. Water crossing structures can become barriers to fish migration in the following situation (Furniss *et al.* 1991):

- The size of the culvert pipe is too small; as a result the water velocity in the structure gets too high;
- The pipe is not deep enough; as a result the water in the pipe is not deep enough;
- The pipe is too long and fish finds no place to rest; as a result fish are unable to swim from one end of the structure to the other;
- Downstream from the pipe there should be a resting pool where fish can rest before entering the structure.

The culverts can be blocked by a beaver dam or collapse. According to S. Lachance (personal communication), culverts made of a series of parallel pipes sometimes act as dams, for they change drastically the water flow. Bridges and arched culverts are less likely to hinder fish migration, because they do not disturb the waterbed nor significantly reduce the width of the waterbed. Removable structures during winter operations leave the water bed intact after forest operations are completed (Légère and Dostie 1999).

The problem is serious enough for correction measures to be implemented in certain locations (McCleary *et al.* 2004). At Foothills Model Forest, for instance, 302 water crossing structures were inspected with a view to determine whether or not they are barriers to fish migration (McCleary *et al.* 2004). It turned out that four of them completely blocked fish mobility, and eighteen were potential barriers. If the first four were to be repaired, they would give fish access to more than 6 km of habitat.

One of the many reasons that lake sturgeon is not abundant in the region under study is the disturbance of its habitat due to forest roads (FAPAQ 2003). Other reasons include slow-growth rate and hydroelectricity-related disturbance (FAPAQ 2003).

4.2.2.3 Access

Increased access to forest environments leads almost invariably to upward fish harvest rates. Fishing intensity can be more threatening to fish than habitat degradation due to road construction (Gunn and Sein 2000).

4.2.2.4 Mitigation measures

Presently, about 10 000 water crossing structures are built every year throughout Quebec. Their number must be brought down (Jetté *et al.* 1998, Delisle *et al.* 2004), for it is still the best way to mitigate road impacts on water streams. Partington (2003) showed that better road planning in a study sector of Gaspésie has enabled the timber industry to bring water crossing structures from 12 to 3. Enhanced road planning is always possible. The Government of Quebec (1997 and 2001) has published a few guides on sound practices providing excellent ideas on how to reduce impacts of forest roads on the aquatic ecosystem.

4.3 Forest drainage

According to Steedman et al. (2003), forest drainage to lower the water table in wet sites has strong impacts on the ecosystem of brooks. Vulori *et al.* (1998) studied first- and second-order brooks, and mention that forest drainage has significantly altered the original features and ecological integrity of most brooks in Finland. It appears that drainage has substantially changed the hydrology and water quality of streams. Forest drainage is not widely used in Quebec. According to S. Jutras (personal communication), drainage has no negative impact on fish if properly carried out and if the mineral soil is not affected. However poor site maintenance may lead to impacts on aquatic ecosystems. Poorly kept drainage ditches and sedimentation basins may bring the latters to fill and become inapt to fulfill their purpose. Suspended organic/inorganic substance input in downstream water systems would increase.

Forest drainage is not a solution to rutting in wetlands, and would be improper to counter rutting impacts on water runoff (Jutras 2004).

4.4 Combined effects on aquatic life

4.4.1 Primary production

Primary production may be influenced by light, water temperature, availability of nutrients, nature of substrate and sediment transport. Logging has impacts that may increase primary production in watercourses: enrichment in nutrients, water warming and light increase. Preservation of riparian treed edges limits changes in light penetration in watercourses and prevents primary production increase. Forest operations also have negative effects on primary production, for they cause sediments to increase. Substrate scouring, destabilization, burying or silting are negative effects caused by bed loads. Water turbidity increase reduces light penetration, hence primary production (Roberge, 1996, St-Onge *et al.* 2001). Increase in DOC also has a negative effect on primary productivity (Planas *et al.* 2000). In the course of a study Planas *et al.* (2000) noted a global increase in primary productivity in fire- or logging-affected lakes. However primary productivity increase was mostly observable in fire-disturbed lakes – with DOC increase in lakes disturbed by logging operations having potentially caused light penetration to decline - and in photosynthesis (Planas *et al.* 2000).

4.4.2 Invertebrates

The variation of abundance and structural composition of planktonic and benthic communities that are a source of food for fish populations reflects the natural and anthropogenic disturbances affecting aquatic life (St-Onge *et al.* 2001). Forestry impacts can modify the abundance and composition of invertebrates. Changes in allochtonous organic debris (logging debris rather than leaves and twigs), increase in sedimentation (loss of habitat) and changes in primary production are accountable for those changes (Roberge, 1996). However the response of invertebrates to forest operations varies from one study to the other (St-Onge *et al*. 2001).

4.4.3 Amphibians

Amphibian communities are very sensitive to their environment. They are important elements of aquatic and riparian ecosystems. They are preys to many fish species, including walleye and northern pike (Scott and Crossman 1974). They abound in small creeks. Water warming, green algae proliferation, abundance of invertebrates and sediment accumulation in habitat can disrupt amphibian populations (Roberge, 1996).

4.4.4 Fish

The various changes in fish habitat affect each of their key component:

- Spawning areas
    - Sedimentation increase in the habitat
    - Direct destruction due to water crossing structures
    - Changes in water quality affecting reproduction (temperature, dissolved oxygen …)

- Food
    - Changes in invertebrate and vegetal communities
    - Changes in bank and shelter

- Shelter and rest
    - Changes in bank and shelter
    - Fewer large woody debris

- Water quality and quantity
    - Change in the physicochemical composition of water (temperature, dissolved oxygen, mercury, dissolved organic carbon)
    - Increase in turbidity and sedimentation
    - Change in peak and low water flows

- Free access
    - Barrier to fish migration due to water crossing structures

Besides changing the habitat, easier access to the territory can increase fishing activities. The combined effect of fish habitat degradation and fishing pressure increase can affect fish populations in managed forest environments.

Table 2 shows the many impacts of forestry on the fish species targeted by this study: brook trout is more sensitive to sedimentation in spawning areas and to temperature rise; lake sturgeon, given its low productivity capacity, is very sensitive to overexploitation and increased access to the forest environment; lake sturgeon, walleye and brook trout need to be given the mobility essential to their vital cycle, and migration barriers can be very harmful to their populations. Every change made to the aquatic ecosystem can affect fish habitat. Such changes can have contradictory and unforeseen effects on fish populations. Hence forest development maximizing on the preservation of the integrity of aquatic ecosystems would be the approach that would least disturb fish populations.

Table 2. Forestry impacts on fish populations

Impact		**Lake Sturgeon** (*Acipenser fulvescens*, Esturgeon jaune)	**Walleye** (*Sander vitreus*, Doré jaune)	**Northern pike** (*Esox luciuss, Grand brochet*)	**Brook trout** (*Salvelinus fontinalis*, Omble de fontaine)	**Lake whitefish** (*Coregonus clupeaformis*, Grand corégone)
Water regime	**Increase in peak flows**	Negative	Negative	Negative	Negative	Neutral
	Increase in low water flows	Neutral	Neutral	Neutral	Neutral	Neutral
Sedimentation	**Increase**	Negative	Negative	Neutral	Negative	Neutral
Temperature	**Modifications**	Negative	Negative	Negative	Negative	Negative
Dissolved oxygen	**Reduction**	Negative	Negative	Slightly Negative	Negative	Negative (lake)
Nutrients	**Increase**	Variable	Variable	Variable	Variable	Variable
Mercury	**Increase**	Negative	Negative	Negative	Negative	Negative
Primary production	**Increase**	Positive	Positive	Positive	Positive	Positive
	Reduction	Negative	Negative	Negative	Negative	Negative
Invertebrates	**Increase**	Positive	Positive	Positive	Positive	Positive
	Reduction	Negative	Negative	Negative	Negative	Negative
	Changes in communities	Possibly Negative	Possibly Negative	Possibly Negative	Possibly Negative	Possibly Negative
Food areas	**Modifications to shoreline, etc.**	Negative	Negative	Negative	Negative	Negative
Reproduction	**Silting of spawning sites**	Negative	Negative	N/A	Negative	N/A
Shelter	**Reduction in large woody debris**	Possibly Negative	Possibly Negative	Possibly Negative	Negative	Possibly Negative
Free mobility	**Stream obstruction**	Negative	Negative	Possibly Negative	Negative	Neutral
Fishing pressure	**Increase**	Negative	Negative	Negative	Negative	Negative

ASSESSMENT OF THREATS ON FISH HABITAT IN THE TRAPPING TERRITORIES OF WASWANIPI

5 INTRODUCTION

Forestry data updated in 2003 were used to conduct a study on fish habitat threats in the trapping territories of Waswanipi. Unfortunately, given the time available to conduct the study, it was impossible to obtain more recent information. Forest harvests and road construction are in all likelihood far more extended today than what is shown on the maps. However it is possible to study those maps bearing in mind that additional territory disturbances have occurred since.

The most affected areas are those found in the southern half of the territory (see general maps attached). Those maps show the extent of the forest harvest and abundance of forest roads in those sectors.

6 FOREST ROAD NETWORK

Forest road-related threats are numerous (see page 15 and following). Water crossing structures – chiefly culverts - are important sources of sediments that can degrade fish habitats and spawning areas. Sometimes water crossing structures area located in a habitat, which is bound to be destroyed during the construction of the infrastructures. They can in many ways become barriers to fish migration and prevent them from reaching important elements of their habitat. Since they involve soil compacting procedures, roads foster peak flow increases and potential sedimentation in water streams. Finally road network development significantly opens access to the territory, thus increasing fishing pressure. The attached maps illustrate the scope and density of the road network in the territory under study. The areas in the southern part of the territory are more affected than the others. The number of water crossing structures – and potential impacts on fish populations - increases with the number of forest roads.

6.1 Erosion

The *ministère des Ressources naturelles et de la Faune du Québec* (MRNF) evaluated erosion occurrences associated with bridges and culverts installed in the 2004-2005 season in common areas 083-87N, 087-04 and 087-20. These common areas more or less correspond to the southwestern part of the Waswanipi Cree territory. The MRNF evaluated 169 water crossing structures. Other data elements required to draw a complete portrait of the territory are not available.

The measuring exercise was carried out one year after forest operations. The structures inspected had not gone through many rigorous winters. Had the measures been taken ten years later, it is probable that the structures would have shown signs of significant and repeated erosion.

Erosion occurs frequently. In common areas 083-87N and 087-04 (113 water crossing structures sampled), there is one (1) case of erosion for every five water crossing structures (20%). In common area 087-20 (56 water crossing structures sampled), there are two (2) cases of erosion for every five water crossing structures (40% of water crossing structures).

Most cases of erosion occurred in sites where the *Regulation respecting standards of forest management for forests in the domain of the State* is in force. This means that the regulation provisions can lack efficiency to ensure protection of the aquatic environment adequately and sound additional practices must be implemented.

While the data do not cover the entire territory of the Waswanipi community, it is reasonable to believe that there are cases of erosion occurring frequently elsewhere in the territory, since timber companies are all bound by the same requirements for construction of water crossing structures.

The attached forest maps suggest that trapping territories where the road network has a high density have a greater number of water crossing structures and impacts on fish habitat.

7 RIPARIAN ENVIRONMENT

The data collected to conduct a study of the territory did not allow to assess the quality, width and windthrow resistance level of riparian strips. Certainly, where logging operations are significant, the aquatic ecosystems in the territory concerned are likely to be bordered by narrow riparian forests. Those strips are prone to windthrow, which may adversely affect the aquatic ecosystems and fish populations.

8 LOGGING AREAS

8.1 Peak flow increase

According to the *ministère des Ressources naturelles et de la Faune du Québec* (MRNF), a forest watershed, observed at a scale of about 100 km^2, rarely has an equivalent cutting area (ECA)[1] of more than 50% (Langevin 2004). The 50% limit would be that where negative peak flow impacts are felt. However the ECA of sub-watersheds of smaller dimension exceeds 50% more often.

Unfortunately with the data available to conduct the study, it was not possible to calculate the ECA of every watershed and sub-watershed found across the territory. This exercise however could be carried out by the Waswanipi Forestry Department or timber companies, or within the context of a subsequent research project. Nevertheless the attached maps were designed in a manner such that stands with greater impact on peak flow increase should be highlighted. Stands arising from logging carried out in the past 15 years have more impact (yellow on the maps). More mature stands arising from logging are colored red, and stands younger than 30 years arising from natural disturbances are colored green. Those stands have an impact on forest hydrology, but of lesser importance than the impact of young stands originating from logging. For instance the maps indicate that traplines W26 and W11b are greatly affected by recent logging operations and that the water regime is probably disturbed.

[1] Equivalent cutting area: Method used to calculate the cutting rate in a given watershed taking into consideration the surface areas of previous cutting operations and mitigation of negative impacts of the cut areas through the years.

8.2 Mercury level increase

The quantity of mercury in predator fish populations such as pike would increase with the size of the logging area in a given watershed. Since significant logging operations were carried out in the southern part of the Waswanipi territory, it is possible to believe that fish originating from those areas are likely to contain higher levels of mercury. This increase in mercury level constitutes a threat to the health of Cree fishermen.

8.3 Forest drainage

Based on the data contained in the ecoforestry maps and 2003 updates consulted, the number of drained hectares in the Waswanipi territory totals a little more than 2,200. Trapline W20 comes first with 1,100 ha, then traplines W11a and W13b with about 450 ha each. Smaller areas were drained in traplines W21, W23a, W26a and W27.

Forest drainage as performed presently in Quebec would not present a sure risk for fish habitat. But if widely used, forest drainage could change the water flow regime and ecology of streams as observed in Finland. For the time being particular attention must be given to the maintenance of those sites to ensure they can continue to play their role correctly and do not disturb the aquatic ecosystem. Vigilance is required to make sure that forest drainage never becomes broadly used.

CONSERVATION STRATEGIES

9 STRATEGY PROPOSED BY THE CREE-QUEBEC FORESTRY BOARD

The *Draft directives on the protection and management of wildlife habitats on the territory of the Agreement concerning a new relationship between le gouvernement du Québec and the Crees of Québec* suggest fine recommendations for the protection of the fish habitat (see box on following page). The directives chiefly recommend protecting the spawning areas, widening sloped riparian strips, and applying sound practices with respect to site selection and construction of water crossing structures.

However certain important elements for conservation of fish habitat are not taken into consideration in the proposed strategies. Additional recommendations are therefore suggested in the following section to complement the strategy proposed by the Cree-Québec Forestry Board.

Riparian zone

Management strategies:

- In sensitive sectors identified for terrestrial aquatic wildlife, and only after consultation between the tallymen, the beneficiary and MRNF, the riparian mosaic of 200 meters could be modulated on one side or both sides of the stream based on the objective for maintaining the Visual Quality of Forest Landscapes (FDPO 9).
- In sectors located on slopes exceeding 30 %, the riparian strip along lakes or permanent watercourses shall be extended to 40 meters wide, and partial cutting shall be allowed only within the first 10 meters of the strip.
- A particular attention aiming at minimizing the risk of windfall should be given to the sectors most vulnerable to the winds of West.

Fish

Management strategies for spawning areas:

- In sectors where a spawning ground is identified, no forest operation can be carried out in the riparian strips. A 40-meters wide protection strip must be maintained along the spawning area on both sides of the shore as well as on a distance of 40 meters, upstream and downstream from the spawning ground.
- When the slope of the riparian strip bordering a spawning site exceeds 30 %, the riparian strip shall be extended to a width of 50 meters.
- During the construction of a temporary or permanent access road, it is forbidden to cross a watercourse within a distance of 100 meters upstream and 40 meters downstream from a spawning area.

Other strategies and recommendations

Aquatic habitat and road network development:

- In sectors of wildlife interest, access road construction (temporary and permanent) must be located outside the residual blocks as a priority.
- To optimize water quality and aquatic habitat conservation, apply and adapt to the Agreement's territory the guide on sound forest road practices developed by the Gaspésie-Iles de la Madeleine regional directorate of MRNF by emphasizing the placement (according to trade practice) of structures such as culverts. Sound practices during winter road construction must also be adapted and applied. Using techniques that minimize disturbance of the stream bed (half pipe culverts, temporary bridge) is to be preferred.

Based on the *Draft directives on the protection and management of wildlife habitats on the territory of the Agreement concerning a new relationship between le gouvernement du Québec and the Crees of Québec*, by the Cree-Quebec Forestry Board, 2006.

10 RECOMMENDED STRATEGY

The incorporation of the concept of fish protection into forest management bring about important consideration of forestry-related road network impact. This element, which may sometimes seem of secondary importance compared to forest rejuvenation, constitutes the major impact on fish habitat.

To prevent reiterating what has been said previously, the following recommendations do not cover the elements presented in the *Draft directives on the protection and management of wildlife habitats on the territory of the Agreement concerning a new relationship between le gouvernement du Québec and the Crees of Québec*. The following recommendations complement those listed in the box in the previous page to preserve or reinstate fish habitat.

- Roads
  - Planning the road network in such manner as to keep water crossing structures and water access to a minimum;
  - Prior to erecting water crossing structures, consulting the tallymen to make sure there are no spawning beds in the contemplated areas for construction.
  - Repairing altered or obsolete structures to prevent habitat disturbances.

- Riparian Areas
  - Preserving a riparian forest canopy in order to maintain the physicochemical features of water and continuous large woody debris input.
  - Protecting the riparian areas of small permanent streams better; do not harvest in the 10 m zone adjacent to these watercourses;
  - Minimizing windthrow in riparian buffer strips, in particular near spawning areas:
    - Widening the riparian strip to more than 40 m, and thinning it progressively (Rollerson et McGourlick 2001), from severe thinning to complete preservation, making sure to remove windthrow prone trees. This method allows significant windthrow minimization. It is important not to perform uniform thinning, either by harvesting all of the big trees, for risks of windthrow occurrence would increase.

      AND/OR
    - Logging only one side of the stream at a time. Risks of windthrow occurrence in riparian buffer strips where both sides are completely logged are much heavier than in riparian buffer strips of water courses where only one side has undergone logging (Rollerson et McGourlick 2001).

- Harvest
  - To preserve water quality, to avoid peak flow increases and to minimize mercury accumulation in fish, logging should not cover more than 50 % of the equivalent cutting area of each watershed and sub-watersheds.
  - Minimizing rutting, and if any, applying corrective measures.
  - Preventing wetland disturbances.

Table 3. Effects of management related recommendations on fish habitat

Recommendations Sources: This study: SD Draft directives of the Cree-Quebec Forestry Board: CQFB		Mitigating Effects							
		Fish mobility	**Peak flows**	**Erosion / Sedimentation**	**Spawning areas in water streams**	**Lacustrine spawning areas (littoral)**	**Food**	**Nutrient input**	**Mercury**
Road network	Road network planning providing for minimum crossing structures (SD)	Important		Important	Important				
	Strict enforcement of sound forestry practices during construction and maintenance of roads and water crossing structures (CQFB)	Important	Potential	Important	Important	Potential	Potential	Potential	
	Reduction of circular culverts (CQFB)	Important		Important	Important				
	Consultation with the tallymen to make sure there is no spawning area prior to erecting any water crossing structure (SD).				Important	Important			
	During the construction of a temporary or permanent access road, it is forbidden to cross a watercourse within a distance of 100 meters upstream and 40 meters downstream from a spawning area (CQFB).				Important	Important			
	Minimizing rutting and applying corrective measures in case of rutting (SD).		Important	Important					
Riparian environment	Preservation of riparian forest cover to maintain the physicochemical features of water and continuous large woody debris input (SD).			Important	Important	Important	Important	Important	
	Further protection of riparian areas of small permanent streams. No thinning within 10 m from water streams (SD).			Important	Important				

	Recommendations Sources: This study: SD Draft directives of the Cree-Quebec Forestry Board: CQFB	Mitigating Effects							
		Fish mobility	**Peak flows**	**Erosion / Sedimentation**	**Spawning areas in water streams**	**Lacustrine spawning areas (littoral)**	**Food**	**Nutrient input**	**Mercury**
	In sectors where a spawning ground is identified, no forest operation can be carried out in the riparian strips. A 40-meters wide protection strip must be maintained along the spawning area on both sides of the shore as well as on a distance of 40 meters, upstream and downstream from the spawning ground (CQFB).			Important	Important				
	A particular attention aiming at minimizing the risk of windfall should be given to the sectors most vulnerable to the winds of West (CQFB). Minimizing windthrow in riparian strips, particularly near spawning areas (SD).	Potential		Potential	Important		Potential	Potential	
Wetlands	Avoid disturbances in wetlands (SD).		Important					Important	
Logging	To preserve water quality, to avoid peak flow increases and to minimize mercury accumulation in fish, logging should not cover more than 50 % of the equivalent cutting area of each watershed and sub-watersheds (SD).	Potential	Important	Important	Important	Potential	Important	Important	Important

REFERENCES

Carignan R. and R.J. Steedman. 2000. Impacts of major watershed perturbations on aquatic ecosystems, *Can. J. Fish. Aquat. Sci.* **57** (suppl. 2): 1-4.

Carignan, R. D'Arcy, P. and S. Lamontagne. 2000. Comparative impacts of fire and forest harvesting on water quality in Boreal Shield lakes, *Can. J. Fish. Aquat. Sci.* **57** (Suppl. 2: 105-117.

Clarke, K.D., Scruton, D.A., Cole, L.J., and Ollerhead, L.M.N. 1998. Large woody debris dynamics and its relation to juvenile brook trout (*Salvelinus fontinalis*) densities in four small boreal forest headwater streams of Newfoundland, Canada. Pages 337-344 *in* Brewin, M.K. et Monita, D.M.A., tech. coords. 1998. *Forest-fish Conference : land management practices affecting aquatic ecosystems.* Proc. Forest-fish Conf., May 1-4, 1996, Calgary, Alberta. Nat. Resour. Can., Can. For.Serv., North. For. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-356.

Dupont, P.-P. and L. Bernatchez. Writing underway. Population structure, dispersal and spatial distribution of Mistassini Lake walleye (*Sander vitreus*).

Eikaas, H.S., McIntosh, A.R. and A.D. Kliskey. 2005. Catchment- and site-scale influences of forest cover and longitudinal forest position on the distribution of a diadromous fish, *Freshwater Biology* **50** : 527-538.

Furniss, M.J., Roelofs, T.D. and C.S. Yee. 1991. Road construction and maintenance, *in Influences of forest and rangeland management on salmonid fishes and their habitats*, American Fisheries Society Special Publication **19** :297-323, 1991.

Garcia, E. 2001. *Contamination en mercure et méthyle mercure des organismes aquatiques de 38 lacs du Bouclier canadien dont le bassin versant a été perturbé par la coupe à blanc ou le feu de forêt*, faculté des Arts et des sciences, département des Sciences biologiques, Université de Montréal, 184 pages et annexes.

Garcia, E. and R. Carignan. 2000. Mercury concentrations in northern pike (*Esox lucius*) from boreal lakes with logged, burned, or undisturbed catchments, *Can. J. Fish. Aquat. Sci.* **57** (Suppl. 2) : 129-135.

Gouvernement du Québec. 1997. *L'aménagement des ponts et des ponceaux dans le milieu forestier*, ministère des Ressources naturelles, Québec, 146 pages.

Gouvernement du Québec. 2001. *Saines pratiques : voirie forestière et installation de ponceaux*, gouvernement du Québec, ministère des Ressources naturelles, Direction régionale de la Gaspésie – Îles-de-la-Madeleine, 27 pages.

Gunn, J.M. and R. Sein. 2000. Effects of forestry roads on reproductive habitat and exploitation of lake trout (*Salvelinus namaycush*) in three experimental lakes, *Can. J. Fish. Aquat. Sci.* **57** (Suppl. 2): 97-104.

Hazel, P.-P and R. Fortin. 1986. *Le doré jaune (stizostedion vitreum mitchill) au Québec : biologie et gestion*, gouvernement du Québec, ministère du Loisir, de la Chasse et de la Pêche, Québec, 417 pages.

Jutras, S. 2004. *Avis scientifique sur l'utilisation du drainage sylvicole pour remédier aux effets négatifs de l'orniérage*, gouvernement du Québec, ministère des Ressources naturelles, de la Faune et des Parcs, 11 pages.

Kreutzweiser, D.P., Good, K.P. and T.M. Sutton. 2005. Large woody debris characteristics and contributions to pool formation in forest streams of the Boreal Shield, *Can. J. For. Res.* **35**: 1213-1223.

Lamontagne, S., Carignan, R. D'Arcy, P., Prairie, Y.T. and D. Paré. 2000. Element export in runoff from eastern Canadian Boreal Shield drainage basins following forest harvesting and wildfires, *Can. J. Fish. Aquat. Sci.* **57** (Suppl. 2): 118-128.

Langevin, R. 2004. *Objectifs de protection et de mise en valeur des ressources du milieu aquatique : importance au Québec des augmentations des débits de pointe des cours d'eau attribuables à la récolte forestière*, Québec, gouvernement du Québec, ministères des Ressources naturelles, de la Faune et des Parcs, Direction de l'environnement forestier, code de diffusion : DEF-0239, 13 pages.

Langevin, R. and A.P. Plamondon. 2004. *Méthode de calcul de l'aire équivalente de coupe d'un bassin versant en relation avec le débit de pointe des cours d'eau dans la forêt à dominance résineuse*, gouvernement du Québec, ministère des Ressources naturelles, de la Faune et des Parcs, Direction de l'environnement forestier et Université Laval, Faculté de foresterie et de géomatique, code de diffusion : 2005-3008, 24 pages.

Légère, G. and R. Dostie. 1999. *Aménagement d'ouvrages temporaires pour traverser les cours d'eau dans les chemins d'hiver du Québec*, Institut canadien de recherches en génie forestier, Rapport spécial n^{o} RS-134.

Macdonald, J.S., MacIsaac, E.A. and H.E. Herunter. 2003. The effect of variable-retention riparian buffer zones on water temperatures in small headwater streams in sub-boreal forest ecosystems of British Columbia, *Can. J. For. Res.* **33**: 1371-1382.

McCleary, R., S. Wilson and C. Spitz. 2004. A stream crossings remediation planning process and example application in the Foothills Model Forest, Alberta. *In Proceedings from the 2003 Access Management Conference*. Edited by H. Epp. Alberta Society of professional biologists.

Moisan, M. and H. Laflamme. 1999. *Rapport sur la situation de l'esturgeon jaune (Acipenser fulvescens) au Québec*, gouvernement du Québec, Faune et Parcs Québec, Québec, Québec, 68 pages.

Moyle, P.B. and J.J. Cech. 2000. *Fishes: an introduction to ichtyology*, 4th edition, USA, 612 pages.

Partington, M. 2003. *Évaluation de la mise en application de « saines pratiques d'aménagement » en Gaspésie : « Sommaire du projet »*, Rapport non confidentiel du rapport interne No. RI-2002-04-17, Pointe-Claire, Québec, Institut canadien de recherches en génie forestier, 10 pages.

Plamondon, A.P. 1993. *Influence des coupes forestières sur le régime d'écoulement de l'eau et sa qualité*, Sainte-Foy, Université Laval, 179 pages.

Planas, D., Desrosiers, M., Groulx, S.-R., Paquet, S. and R. Carignan. 2000. Pelagic and benthic algal responses in eastern Canadian Boreal Shield lakes following harvesting and wildfires, *Can. J. Fish. Aquat. Sci.* **57** (Suppl. 2): 136-145.

Roberge, J. 1996. *Impacts de l'exploitation forestière sur le milieu hydrique (revue et analyse de documentation)*, Québec, ministère de l'Environnement et de la Faune du Québec, 68 pages.

Rollerson, T. and K. McGourlick. 2001. Riparian windthrow – Northern Vancouver Island. Pages 139-155 *in* Mitchell, S.J. et J. Rodney. 2001. *Windthrow assessment and management in British Columbia*, Proceedings of the Windthrow Researchers Workshop, January 31-February 1st, Vancouver, University of British Columbia and Forestry Continuing Studies Network.

Ruel, J.-C., Pin, D. and K. Cooper. 2001. Windthrow in riparian buffer strips: effect of wind exposure, thinning and strip width, *Forest Ecology and Management* **143**: 105-113.

Scott, W.B. and E.J. Crossman. 1974. *Poissons d'eau douce du Canada*, Environment Canada, Fisheries and Ocean Sciences, Ottawa, 1026 pages.

Scully, N.M., Leavitt, P.R. and S.R. Carpenter. 2000. Century-long effects of forest harvest on the physical structure and autotrophic community of a small temperate lake, *Can. J. Fish. Aquat. Sci.* **57** (Suppl. 2) : 50-59.

Société de la Faune et des Parcs du Québec (FAPAQ). 2003. Plan de développement régional associé aux ressources fauniques du Nord-du-Québec. Direction de l'aménagement de la faune du Nord-du-Québec, Chibougamau, 115 pages.

Steedman, R.J. and R.S. Kushneriuk. 2000. Effects of experimental clearcut logging on thermal stratification, dissolved oxygen, and lake trout (*Salvelinus namaycush*) habitat volume in three small boreal forest lakes, *Can. J. Fish. Aquat. Sci.* **57** (suppl. 2) : 82-91.

Steedman, R.J., Allan, C.J., France, R.L. and R.S. Kushneriuk. 2003. Land, water, and human activity on boreal watersheds. Pages 59-85 *in* Gunn, J.M., Steedman, R.J. and R.A. Ryder. 2003. *Boreal shield watershed: lake trout ecosystems in a changing environment*, Boca Raton, Florida.

Steedman, R.J., Kushneriuk, R.S. and R.L. France. 2001. Littoral water temperature response to experimental shoreline logging around small boreal forest lakes, *Can. J. Fish. Aquat. Sci.* **58**: 1638-1647.

St-Onge, I., Bérubé, P., and P. Magnan. 2001. Effet des perturbations naturelles et anthropiques sur les milieux aquatiques et les communautés de poissons de la forêt boréale, rétrospective et analyse critique de la littérature, *Le naturaliste canadien*, **125** (3) : 81-95.

Vallières, L. and R. Fortin. 1988. *Le grand brochet (Esox lucius) au Québec : biologie et gestion*, gouvernement du Québec, ministère du Loisir, de la Chasse et de la Pêche, Direction de la gestion des espèces et des habitats, Québec, 298 pages.

Vuori, K.-M., I. Joensuu, J. Latvala, E. Jutila and A. Ahvonen. 1998. Forest drainage: a threat to benthic biodiversity of boreal headwater streams?, *Aquatic Conserv: Mar. Freshw. Ecosyst*. **8**: 745-759.

Zalewski, M. Thorpe, J.E. and R.J. Naiman. 2001. Fish and riparian ecotones – a hypothesis, *Ecohydrology & Hydrobiology* **1** (1-2): 11-24.

APPENDIX: MAPS OF THE TERRITORY OF WASWANIPI