Return of the Ouananiche to Trout Lake, near North Bay, Ontario

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ABSTRACT. Due to stockings beginning in 1935, an ouananiche population in Trout Lake became the only known self-perpetuating Atlantic salmon population in Ontario. The only documented spawning area in the lower reaches of Four Mile Creek was designated as a fish sanctuary in 1958. A train derailment spill of zinc concentrate in 1967 resulted in the extirpation of the ouananiche population by 1976. After spill site remediation in the early 1980s, zinc concentrations in the creek had declined substantially. A restocking program for Atlantic salmon was initiated in 1989.

Increased zinc concentrations above background in sediment cores collected in 1994 from Trout Lake reflected loadings from the spill site. A subsequent decline of zinc levels in recent sediments reflected spill site remediation. Zinc levels in the creek in 1994 and 1995 were generally below the PWQO of 0.03 mg/L.

Spawners were observed in Four Mile Creek in the fall of 1992 and 1994. Sampling of young-of-the-year in 1993, 1994 and 1995 confirmed that spawning in the previous year was successful. Overwinter fry survival was established by the presence of naturally produced parr in 1994 and 1995. One naturally produced grilse was captured in 1995. These findings indicate that ouananiche may once again be established as a self-sustaining population in Trout Lake.

INDEX WORDS: Atlantic salmon, Trout Lake, zinc, extirpation, stocking, restoration.

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Introduction

Historically, land-locked Atlantic salmon, or ouananiche (*Salmo salar*) were native to the Province of Ontario with a large population present in Lake Ontario and a number of tributaries providing spawning habitat, e.g., the Credit, Humber, Don, Rouge and Ganaraska rivers, as well as Duffin, Bowmanville, Highland and Wilmot creeks. However, as human settlement increased and the lands developed, the Atlantic salmon populations were subjected to a number of negative impacts including: overexploitation (overfishing); blockage of spawning migration by dams; increased water temperatures due to removal of riparian vegetation; water pollution particularly due to the discharge of organic waste; and deterioration of the spawning habitat due to siltation from clearing of land for agricultural use or urbanization and the deposition of waste materials (Christie 1973; Whillans 1979; Carcao 1987; Heiber 1987). By the late 1800s, the Atlantic salmon population in Lake Ontario was basically extirpated with the last salmon officially recorded in 1898 (Heiber 1987). As a result, a unique, landlocked gene pool of the usually anadromous Atlantic salmon had disappeared.

Between 1938 and 1962, many Ontario waters had been experimentally stocked with Atlantic salmon (Carcao 1987). There are few records of the survival of these fish and it is assumed that the stockings were unsuccessful. For example, MacCrimmon (1954) undertook to assess whether Atlantic salmon could be successfully re-introduced to its previous habitat of Lake Ontario. However, stockings of fry to Wilmot Creek between 1944 and 1949 resulted in the return of only one adult. High water temperatures and sedimentation appeared to be the primary environmental factors affecting fry survival.

More recently, a five-year Atlantic salmon re-introduction program for Lake Ontario was initiated in 1987 by the Ontario Ministry of Natural Resources (OMNR 1991). With improvements in land use practices and regulatory control of wastewater discharges, water quality and habitat in the tributaries draining to Lake Ontario have improved dramatically. Stream rehabilitation programs have further enhanced fish habitat. The removal of dams and other obstacles and the construction of fishways have facilitated upstream fish migration. This stocking program which involved annual releases of 50,000 to 60,000 mainly large yearlings into the Credit River and Wilmot Creek has had limited success. Both adult spawning returns and angling catches have been low relative to the size of the stocking program. The poor results have been attributed to a number of factors including lack of imprinting by the large yearlings on the stocking streams (J. Bowlby, Ontario Ministry of Natural Resources, Lake Ontario Fisheries Unit, Picton, Ontario) and competition and possibly predation by other salmonines (Jones and Stanfield 1993). In 1995 and 1996, the stocking program was altered from large yearlings to fry and expanded to include additional tributaries that historically supported Atlantic salmon (T. Rance, Ontario Ministry of Natural Resources, Maple, Ontario, personal communication).

One Atlantic salmon stocking that was successful during the early to mid-1900s was that in Trout Lake, just east of the City of North Bay. The first planting of 1,700 yearlings of Quebec anadromous and Vermont freshwater stock occurred in 1935. Five subsequent plantings ranging from 800 to 10,000 yearlings or fry including Miramichi, New Brunswick, stock occurred in Trout Lake or in two tributaries to the lake, Four Mile Creek and Doran Creek. Remarkably, this resulted in a self-propagating population, supporting a small fishery. The only documented spawning area was situated in the lower reaches of Four Mile Creek and, as a result, this area was designated as a fish sanctuary in 1958. A 1972 OMNR Sensitive Areas Study factsheet for the Four Mile Creek sanctuary indicated that this watercourse is a spawning area for the ouananiche population in Trout Lake, "the only known self-perpetuating population in Ontario". The population was described as small and "not contributing significantly to the sport fishery or the tourist business". The factsheet further indicated that the watercourse is "susceptible to many forms of damage due to its location in a developed area, and parts of the stream being privately owned".

On 07 March 1967, an Ontario Northland Railroad (ONR) train derailment near Four Mile Creek resulted in the spill of large quantities of zinc and lead concentrate (Bowman 1979). Despite cleanup attempts, a zinc concentration of 0.39 mg/L was measured in Four Mile Creek downstream of the spill site in September 1979, well above the Provincial Water Quality Objective (PWQO) of 0.03 mg/L (Ontario Ministry of the Environment 1984) and the background levels of <0.01 mg/L. This zinc spill from the 1967 train derailment appears to have eliminated ouananiche spawning in Four Mile Creek, resulting in the extirpation of the self-sustaining population in Trout Lake. Ouananiche have not been observed in the lake since 1976.

Additional cleanup and attempted revegetation of the spill site were undertaken in 1980 and 1982, respectively. In subsequent years, the zinc concentrations in Four Mile Creek declined to near the PWQO level. Consequently, the OMNR initiated an Atlantic salmon stocking program in 1989 in an attempt to re-establish ouananiche in Trout Lake. Additional stockings were undertaken in 1990, 1991, 1994 and 1995.

In the fall of 1991, TransCanada PipeLines Limited constructed 49.9 km of 1,067 mm O.D. natural gas pipeline, known as the North Bay Loop, along the existing North Bay Shortcut pipeline facilities in northeastern Ontario. The loop extended from (Mainline Valve) MLV 1201 at Compressor Station No. 116, located a few kilometres north of the City of North Bay, eastward to MLV 1203 + 8.8 km, located east of the Town of Rutherglen. Following a heavy rainfall event during 24 and 27 October 1991, elevated turbidity was observed and documented (videotaped) by the OMNR and the Ontario Ministry of Environment and Energy (MOEE) in several watercourses, including Four Mile Creek, traversed by pipeline loop construction. At the time of the rainfall event, pipelaying, trench backfilling and grading activities along the exposed pipeline right-of-way were either complete or nearing completion. Beak Consultants Limited and its subsidiary companies Geomatics International Inc. and Aquafor Beech Limited were retained by TransCanada to undertake a number of water quality monitoring and fisheries assessment studies to evaluate the effects of North Bay Loop construction on watercourses, including Four Mile Creek (Eakins 1995). This paper documents the re-establishment of a self-perpetuating population of Atlantic salmon between 1991 and 1995 taking into account the OMNR stocking program initiated in 1989 and the decline of zinc levels in Four Mile Creek.

Study Area

Trout Lake occurs at the headwaters of the Mattawa River (Figure 1), which is a major tributary of the Ottawa River. The City of North Bay is located to the west of Trout Lake, which is the source of municipal water supply. The most prominent physical feature of the Trout Lake drainage basin is an escarpment located along an east-west fault line on the north side of the lake (Conestoga Rovers & Associates Ltd. and Ecoplans Ltd. 1988). The steep slopes pose a constraint to development due to their susceptibility to rock slippage, soil creep and possibly mass movements. North of the lake, the predominant surficial landforms are morainal and glaciofluvial deposits. Exposed bedrock knobs are present along the Trout Lake shoreline, the main peninsula and to the northeast. Typical soil materials include gravelly sand, sandy gravel, sand and glacial till. These deposits are fairly porous and permeable.

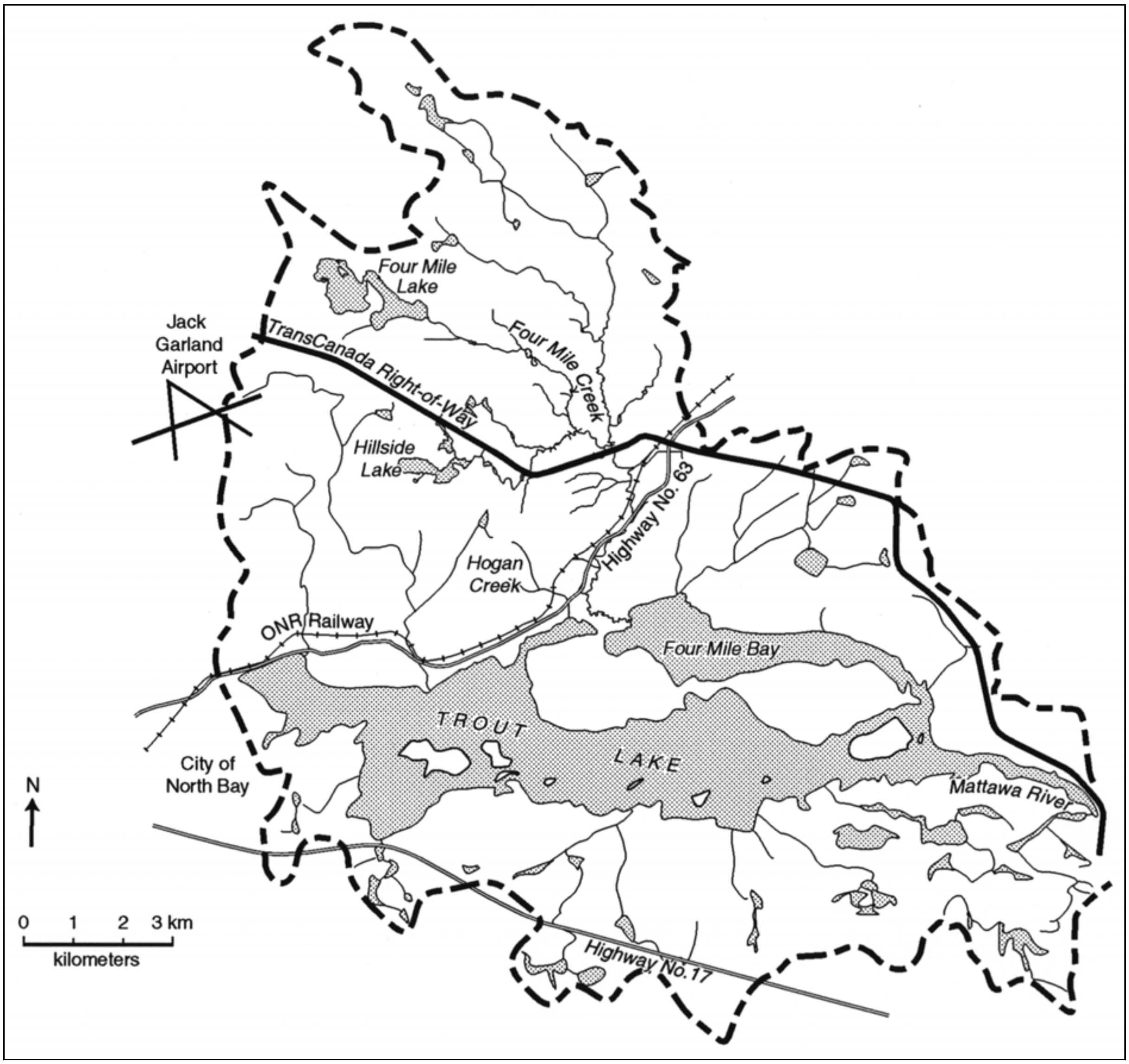

Figure 1: Trout Lake drainage basin.

Several watercourses, including Four Mile Creek, which have relatively steep north-south gradients to the lake, dissect the escarpment. Typically, these streams are clear and cold with sand, gravel and cobble substrates. Due to the nature of the surficial deposits and the steep gradients, these streams transport sands and silts downstream to Trout Lake as part of the natural erosion process during hydrograph events. Organic deposits associated with wetland habitat are infrequent; however, beaver ponds and meadows are common along the watercourses. The process of natural erosion has been periodically supplemented by erosion associated with human activities. Notable examples include erosion of roadbed materials next to stream channels, at culverts and during roadside storm sewer work; erosion which has occurred at the channel diversion sites associated with historic zinc concentrate spills from train derailments near Hogan Creek and Four Mile Creek; erosion and subsequent transport of sand and silt from pit and quarry operations; and soil erosion from agricultural activities and land development. In general, these watercourses have excellent water quality (Northland Engineering Limited and Beak Consultants Limited 1992). However, elevated zinc concentrations have been recorded in Four Mile Creek and Hogan Creek due to ore concentrate spills associated with ONR derailments in 1967 and 1970, respectively. Elevated levels of copper have been consistently measured in Lees Creek possibly due to an ore train spill in the 1960s.

Land uses in the northern drainage basin of Trout Lake include agriculture (primarily oats, hay, potatoes, turnips), aggregate extraction, transportation (e.g., Highway No. 63, Four Mile Lake Road, Northshore Road, Ontario Northland Railway, Jack Garland Airport), urban development (e.g., Birchhaven Subdivision of North Bay at the western end of Trout Lake and the settlements of Trout Mills, Hornell Heights and Feronia), and shoreline development (at least 85% of the Trout Lake shoreline is developed and includes a mixture of seasonal cottages, permanent residences and tourist camps). Overall, most of the northern drainage basin remains forested.

With a drainage area of about 3,255 ha, Four Mile Creek is the largest tributary to Trout Lake. The source of the creek is Four Mile Lake, located about 3.5 km north-northeast of the Jack Garland Airport. Four Mile Creek has two main tributaries: a southwestern tributary which discharges from Hillside Lake and a northeastern tributary that drains a number of seasonally inundated areas. Four Mile Creek outlets into the west end of Four Mile Bay of Trout Lake. The creek has a moderate to low gradient. Measured flow rates (1993-1995) ranged from a high of 8.6 m^3/s during a period of heavy rainfall in May 1995 to approximately 0.3 m^3/s during typical summer baseflow. The surficial geology of the drainage basin is characterized primarily by fluvial sand and gravel with some glacial till. The stream is prone to bank undercutting, particularly during hydrograph events, due to the abundance of soft sand and gravel. Consequently, although surficial sediment ranges from silty sand to rock depending upon the hydraulic conditions, coarse to fine sand predominates.

Methods

Water samples for zinc analysis were collected from the ONR derailment area ditch and Four Mile Creek, upstream and downstream of the ditch outlet, on four occasions: 13 May and 14 June 1994, and 19 and 21 April 1995.

Sediment cores were collected on 16 June 1994 in the depositional basin of Four Mile Bay about 500 m offshore of Four Mile Creek mouth. The cores were sectioned in 5 mm depth intervals from 0 to 30 mm and then subsequently in 1 cm depth intervals from 3 to 10 cm (the average length of cores collected). The subsamples from the cores were composited by depth interval and analyzed for zinc. However, based on the analytical results, background zinc levels, i.e., prior to the ONR derailment in 1967, could not be delineated at a sediment core depth of 10 cm. As a result, another sediment core collection was undertaken on 28 June 1994 and the cores were sectioned in 1 cm depth intervals from 0 to 15 cm. Apparent background zinc concentrations were delineated below the 12 cm depth interval.

Zenon Analytical Laboratories, located in Burlington, Ontario, undertook zinc analyses of water and sediment.

Two fish surveys involving a qualitative sampling of fish populations were undertaken in the fall of 1991, i.e., in October and November 1991 to assess the effects of pipeline construction activities on Four Mile Creek. Subsequently, fish surveys involving fish habitat characterization and fisheries resource evaluation at a number of stations on Four Mile Creek were undertaken in June 1992, May/June 1993, September 1993, October 1994 and October 1995. Figure 2 presents the sampling locations assessed one or more times between 1991 and 1995. Sampling of fish populations was conducted by electrofishing using a Smith-Root Model 12 battery-powered or Smith-Root Model 15A generator-powered backpack electrofisher. Comprehensive ouananiche spawning surveys were also undertaken in October and November 1992, November 1993, October-November 1994 and October 1995.

Results and Discussion

Effects of ONR Derailment on Zinc Levels in Four Mile Creek

On 07 March 1967, an ONR trail derailment at Four Mile Creek resulted in the spill of large quantities of zinc and lead concentrate (Bowman 1979). Despite cleanup attempts, it was estimated that about 179 tons of lead concentrate and 630 tons of zinc concentrate were not recovered. As indicated in the Introduction, although subsequent cleanup work in December of 1971 removed the bulk of the residual concentrate, a zinc concentration of 0.39 mg/L was measured in Four Mile Creek in September 1979, well above the PWQO of 0.03 mg/L and the background levels of <0.01 mg/L.

Based on electrofishing surveys undertaken on 19 June and 16 October 1979, brook trout (*Salvelinus fontinalis*), creek chub (*Semotilus atromaculatus*), mottled sculpin (*Cottus bairdi*) and white sucker (*Catostomus commersoni*) were captured at a sampling location upstream of the spill impact zone (Bowman 1979). No fish were collected at the sampling location downstream of the spill area near Northshore Road. However, in-stream toxicity testing involving a 24-hr exposure of creek chub documented no apparent acute toxicity and/or abnormal behaviour in the fish at either sampling location.

Two potential pathways for ongoing zinc loadings to Four Mile Creek were surface runoff from the spill site to an existing drainage channel flowing into the creek, and percolation into the ground water with subsequent discharge to the creek. Beak Consultants Limited (1980) reported zinc levels in the spill area soils ranging from 0.01 to 47.9% (100-479,000 µg/g). Downgradient of the spill area, a large alluvial fan was present within a vegetation kill zone. Zinc levels in the alluvial fan sediments ranged from 630 to 3,300 µg/g. In contrast, a guideline concentration of 600 µg/g has been established by the MOEE for the clean-up of soils contaminated by zinc (Ontario Ministry of the Environment 1989). The nature of the deposits and the number of dead trees indicated that this alluvial fan was a recent depositional feature. Zinc concentrations in seepage and ditch water ranged from 5.3 to 300 mg/L, whereas in the groundwater, levels ranged from 5.89 to 280 mg Zn/L (Beak Consultants Limited 1980). In contrast, Bowen (1966) reported an optimum zinc concentration range of 0.02 to 0.2 mg/L for angiosperm growth in nutrient solutions. Hunter and Vergnano (1953) found that oat plants were stunted and very chlorotic when exposed to zinc concentrations of 100 to 150 mg/L in nutrient solutions added to sand cultures. Beak Consultants Limited (1980) recommended the excavation and removal of all residual spilled contaminants; excavation of a single ditch channel through the alluvial fan to reduce sediment-water interaction; the addition of limestone to neutralize the soils; and revegetation of the exposed areas to decrease erosion.

In the fall of 1980 and in 1981, the MOEE undertook water quality, toxicity and fisheries studies to evaluate the cleanup undertaken by the ONR in 1980 (Bowman 1982; Flood 1982; Bowman and Linquist 1984). The mean zinc concentrations in Four Mile Creek at the Northshore Road crossing were significantly lower (0.14 ± 0.5 mg/L) after cleanup in 1982 than those (0.23 ± 0.09 mg/L) before cleanup (Bowman 1982). A water sample with 0.087 mg Zn/L collected in June 1981 from Four Mile Creek at Northshore Road was found to be lethal to 80% of rainbow trout (*Oncorhynchus mykiss*) fingerlings in 7-d static laboratory bioassays (Flood 1982). An in-stream exposure at Northshore Road conducted during the same week of the water collection for the laboratory bioassays produced 20% mortality of rainbow trout yearlings during a 96-h exposure period. Zinc levels during the in-stream exposure period ranged from 0.110 to 0.160 mg/L. Static laboratory bioassays of drainage ditch water indicated a 96-h LC50 of 16% v/v for rainbow trout fry when diluted with Four Mile Creek water collected upstream of the ditch outlet (Flood 1982). At this dilution, the zinc concentration was 0.170 mg/L. In a similar test using rainbow trout fingerlings, a 96-h LC50 of 0.260 mg/L was determined. In-stream exposure of brook trout yearlings to the ditch waters with zinc concentrations ranging from 0.9 to 1.0 mg/L resulted in 100% mortality over a 48-h exposure period in the early fall of 1981 (Flood 1982). In contrast, a 5-d in-stream exposure of brook trout yearlings in Four Mile Creek at Northshore Road produced no mortalities. Zinc levels in Four Mile Creek during the in-stream exposure ranged from 0.069 to 0.110 mg/L. Similarly, a number of additional static laboratory bioassays of Four Mile Creek water produced no mortalities, including 96-h exposures of rainbow trout fingerlings and 48-h exposures of *Daphnia pulex* to zinc concentrations of 0.069, 0.089 and 0.100 mg/L (Flood 1982). Finally, a 14-day zebrafish (*Brachydanio rerio*) egg hatchability and fry survival test using Four Mile Creek water with a zinc concentration of 0.069 mg/L showed no significant difference from the controls, i.e., Four Mile Creek water upstream of the spill site and Toronto tap water (Flood 1982). No fish were collected in trap-nets set in Four Mile Creek in the vicinity of the ONR spill area drainage ditch outlet, as well as at the Northshore Road crossing (Flood 1982). In contrast, brook trout, creek chub and pearl dace (*Semotilus margarita*) were collected in Four Mile Creek upstream of the drainage ditch outlet, whereas pearl dace, white sucker and pumpkinseed (*Lepomis gibbosus*) were collected downstream of the Northshore Road crossing.

The data reported by Flood (1982) were consistent with toxicity data reported in the literature. Holcombe and Andrew (1978) determined that juvenile rainbow trout were about three times more susceptible to the acute effects of zinc in soft water (about 46 mg/L as $CaCO_3$) than juvenile brook trout. The 96-h LC50s in different conditions of alkalinity and pH ranged from 0.370 to 0.756 mg Zn/L for rainbow trout, and from 1.55 to 2.42 mg Zn/L for brook trout. Sinley et al. (1975) reported a 96-h LC50 of 0.430 mg Zn/L for juvenile rainbow trout in soft water (26 mg/L as $CaCO_3$), whereas Holcombe et al. (1979) reported a 96-h LC50 of 2.000 mg Zn/L for juvenile brook trout in water with a hardness of 45 mg/L as $CaCO_3$. Holcombe et al. (1979) indicated that exposure of three generations of brook trout to a zinc concentration of 0.534 mg/L produced no significant harmful effects. Moreover, they found that the embryo-larval and early juvenile states were more sensitive to zinc than later life stages. Significantly reduced egg chorion strength and embryo survival occurred at 1.360 mg Zn/L. This effect on the chorion of trout (and salmon) eggs is important because naturally spawned eggs are buried within loose gravel and weakened eggs would be more likely to rupture by pressure or movement of the gravel than would normal eggs.

Warmwater fish species are generally more tolerant of zinc than coldwater species. For example, 96-h LC50s for bluegill (*Lepomis macrochirus*) ranged from 4.85 to 5.46 mg Zn/L (as $ZnS0_4$) in water with a hardness of 20 mg/L as $CaCO_3$ (Pickering and Henderson 1966). However, fathead minnow (*Pimephales promelas*) are more sensitive to zinc. Benoit and Holcombe (1978) reported a mean 96-h LC50 of 0.600 mg Zn/L in soft water (46 mg/L as $CaCO_3$), whereas Pickering and Henderson (1966) reported 96-h LC50s ranging from 0.78 to 0.96 mg Zn/L (as $ZnS0_4$) in soft water (20 mg/L as $CaCO_3$). Benoit and Holcombe (1978) also found that the most sensitive indicators of zinc toxicity were egg adhesiveness and fragility which were significantly affected at zinc concentrations of 0.145 mg/L and higher, but were not affected at 0.078 mg/L and lower. Pierson (1981) reported a 96-h LC50 for 5-d-old guppy (*Poecilia reticulata*) fry of 1.74 mg Zn/L in water with a mean hardness of 42.4 mg/L (as $CaCO_3$), whereas Spehar (1976) determined a 96-h LC50 of 1.500 mg/L for juvenile flagfish (*Jordanella floridae*) in water with a hardness of 44 mg/L (as $CaCO_3$). Moreover, Pierson (1981) found that at a zinc concentration of 0.607 mg/L the percentage of female guppy giving birth declined to half that of the control females, and the time until birth of the first brood increased. Finally, Biesinger and Christensen (1972) determined 48-h LC50s of 0.28 and 0.1 mg Zn/L for *D. magna* with or without food, respectively, in water with a hardness of 45.3 mg/L as $CaCO_3$. These results are generally consistent with the *D. pulex* bioassays in which no mortalities were recorded at zinc concentrations of 0.069, 0.100 and 0.089 mg/L over 48-h periods.

Revegetation of the spill site and manmade drainage channel was undertaken in 1982; however, the spill site has continued to this day to be sparsely vegetated and continues to be a source of zinc loadings to Four Mile Creek. Bowman and Linquist (1984) estimated that between 0.3 and 22.4% of the observed in-stream zinc loadings in Four Mile Creek were due to surface water inputs from the ONR derailment site. Presumably, the remainder was due to subsurface (groundwater) flows from the site to the creek.

In subsequent years after ONR derailment site remediation in 1980, the zinc concentrations levels have generally decreased in Four Mile Creek from a mean of 0.23 mg/L in 1979 to 0.033 mg/L in 1991 (see Table 1). A similar decline in zinc levels has occurred in the surface drainage from the ONR derailment site (see Table 2). As part of the current study, water samples for zinc analysis were collected from the ONR derailment area ditch and Four Mile Creek on 05 May and 14 June 1994, and 19 and 21 April 1995. The elevated zinc levels in the ditch were effectively diluted by Four Mile Creek (Table 3). The relatively elevated zinc concentration of 0.20 mg/L measured on 05 May 1994 in Four Mile Creek upstream of the ONR derailment area ditch is likely spurious, although the sampling location may have been affected by ongoing groundwater inflows.

Table 1: Zinc concentrations at Ontario Ministry of Environment and Energy Water Quality Monitoring Station near Four Mile Creek mouth

		Concentration (mg/L)		
Year	No. of Samples	Mean	S.D.	Range
1979[a]	11	0.23	0.09	0.11 - 0.34
1981[b]	12	0.14	0.05	0.09 - 0.26
1982	9	0.123	0.059	0.044 - 0.220
1983	9	0.098	0.057	<0.001- 0.220
1983[c]	8	0.126	0.069	0.045 - 0.270
1984	10	0.065	0.022	0.035 - 0.098
1985	10	0.081	0.024	0.035 - 0.120
1986	6	0.059	0.015	0.040 - 0.088
1986[d]	4	0.076	0.016	0.056 - 0.093
1987	9	0.065	0.021	0.027 - 0.089
1988	8	0.052	0.024	0.021 - 0.102
1989	8	0.052	0.015	0.028 - 0.075
1990	2	0.044	0.007	0.037 - 0.050
1991	7	0.033	0.009	0.019 - 0.044
1993	2	0.05	0.015	0.035 - 0.065
1994[e]	2	0.021	0.005	0.016 - 0.025
1995[e]	2	0.061	0.024	0.037 - 0.085

[a] Bowman (1979); sampling location at Northshore Road, about 400 m upstream of Four Mile Creek mouth.
[b] Bowman (1982); sampling location at Northshore Road.
[c] Bowman and Linquist (1984); sampling location at Northshore Road.
[d] Carbone (1988); sampling location near Four Mile Creek mouth.
[e] This study; sampling location about 50 m downstream of ONR derailment site ditch outlet.

It would appear based on available data that zinc concentrations in Four Mile Creek were high enough after the ONR derailment to result in the extirpation of the ouananiche population in Trout Lake. As indicated previously, the only documented spawning area for this population occurred in the lower reaches of Four Mile Creek. The mean zinc concentration of 0.23 mg/L recorded in 1979 (see Table 1) is about 8 times higher than the PWQO of 0.030 mg/L. It is very likely that much higher concentrations of zinc occurred in Four Mile Creek prior to 1979 particularly between 1967 (the year of derailment) and 1971 (the year of supplementary cleanup). Mean zinc levels in Four Mile Creek between 1967 and 1983 were above the U.S. Environmental Protection Agency (1980) instantaneous numerical limit for total zinc based on the following equation, which takes water hardness into account:

$$\text{Zn conc.} = e(^{0.83\,[\text{In(hardness)}] + 1.95})$$

Table 2: Zinc concentrations in ONR derailment drainage

Sampling Location:	East Seepage		West Seepage		Manmade Ditch				
Year:	1979[a]	1980[b]	1979[a]	1980[b]	1981[c]	1983[d]	1989[e]	1994[f]	1995[f]
No. of Samples:	11	3	7	10	12	7	1	4	2
Mean Zn Conc. (mg/L):	17.1	11.7	34.6	39.3	4.7	1.4	7.5	0.42	0.41
Range:	(0.64-43)	(5.3-17.8)	(16-120)	(2.2-300.0)	(0.55-20.0)	(0.4-3.1)	-	(0.26-0.66)	(0.40-0.42)

[a] Bowman (1979).
[b] Beak Consultants Limited (1980).
[c] Bowman (1982).
[d] Bowman and Linquist (1984).
[e] Cartier (1989).

Table 3: Zinc concentrations in ONR derailment site ditch and Four Mile Creek

	Zinc Concentration (mg/L)			
Sampling Location[a]	13 May 1994	14 June 1994	19 April 1995	21 April 1995
<u>ONR Derailment Ditch</u>				
FMC5-1	9.5	-	-	-
FMC5-2	0.26	0.39	0.40	0.42
FMC5-2M	0.36	0.66	-	-
<u>Four Mile Creek</u>				
FMC-1	0.20	0.014	0.022	0.056
FMC5-2I	0.015	0.055	-	-
FMC-2	0.016	0.025	0.037	0.085

[a] FMC-1: East Ditch, north of Highway No. 63 (East Ditch outlet to West Ditch was dry); FMC5-2: West Ditch, north of Highway No. 63; FMC5-2M: West Ditch outlet to Four Mile Creek; FMC5-2I: Four Mile Creek, in-stream, just downstream of ditch outlet; FMC-1: Four Mile Creek, upstream of ditch outlet; and FMC-2: Four Mile Creek, about 50 m downstream of ditch outlet.

Based on a mean water hardness of about 20 mg/L as $CaCO_3$ in Four Mile Creek (Cundari 1982; Carbone 1988), the instantaneous numerical limit for zinc would be about 0.085 mg/L. Moreover, this limit was still being exceeded occasionally between 1984 and 1988.

It is unlikely, however, that the zinc concentrations in Four Mile Creek were high enough to elicit acute toxicity in juvenile or adult salmon. For example, Carson and Carson (1972) determined an LC50 of 0.740 mg Zn/L for juvenile Atlantic salmon in soft water (hardness of 14 mg/L as $CaCO_3$). Sprague (1964a) reported an incipient lethal level (ILL) of 0.600 mg Zn/L for juvenile Atlantic salmon in soft water (hardness of 20 mg/L as $CaCO_3$). Moreover, Zitko and Carson (1977) reported that the ILL of zinc to juvenile Atlantic salmon in soft water (hardness of 14 mg/L as $CaCO_3$) varies from 0.150 to 1.0 mg/L as a function of season and developmental stage of the fish. The ILL increases from 0.500 to 1.0 mg Zn/L during the first year and decreases to 0.150 mg Zn/L in the following spring. The decrease was attributed to an increased sensitivity among the larger salmon during the initial stages of parr-smolt transformation. Farmer et al. (1979) reported that 21-d LC50 concentrations varied from 0.34 to 1.60 mg Zn/L for juvenile Atlantic salmon in soft water (hardness ranging between 12.1 and 24.4 mg/L as $CaCo_3$) and was dependent upon the size of the test fish, with smaller fish generally being more tolerant than larger fish.

Although zinc concentrations may have been high enough to cause some mortality particularly in the more sensitive life stages, e.g., fry and at parr-smolt transformation, the extirpation of ouananiche in Trout Lake was likely due to effects of zinc on spawning migration and/or egg-alevin development. Sprague (1964b) reported a threshold avoidance level of about 0.056 mg Zn/L for Atlantic salmon in soft water (hardness between 13 and 15 mg/L as $CaCO_3$). Since the mean zinc levels in Four Mile Creek were likely significantly higher than 0.056 mg/L between 1967 and 1976 (the last ouananiche record for Trout Lake), the ouananiche population may have avoided the only available spawning habitat resulting in no recruitment during those years. Although no data specific to Atlantic salmon were available, the elevated zinc concentrations may also have had a detrimental effect on egg-alevin development, assuming spawning did occur in Four Mile Creek. As indicated previously, Holcombe et al. (1979) reported that for the more tolerant brook trout the embryo-larval and early juvenile stages were more sensitive to zinc than later life stages. In particular, elevated zinc levels significantly reduced egg chorion strength and embryo survival. Beak Consultants Limited (1980) reported zinc levels ranging from 3.89 to 280 mg/L in the groundwater beneath and downgradient of the ONR derailment site. Compared to the rapid dilution of zinc loadings in surface drainage by the much higher flows of Four Mile Creek, it can be expected that the zinc concentrations remained elevated in the groundwater as it percolated through the sediment substrate prior to dilution at the sediment-water interface. As a result, any eggs and alevins buried in the sediments would be exposed to these elevated and likely acutely toxic zinc concentrations.

Zinc Concentrations in Sediment Cores in Four Mile Bay

No data are available for zinc concentrations in Four Mile Creek between 1967 and 1979. However, based on the occurrence of the concentrate spill in 1967 and site remediation in 1980, elevated discharges of zinc to Four Mile Bay can be expected to have occurred between 1967 and 1980 and subsequently these discharges progressively decreased between 1981 and 1994 (the year of sediment core collection in Four Mile Bay). During this period of zinc loadings from Four Mile Creek, the dominant process of zinc removal from the waters of Four Mile Bay was sedimentation, whereby the suspended particulate matter, with zinc sorbed to its surface, accumulated in the depositional basins. Therefore, it was expected that the zinc concentrations in the bottom sediments of the depositional basins in Four Mile Bay would reflect these zinc loadings from Four Mile Creek. That is, low (background) concentrations of zinc would occur in the deeper sediments deposited prior to 1967, with increased zinc concentrations in the sediments deposited between 1967 and 1980, and decreased zinc concentrations in the sediments deposited between 1981 and 1994.

As discussed in the Methods section, the initial sediment cores collected were too short (10 cm in length) to delineate background zinc levels, i.e., prior to the ONR derailment in 1967 (Figure 2). As a result, additional sediment cores of greater length (15 cm) were collected. Apparent background zinc concentrations (54 to 62 µg/g) were delineated below the 12 cm depth interval (Figure 2 and Table 4). The relatively sharp increase in zinc levels from 62 to 120 µg/g in the 12-13 and 11-12 cm depth intervals, respectively, likely reflects the zinc loadings associated with the ONR derailment in 1967. Subsequently, zinc concentrations in the sediment core increased from 120 µg/g in the 11-12 cm depth interval to a high of 310 µg/g in the 7-8 cm depth interval and then declined to 94 µg/g in the 0-1 cm depth interval. The marked decrease in zinc levels from 260 to 130 µg/g in the 6-7 cm and 5-6 cm depth intervals, respectively, likely reflects the final remediation of the ONR derailment site in 1980. Based on these zinc levels in the sediment cores, about 6 cm of sediment were deposited in Four Mile Bay during both periods between 1967 and 1980 and between 1981 and 1994. Since both periods were of similar duration, i.e., 13 to 14 years, there is no evidence of significant sediment deposition in Four Mile Bay after the remediation of the ONR derailment site, e.g., due to construction activities by TransCanada PipeLines Limited along the North Bay Loop during the fall of 1991. Over the period of 1967 to 1994, the sediment deposition rate in Four Mile Bay has averaged only about 5 mm per year.

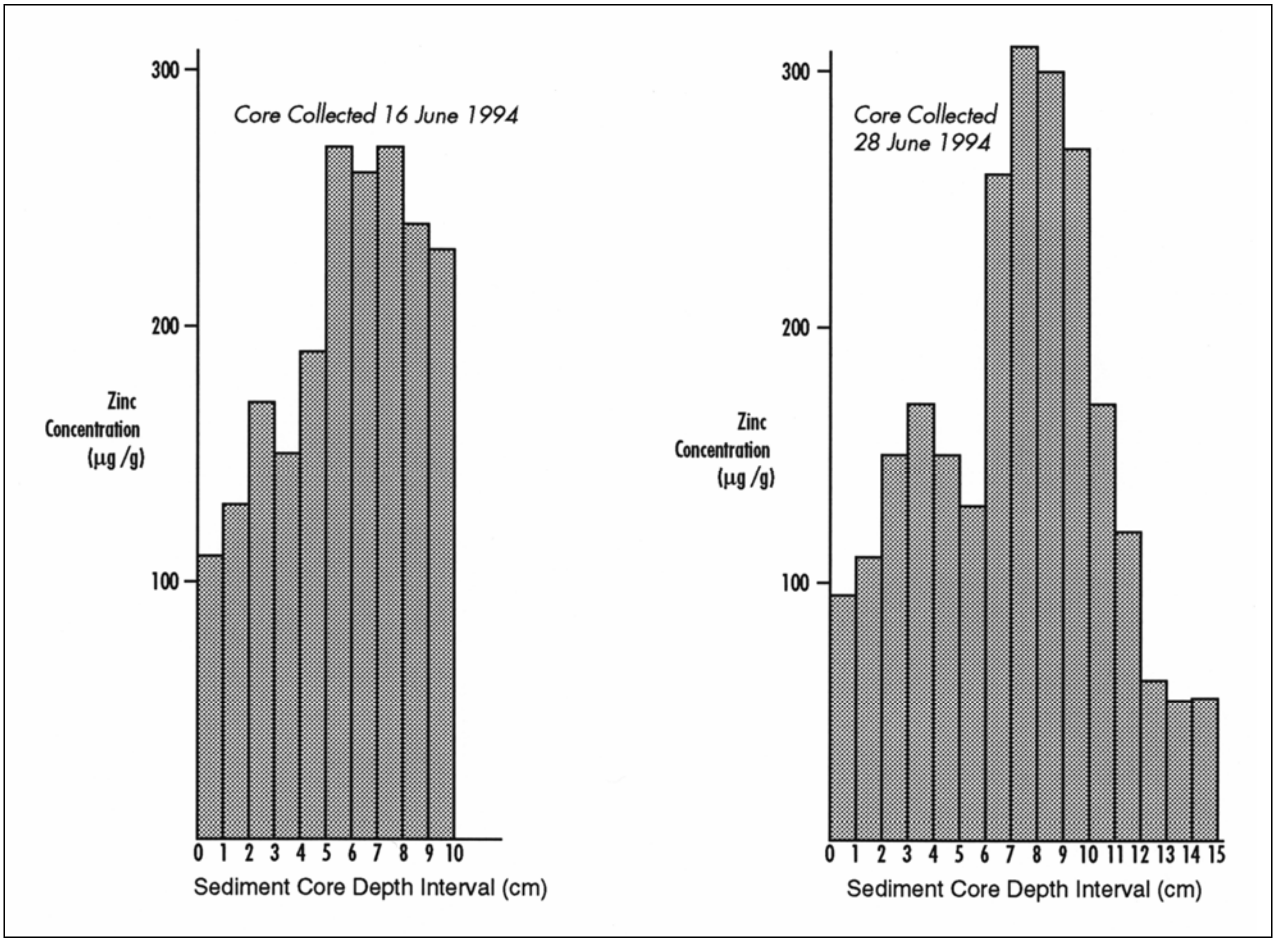

Figure 2: Zinc concentrations in sediment cores collected in Four Mile Bay.

Table 4: Zinc concentrations by depth interval in sediment core collected in Four Mile Bay on 28 June 1994

Depth Interval (cm)	Zinc Concentration (µg/g)	Estimated Year
0-1	94	1994
1-2	110	
2-3	150	
3-4	170	
4-5	150	
5-6	130	1981
6-7	260	
7-8	310	
8-9	300	
9-10	270	
10-11	170	
11-12	120	1967
12-13	62	
13-14	54	
14-15	56	

Stocking Programs

Prior to 1989, Four Mile Creek supported a coldwater fishery comprised of native brook trout, and introduced rainbow trout and Atlantic salmon (extirpated since 1976). All three salmonid species have been stocked historically by the OMNR (Conestoga Rovers & Associates Ltd. and Ecoplans Ltd. 1988). For example, brook trout were planted in Four Mile Creek between 1950 and 1970. Rainbow trout were stocked in large numbers from 1983 to at least 1987. This stocking program was to be discontinued if ouananiche were successfully re-introduced to Trout Lake. As indicated in the Introduction, stocking of Atlantic salmon, initiated in 1935, resulted in the establishment of a self-perpetuating population in Trout Lake, which was extirpated subsequent to the ONR derailment in 1967.

With the recent decline in zinc concentrations in Four Mile Creek, the OMNR initiated a stocking program for Atlantic salmon in an attempt to re-establish this species in Trout Lake. This stocking program is summarized in Table 5. Based on one or two years of lake residence, a spawning run of sexually mature ouananiche was expected to occur in the fall of 1992 and/or 1993.

Table 5: Atlantic salmon stocking chronology for Four Mile Creek[a]

Year of Stocking	Number and Description of Stocked Fish	Description of Fin Clips
1989 (fall)	~10,000 fingerlings (0+) ouananiche from Grand Lake, Maine, stock	No fin clips
1990 (spring)	4,820 yearlings (1+) anadromous salmon from La Have, Nova Scotia, stock	Adipose and left ventral fins clipped
1991 (spring)	4,505 yearlings (1+) anadromous salmon from La Have, Nova Scotia, stock	Adipose and left pectoral fins clipped
1994 (spring)	~2,000 yearlings (1+) anadromous salmon from the Universtiy of Guelph, originally obtained from La Have, Nova Scotia, stock; average weight 36 g	No fin clips
1994 (24 October)	4,912 fingerlings (0+) andadromous salmon from La Have, Nova Scotia, stock; average weight 5.26 g	Adipose and left pectoral fins clipped
1995 (16 October)	~4,700 yearlings (1+) anadromous salmon from La Have, Nova Scotia, stock; average weight 13 g	Adipose fin clipped

[a] D. Maraldo, M. Gillies, OMNR North Bay District, North Bay, Ontario, personal communications.

Fisheries Resources Assessments and Ouananiche Spawning Surveys

As indicated in the Methods section, a number of qualitative and quantitative fish surveys were undertaken between the fall of 1991 and the fall of 1995 (Eakins 1995). Table 6 summarizes the presence of fish species at the various sampling locations on Four Mile Creek.

The first field survey of Four Mile Creek was undertaken on 18 October 1991 prior to the 25-26 October 1991 rainfall event in response to a request of TransCanada by the OMNR to investigate the effects of pipeline crossing construction activities on downstream fisheries habitat, particularly the spawning and rearing sanctuary area for ouananiche in the lower reaches of the creek. The entire length of the main channel of the creek was surveyed, from the creek mouth at Four Mile Bay to Four Mile Lake Road (100 m upstream of the TransCanada right-of-way crossing). Stream gradient and morphology were found to vary widely between the crossing and the stream mouth. As a result, the fish habitat is also highly variable. Fish habitat in Four Mile Creek proper can be roughly divided into seven distinct zones. The locations of these zones are shown relative to the hydrograph presented in Figure 3. A general description of the habitat in each zone is provided in Table 7.

Table 6: Summary of fish species collected/observed in Four Mile Creek

	Sampling Location[a]																			
Species	F2a	F2b	F2c	F2d	F2e	F2f	F2g	F2h	F2i	F2j	F2k	F2l	F2m	F2n	F2o	F2p	F2q	F2r	F2s	F2t
Rainbow trout (*Oncorhynchus mykiss*)												X	X	X	X	X	X			
Ouananiche (*Salmo salar*)														X	X	X	X	X		
Brook trout (*Salvelinus fontinalis*)									X	X	X	X	X	X	X	X	X	X		
Central mudminnow (*Umbra limi*)		N	X	N			X			X	X	X			X	X	X	X	N	
Northern pike (*Esox lucius*)		o		o												X			o	X
Blacknose dace (*Rhinichthys atratulus*)			X		X	X	X		X	X	X	X	X	X	X	X	X	X		
Northern redbelly dace (*Phoxinus eos*)		f		f	X					X	X								f	
Finescale dace (*P. neogaeus*)		i		i	X	X													i	
Pearl dace (*Semotilus margarita*)		s		s														X	s	
Creek chub (*S. atromaculatus*)	X	h	X	h	X	X	X	X	X	X	X	X	X		X	X	X	X	h	
Blacknose shiner (*Notropis heterolepis*)																	X			
Common shiner (*Luxilus cornutus*)	X	c		o									X		X	X	X	X	s	
Lake chub (*Couesius plumbeus*)		o		b												X			a	
Bluntnose minnow (*Pimephales notatus*)		l		s									X					X	m	
Brassy minnow (*Hybognathus hankinsoni*)		l		e														X	p	
White sucker (*Catostomus commersoni*)		e		r	X							X	X			X	X	X	l	
Brown bullhead (*Ameiurus nebulosus*)		c		v						X	X				X	X			i	
Brook stickleback (*Culaea inconstans*)		t		e			X				X								n	
Pumpkinseed (*Lepomis gibbosus*)		e		d						X									g	X
Smallmouth bass (*Micropterus dolomieu*)		d														X	X			
Largemouth bass (*M. salmoides*)																				X
Yellow perch (*Perca flavescens*)																	X			
Johnny darter (*Etheostoma nigrum*)															X		X	X		
Logperch (*Percina caprodes*)																	X	X		
Mottled sculpin (*Cottus bairdi*)															X	X	X	X		
Slimy sculpin (*C. cognatus*)									X	X	X	X	X	X	X	X	X	X		

[a] See Figure 4

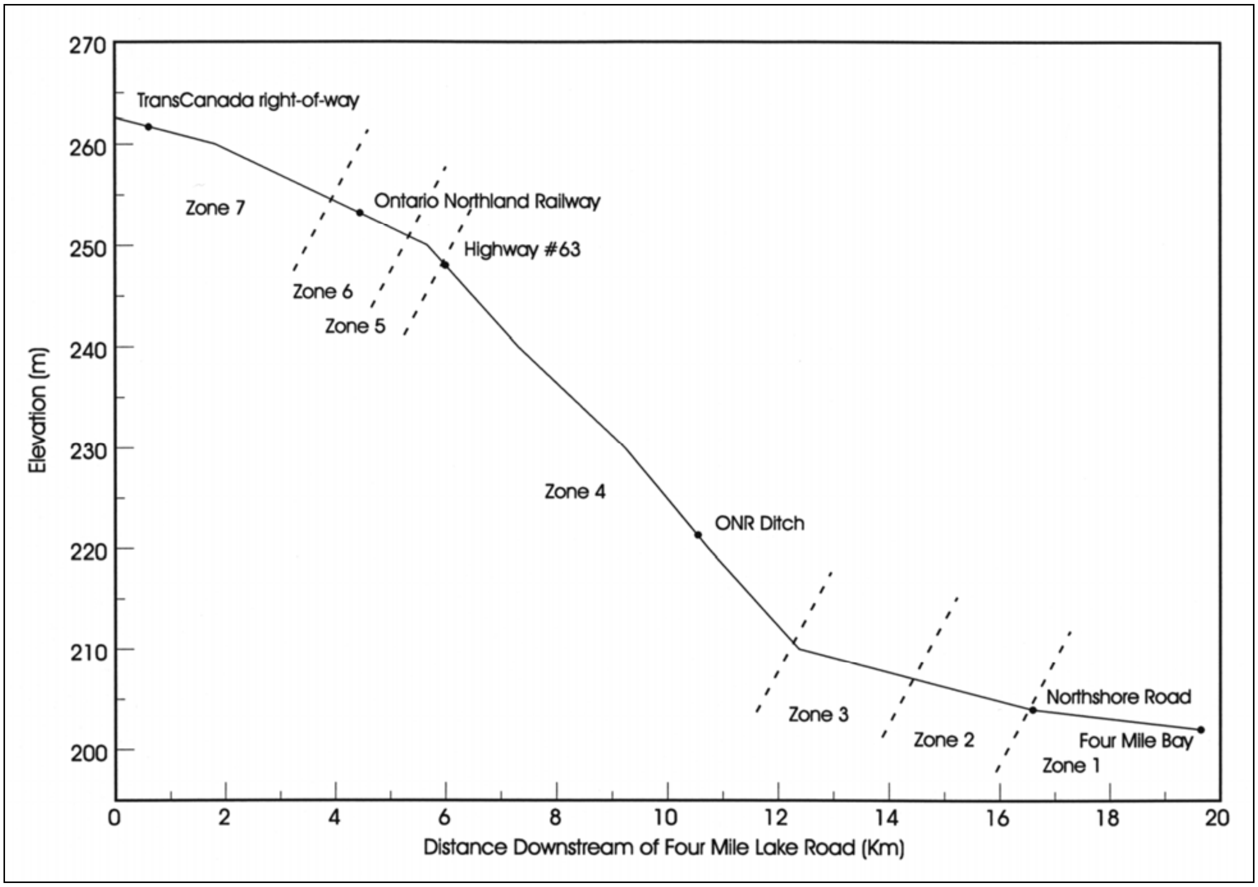

Figure 3: Gradient profile of Four Mile Creek. Fish habitat in Four Mile Creek proper can be roughly divided into seven distinct zones (see Table 7).

Electrofishing on 18 October 1991 and again on 11 and 12 November 1991 after the 24-27 October 1991 rainfall event was undertaken at Sampling Location F2o (see Figure 4) in Zone 4 (downstream of the ONR derailment site ditch outlet). Species composition and relative abundance were similar during both surveys, indicating no effects of antecedent short-term turbidity events. All captured ouananiche appeared healthy and full-bodied. The ouananiche appeared to be comprised of two separate age classes and different stocks. Some fish were comparatively large (25-30 cm) and had typical ouananiche markings and colouration. These parr (2+) were not fin-clipped. Some fish from this stock were subsequently determined to be stream residents. The smaller (12-20 cm) salmon had parr markings and colouration more typical of a juvenile anadromous Atlantic salmon. These fish had adipose and left pectoral fin-clips. The biology of this salmon species suggested that most of these parr would overwinter in Four Mile Creek before migrating to Four Mile Bay next spring as smolts. Rainbow trout fry (0+) were also present, but were of much lower abundance than ouananiche. These fry appeared to be progeny of reproduction in Four Mile Creek. The brook trout collected were resident juveniles and adults. Based on these qualitative fisheries surveys, it was concluded that construction activities associated with the North Bay Loop had no perceptible impact on the salmonid populations of Four Mile Creek.

Table 7: Characteristics of fish habitat zones in Four Mile Creek proper

Zone[a]	Description
1	High order; low gradient; meandering sections with fluvial deposition; banks and substrate are soft sand and silt with high erosion potential; dense riparian alder; this reach is a migration zone for ouananiche
2	Low to moderate gradient section with silt, sand and gravel substrate; deep pools, runs, flats and some riffles are present; good riparian and in-stream cover are present; this reach provides adult holding pools and marginal spawning, nursery and rearing habitats
3	Low to moderate gradient section with good exposure to runs, riffles, flats and pools; substrate is primarily gravel, cobble and sand; moderately dense riparian cover; many logs/logjams provide in-stream cover; this zone provides excellent spawning habitat as well as good nursery and moderate rearing habitats
4	Moderate/high gradient section dominated by boulder/cobble riffles/runs; this zone provides ideal rearing habitat as well as marginal nursery and pocket spawning habitats
5	High gradient section which is dominated by steep bedrock steps, large boulders, some riffles and logs; substrate is primarily bedrock; this reach is a potential obstacle for upstream migration of juvenile salmon; moderate rearing habitat is present in this zone
6	Moderate gradient section which also is dominated by cobble riffles with ample bouldery in-stream cover; this zone provides salmon rearing habitat which may not be utilized due to the potential migration barrier downstream
7	Low gradient section which is dominated by beaver activity; reduced flow velocity; substrate consists of sand and silt, interspersed with small cobble/gravel riffles; this zone provides marginal ouananiche habitat

[a] See Figure 3.

More extensive fisheries surveys of Four Mile Creek were undertaken on 02 and 03 June 1992 and on 14 and 15 October 1992 to further investigate the effects, if any, of pipeline construction clean-up activities on downstream fisheries habitat. Brook trout were collected at most sampling locations in Four Mile Creek, including young-of-the year (YOY) immediately downstream of the TransCanada right-of-way. Rainbow trout and Atlantic salmon were only found downstream of Highway No. 63. Rainbow trout were subsequently collected further upstream near the right-of-way in September of 1993. Four ouananiche were collected at Sampling Location F2o. Three of the fish were 20 to 24 cm in length and had no fin clips. These fish exhibited markings typical of stream resident fish and represent stock planted in Four Mile Creek as fingerlings in the fall of 1989. One smaller ouananiche exhibiting typical parr markings with clipped adipose and left pectoral fins was also collected, and was from stock planted in the creek in the spring of 1991. Ten thousand fingerlings (0+) of true ouananiche stock from Grand Lake, Maine, were planted in Four Mile Creek in the fall of 1989 (see Table 5). These fish were expected to spend two years in the creek and smolt downstream to Trout Lake in the spring of 1991. As evidenced by resident salmon collected at Sampling Location F2o in 1992, not all fish smolted. Those fish that did migrate were expected to spend one or two years in the lake, as they grew and matured. The first returning adult salmon were expected in Four Mile Creek during the fall (October and/or November) of 1992.

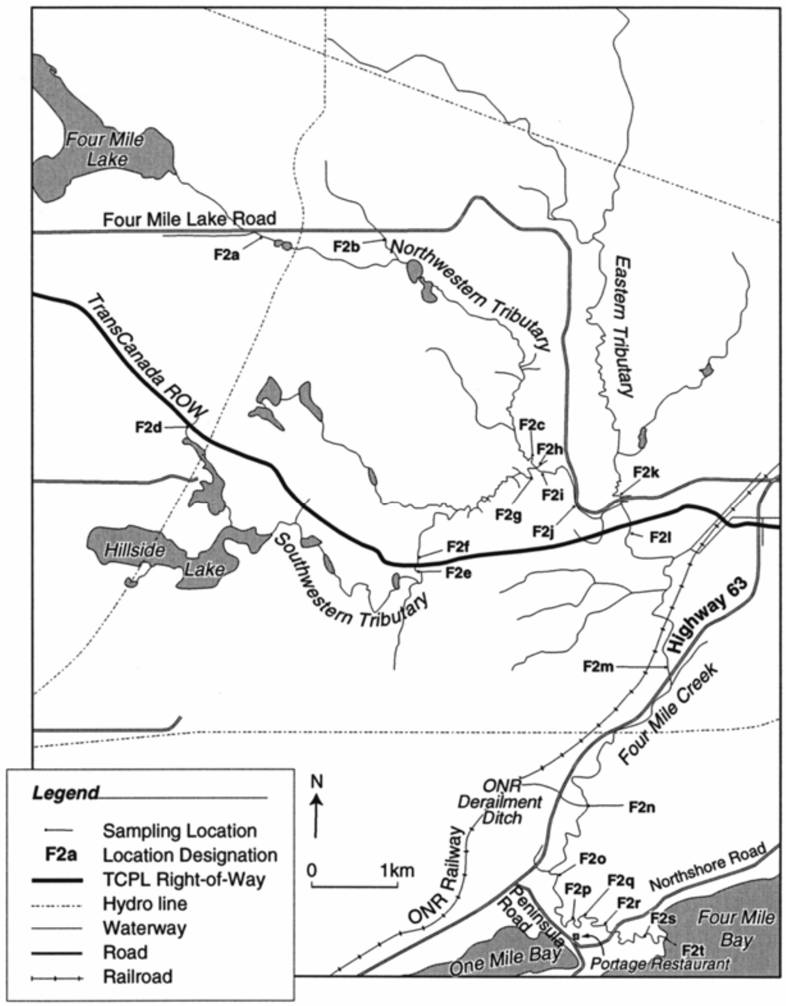

Figure 4: Four Mile Creek fisheries assessment sampling locations.

On 14 October 1992, Four Mile Creek was walked upstream from Northshore Road in an attempt to locate spawning adult salmon. The water temperature was 7.5°C. A beaver dam was observed approximately 150 m upstream of Northshore Road (Figure 5). As there was little flow over the dam and no scour pool below, this dam created a barrier to the upstream migration of returning salmon. Two other beaver dams which posed barriers to fish movements were also located further upstream (Figure 5). No salmon were observed between Northshore Road and the third beaver dam upstream. Prime spawning habitat is located behind the Portage Restaurant near Sampling Location F2q (see Figure 2), but the beaver dams located downstream were likely blocking fish from utilizing this habitat (Figure 5). Electrofishing from Northshore Road to the first beaver dam produced no salmon. The occurrence of the three beaver dams which posed a barrier to fish migration were brought to the attention of the OMNR North Bay District, which indicated that these dams would be removed.

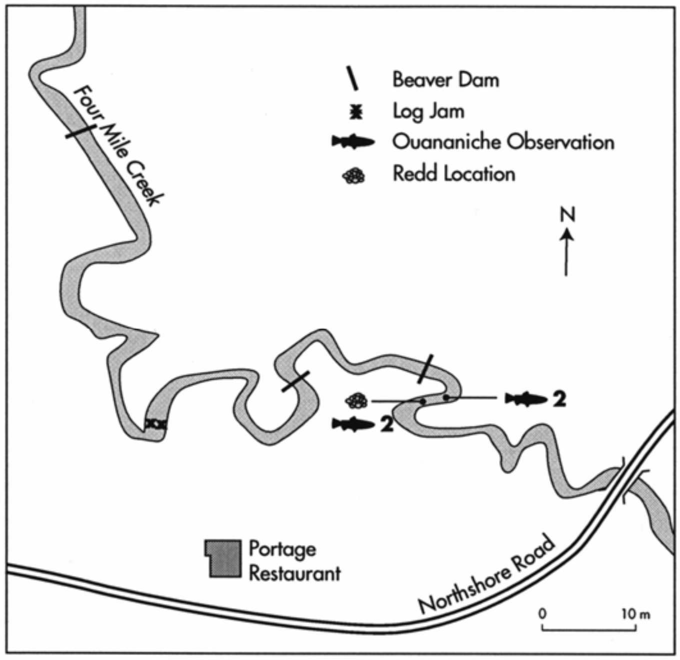

Figure 5: Adult ouananiche and redd on locations on Four Mile Creek in 1992. No ouananiche were observed between Northshore Road and the third beaver dam upstream. However, on 06 November 1992, two adult ouananiche were observed on a redd. At least, two other ouananiche appeared at times near the redd.

On 06 November 1992, a second survey of the lower Four Mile Creek, upstream of Northshore Road, was undertaken to monitor returning adult Atlantic salmon. Approximately 100 m upstream of Northshore Road (Zone 2), two adult salmon were observed on a redd (Figure 5). The redd was located downstream of a deep meander bend, above a submerged log. Pool cover was available upstream and downstream of the redd. The female was observed periodically digging the redd, while the male held in the current slightly downstream and nearshore. Occasionally, the male would side up to the female over the redd to spawn. The substrate consisted of gravel, fine gravel and coarse sand. Water depth was about 20 cm and flow velocity was approximately 0.3 m/s. The water temperature was 3.5°C. The redd was approximately 30 cm in diameter and 10 cm deep. The salmon had a blue/green dorsal colouring with silver on the sides. The dorsal fin, adipose fin and forked caudal fin were outlined in black. Both male and female were similar in size, estimated to be 40 to 50 cm in length and 1 kg in weight. At least two other salmon appeared at times, moving downstream from the upper pool only to be chased off by the spawning male. One of the non-spawning fish was larger than the spawning pair, while the other was smaller. The survey was continued upstream to the first beaver dam, which was to have been removed by the OMNR. However, it was determined that the beavers had repaired this dam, which was once again a barrier to migrating salmon. The other two dams located further upstream were, however, sufficiently breached to allow for fish passage. Nevertheless, no salmon were observed upstream of the first beaver dam. These observations of spawning ouananiche in Four Mile Creek (the first since salmon were extirpated almost 20 years hence) as well as the rebuilt beaver dam were reported to the

OMNR North Bay District. Four ouananiche were observed on the following day by D. Maraldo, OMNR North Bay District; however, no spawning behaviour was witnessed.

Comprehensive fisheries surveys were undertaken at additional sampling locations on Four Mile Creek in May/June and September 1993. The September survey was undertaken to determine, by the actual presence of YOY salmon, whether ouananiche spawning observed in the fall of 1992 had successfully produced fry. On 17 September 1993, brook trout comprising all age groups (YOY, juveniles and adult) were collected at Sampling Location F2l (see Figure 4), immediately downstream of the TransCanada right-of-way (Zone 7). No ouananiche were observed. The occurrence of many brook trout fry and parr indicated that important nursery habitat is present at and immediately downstream of the crossing. These findings are consistent with the findings of the previous surveys in June and October 1992. At Sampling Location F2o (see Figure 4), brook trout comprising all age groups and ouananiche were collected. The ouananiche consisted of three fry (0+) and one resident adult. None of the salmon were fin-clipped. The presence of YOY salmon confirmed that spawning which occurred in the fall of 1992 was successful. The resident salmon, which was approximately 27 cm in length, was likely a male. As has been documented with this species, some of the males do not smolt but remain in the stream for their entire lifetime (Schiefer 1971). With no fins clipped, this adult came from stock planted as fingerlings in the fall of 1989 (see Table 5) and would be over four years old and sexually mature. On 16 September 1993, brook trout, rainbow trout and ouananiche were collected at Sampling Location F2p (see Figure 4). All age groups of brook trout, five ouananiche fry (0+) and one rainbow trout fry (0+) were collected. In addition, brook trout adults, rainbow trout fry (0+) and one ouananiche fry (0+) were collected at Sampling Location F2q located downstream of Sampling Location F2p. None of the salmon were fin-clipped. The presence of YOY salmon at these locations again confirmed that spawning which occurred in the fall of 1992 was successful.

On 13 November 1993, a visual assessment, supplemented by backpack electrofishing, was undertaken for a distance of about 350 m upstream of the Northshore Road crossing to determine whether ouananiche had again migrated from Trout Lake to spawn in Four Mile Creek. Since, the most suitable spawning habitat is located behind and upstream of the Portage Restaurant (see Figure 5), effort was concentrated in this area (Zone 3). Observations of suitable spawning areas were conducted in an attempt to locate spawning salmon. Potential salmon holding areas, e.g., deep pools and dense cover, were electrofished. The water temperature was 0.5°C. No adult ouananiche were observed spawning or captured from holding areas during the survey. One ouananiche fry (0+) and adult brook trout were captured incidentally. The beaver dam that was observed during the September 1993 survey was still present; however, a large scour pool below and sufficient water overflow allowed for easy passage by adult salmon. D. Maraldo reported that regular monitoring by OMNR staff during October and November failed to turn up any sign of adult salmon.

Since ouananiche were observed spawning in Four Mile Creek during 1992 and salmon fry (0+) were collected in 1993, a survey was undertaken on 20 October 1994 to determine if fry survived to parr (1+) and whether successful spawning occurred in 1993. As indicated above, no adult ouananiche were observed in Four Mile Creek in the fall of 1993. Fish sampling was undertaken at Sampling Location F2n (see Figure 4), upstream and downstream of the ONR derailment ditch outlet. Brook trout, rainbow trout and ouananiche were collected both upstream and immediately downstream of the ONR ditch outlet. Brook trout consisted of juveniles and adults, while rainbow trout fry, juveniles and one resident adult were also collected. One ouananiche fry (0+) and 15 parr (1+) were collected. The presence of YOY salmon confirmed that spawning had occurred in the fall of 1993 and was successful, while the abundance of parr indicated that overwinter fry survival was good. Two of the parr (1+) were extraordinarily large, and were likely stocked fish from the University of Guelph, planted as yearlings in the spring of 1994 (see Table 5). The distribution of fish was similar upstream and downstream of the ONR derailment site ditch outlet. No fish were observed within the ditch. This section of Four Mile Creek provides ideal rearing habitat for ouananiche parr (Zone 4). At Sampling Location F2p (see Figure 4), two large beaver dams were present within the sampling reach. At the time of the survey, sufficient flow was present to allow upstream passage of adult salmon. However, no adult salmon or redds were observed above the dams. Fourteen ouananiche fry (0+) and 11 parr (1+) were collected. None of the salmon were fin clipped. The presence of YOY salmon again confirmed that successful spawning occurred in the fall of 1993, while the abundance of parr indicated that fry survival was good. One of the parr (1+) was extraordinarily large, again likely a stocked fish from the University of Guelph. This section of Four Mile Creek provides excellent nursery habitat for ouananiche fry. Suitable ouananiche spawning habitat also occurs in this reach (Zone 3). Three adult ouananiche were observed in the reach associated with Sampling Location F2q (see Figure 4). One adult female was captured by electrofishing. This fish was ripe and in healthy condition. The fish had no fin clips which suggested that it came from stock planted in the fall of 1989 (see Table 5). Based on the age class evolution, this salmon would have been over five years old. No redds were observed at the time of the survey and no beaver dams had been constructed in this reach. Two ouananiche parr (1+) were also collected. Neither parr was fin-clipped; however, one parr was much larger, likely a stocked fish from the University of Guelph. This section of Four Mile Creek provides ideal spawning habitat for ouananiche (Zone 3).

A survey of returning ouananiche was again undertaken in the fall of 1994 between 20 October and 02 November 1994. A total of 16 adult ouananiche were observed in Four Mile Creek in the vicinity of the Portage Restaurant (see Figure 6). Spawning activity was confined to five locations. The two beaver dams within Zone 3 failed on 25 or 26 October 1994 due to the higher water levels resulting from an 18 mm rainfall the previous day. New gravel beds were exposed above the uppermost dam due to the resuspension of the overlying finer substrate by the increased flows and dam failure. Removal of the breached lowermost dam as well as the log jam near the Portage Restaurant was undertaken by OMNR personnel on 27 October. One adult Atlantic salmon was observed on 27 October 1994 upstream of the breached uppermost beaver dam. A possible redd site was observed on 30 October 1994 at this previous dam location. Beavers began to rebuild the lowermost dam on 30 October and by 01 November the dam was repaired resulting in the impairment of fish migration. The log jam downstream of the breached uppermost dam was removed prior to 01 November. By 02 November 1994, the rebuilt beaver dam had increased water levels upstream by more than 0.3 m.

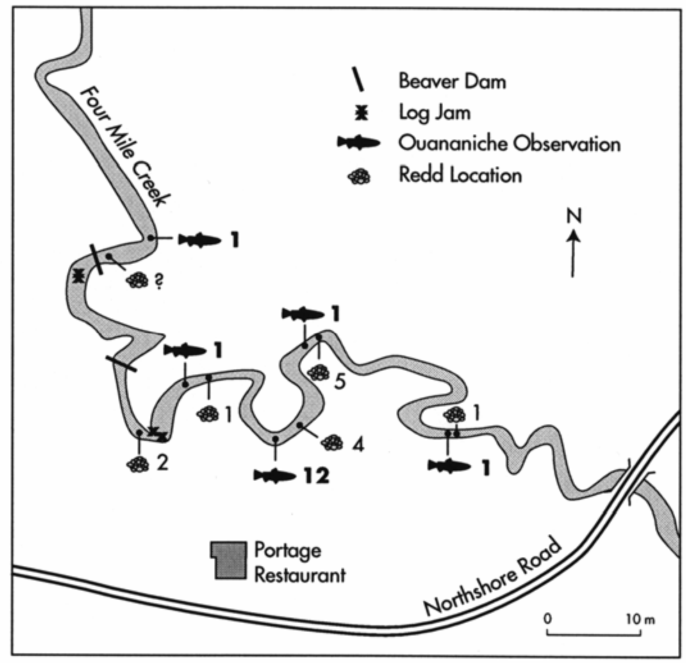

Figure 6: Adult ouananiche and redd locations on Four Mile Creek in 1994. A total of 16 adult ouananiche and five spawning locations were observed during the monitoring period between 20 October and 02 November 1994.

A final fish survey was undertaken in the fall of 1995. No adult ouananiche were collected or observed, and no redds were noted, despite the presence of abundant suitable spawning habitat, particularly in the area of Sampling Location F2q (see Figure 4). However, one grilse (2+), with no fin clips was captured at Sampling Location F2r. This fish, likely a male, had smolted to Four Mile Lake in the spring of 1995, spent the summer in the lake and returned to Four Mile Creek in the fall of 1995. This behaviour is not uncommon for males of this species (Schiefer 1971; Scott and Crossman 1973). A large number of salmon fry (0+) and parr (1+) were collected at Sampling Location F2q (Zone 3). Five parr with left pectoral fin clipped and 33 parr with adipose fin clipped were captured. Based on stocking records (see Table 5), the adipose-clipped fish were stocked on 16 October 1995 as yearlings, while the left-pectoral fin clipped fish were stocked 24 October 1994 as fingerlings (0+). Five parr (1+) and 14 fry (0+) with no fin-clips were also collected. The abundance of naturally produced fry and parr indicate successful spawning occurred in the fall of 1994 and fry over-wintering survival from the 1993 spawning was good. Brook trout (adult and juvenile) were also collected. In addition, eight salmon parr (1+) were collected at Sampling Location F2r. Seven parr were adipose fin clipped and one parr was left pectoral fin clipped. Based on stocking records (see Table 5), the adipose-clipped fish were stocked on 16 October 1995 as yearlings, while the left-pectoral fin clipped fish was stocked 24 October 1994 as a fingerling (0+). No naturally produced salmon fry or parr were collected. This observation is not surprising, since this portion of Four Mile Creek provides marginal salmon nursery habitat and no salmon fry or parr (stocked or naturally produced) had previously been encountered at Sampling Location F2r (Zone 2).

Summary

The theoretical survival of the stocked fish, based on life cycle mortality factors for this species (Carcao 1987), is presented in Table 8. A number of variables related to the introduction of an exotic anadromous species into an entirely freshwater environment, with little to no intra-specific but unquantified inter-specific competition, increase the uncertainty and potential variability of the predicted values. Therefore, a range of values, based on the lowest and highest expected survival rates, was used. This allows a relative interpretation of the values for each successive life stage year to year.

Table 8: Theoretical survival of ouananiche stocked in Four Mile Creek, 1989-1997[a]

	Life Stage			
Year	Fry	Parr	Smolt	Salmon
1989	**10,000**[b]	-	-	-
1990	-	6,070-6,820[c]	-	-
		(4,280)		
1991	-	**4,505**	1,821-3,410	-
1992	-	-	1,352-2,253	18-341
1993	-	-	-	14-225
1994	**4,912**	**2,000**	-	-
1995	-	5,314-5,684[d]	600-1,000	-
		(4,700)		
1996	?	?	1,594-2,841	6-100
1997	?	?	?	16-284

[a] Theoretical survival based on Carcao (1987), adapted from Dymond (1963) and MacCrimmon (1949), as delineated below:

Period	Survival Range
fry to parr	12.5 to 20%
parr to smolt	30 to 50%
smolt to salmon	1 to 10%

[b] Numbers of stocked salmon in **bold.**
[c] Includes 4280 salmon parr stocked in spring of 1990.
[d] Includes 4700 salmon parr stocked in fall of 1995.

Juvenile ouananiche catches between 1991 and 1995 are summarized in Table 9. During the fall of 1991, juvenile ouananiche ages 1+ and 2+ were collected. As evidenced by their fin clips (or lack thereof), fish from the 1989 and 1991 plantings were represented. The spring 1992 sampling yielded a juvenile ouananiche aged 2+ and several stream residents aged 3+. Judging by the fin clips, the juvenile salmon was from stock planted in 1991, while the resident salmon originated from stock planted in 1989. Based on the premise that ouananiche would smolt at age 2+ and spend a minimum of one year in Trout Lake, it was expected that a small run of age 3+ fish may occur in the fall of 1992. Affirming that premise, four adult ouananiche spawners were observed at and near a redd in lower Four Mile Creek on 06 November 1992 (see Figure 5). Sampling in 1993 confirmed that spawning observed the previous fall was successful, as many ouananiche fry (0+), with no fin clips were collected. One stream resident (4+) was also collected. Following the success of observing spawning salmon in 1992, it was expected that an even larger run would occur in 1993. However, no spawners were observed and none were reported by the OMNR. During 1994, spawning during the previous year was affirmed by the presence of YOY ouananiche. As well, the presence of age 1+ parr established that fry survived over the winter. Three adult ouananiche spawners were observed on 20 October 1994. One female was captured and determined to have originated from stock planted in 1989, as it had no fin clips. This fish would have been age 5+. An additional 13 adult ouananiche, as well as five spawning locations containing up to 13 redds, were observed between 21 October and 02 November 1994 (see Figure 6). During the fall of 1995, good numbers of salmon fry (0+) were captured, confirming that spawning observed in 1994 was successful. The presence of unclipped parr (1+) affirmed recruitment from the 1993 spawning. Stocked parr (1+) from both the 1994 and 1995 plantings were also collected. No spawning adults or redds were observed on 27 October 1995. Due to the lapse in stocking between 1991 and 1994, a large run in 1995 was not expected. However, one naturally produced grilse (2+) that was spawned in 1992 was captured. This salmon smolted to Four Mile Lake in the spring and returned to Four Mile Creek after one growing season.

Table 9: Age class distribution of juvenile ouananiche captured in Four Mile Creek, 1991-1995

Year	Spawners Observed	Juvenile Age Class					
		0+	1+	2+	3+	4+	5+
1991	0	0	4	3	0	0	0
1992	4	0	0	1	3[b]	0	0
1993	0	**10**[a]	0	0	0	1[b]	0
1994	16	**15**	**27**[c]	0	0	0	0
1995	0	**14**	**5**/46	**1**[d]	0	0	0

[a] **bold** denotes naturally reproduced.
[b] stream resident.
[c] includes both stocked and naturally reproduced.
[d] grilse.

Salmon are repeat spawners, which may live for more than five years of age (Scott and Crossman 1973). Spawning runs of salmon from stocks planted between 1989 and 1991 began in 1992 and were again observed in 1994. By 1996, recruitment of new spawners age 3+ from natural reproduction in 1993 and supplemented by stocking in 1994 should occur. Further recruitment will continue in 1997, comprised of naturally produced salmon observed in 1994 and salmon stocked in 1994 and 1995 (see Table 8). YOY salmon observed in 1995 will not join the spawning run until 1998 at the earliest.

A number of factors will influence or limit ouananiche production in Four Mile Creek, including interspecific competition, the extent of suitable spawning habitat, predation and adverse natural or anthropogenic environmental conditions. The survival and growth of ouananiche has been reported to be significantly lower when other salmonines are present (Jones and Stanfield 1993). However, a number of studies have suggested that juvenile Atlantic salmon are able to co-exist quite well with brook trout. In fact, brook trout and Atlantic salmon co-exist over most of their native range in Canada (Scott and Crossman 1973). Competition between these two species appears to be minimized by habitat segregation. Brook trout generally stay under cover in slower, deeper, pool-like habitats, whereas salmon parr typically occur in unshaded, shallow, fast-flowing riffle areas (Keenleyside 1962; Gibson 1965, 1966, 1973, 1981; Gibson and Keenleyside 1966; Gibson et al. 1993). The distribution of brook trout (primarily Zone 7) and ouananiche (primarily Zone 4) in Four Mile Creek conforms to these two different habitat types. Studies of dominance during agonistic encounters between Atlantic salmon and brook trout provide conflicting results (Gibson 1981; Dickson and MacCrimmon 1982). Based on available data, although salmon parr and brook trout may compete for food and space to some extent, it is not expected to seriously affect the growth or survival of either species. Rainbow trout are congeneric with Atlantic salmon and would therefore be expected to be more intense competitors for space and food than brook trout. Gibson (1981) observed rainbow trout to be more aggressive and to consistently dominate Atlantic salmon in agonistic trials. Although overlaps in habitat and food preference occur between these two species, Hearn and Kynard (1986) found that habitat segregation, with salmon parr generally occupying shallower, faster water, tends to minimize competition. However, rainbow trout may have an advantage since they spawn in the spring, i.e., after spring floods and anchor ice have scoured the gravel beds, often destroying eggs and alevins of fall spawning salmonids. Furthermore, the spawning activities of rainbow trout may result in the disruption of incubating salmon eggs or exposure of alevins. Based on the findings of this study, Four Mile Creek supports few rainbow trout. The low numbers of rainbow trout and cessation of stocking should minimize competition with ouananiche. Adult Atlantic salmon in Trout Lake would most likely be in direct competition with lake trout (*Salvelinus namaycush*) and rainbow trout for available forage fish, e.g, cisco (*Coregonus artedii*), rainbow smelt (*Osmerus mordax*), sculpins (*Cottus spp*.) and others.

The small area of available spawning habitat in the lower reaches of Four Mile Creek (Zone 3), relative to the size of available adult habitat in Trout Lake will likely significantly constrain ouananiche production. Moreover, female salmon may dig up one another's eggs while spawning in a section that is overpopulated resulting in egg mortality due to mechanical abrasion or being carried downstream.

Riley and Power (1987) surmised that fish predation on juvenile Atlantic salmon may be an important limiting factor to salmon production. The main predators of juvenile ouananiche in Four Mile Creek are likely brook trout, rainbow trout, creek chub, common shiner (*Luxilus cornutus*) and northern pike (*Esox lucius*). MacCrimmon (1954) reported that brook trout and rainbow trout preyed heavily on fry and underyearling parr when the opportunity arose, e.g, during stocking. Symons (1974) reported that juvenile Atlantic salmon without territories were more susceptible to predation by brook trout than those with territories. MacCrimmon (1954) also reported predation by common shiner and creek chub on Atlantic salmon fry and small parr, as well as by northern pike on smolts. However, Atlantic salmon parr may be less vulnerable to predation than other salmonids due to their preference for fast water (Riley and Power 1987).

A number of natural and anthropogenic factors may impact on ouananiche production in Four Mile Creek. Flooding due to heavy rainfall in the late fall or during the spring freshet may flush eggs or alevins out of the gravel. Scouring by anchor ice would have a similar effect. Freezing temperatures in the winter may kill eggs that are not adequately protected by minimum water flows. Siltation may decrease the oxygen supply to the developing eggs and alevins. In 1982, the North Bay-Mattawa Conservation Authority undertook a fish habitat reclamation study of Four Mile Creek (Cundari 1982). Based on visual inspection, a number of moderate to heavy siltation problem areas were identified in the lower reaches of Four Mile Creek, i.e., between the ONR crossing and its mouth (see Figure 4). The most severe problem areas occurred northeast of the Portage Restaurant where a very unstable bank was located; just below the drainage ditch outlet from the ONR derailment spill area; and just downstream of another very steep, unstable bank further upstream. Cundari (1982) indicated that Four Mile Creek is prone to bank undercutting because of the fast water and abundance of soft sand and gravel. Although sections of the creek provided suitable spawning habitat for salmonids, i.e., boulder, rubble and gravel substrate, many sections have been covered by silt and sand carried in from the nearby erosion sites described above. Cundari (1982) concluded that the site of the ONR cleanup was one of the main sources of heavy siltation problems further downstream. Several other erosion sites were present along the banks of the creek, e.g., steep banks, undercutting, which also exerted a heavy siltation problem on the creek.

In 1989, the North Bay-Mattawa Conservation Authority conducted a fish habitat study of Four Mile Creek from the headwaters at Four Mile Lake to its mouth (Cartier 1989). One major objective of this study was to determine the presence of heavy siltation and erosion and to develop possible corrective measures. The creek was walked from its mouth to its source at Four Mile Lake to map and determine physical stream characteristics, particularly bank stability and erosion problems. Erosion and siltation were determined to be of concern in the lower section of Four Mile Creek. Habitat analysis indicated that most of the sediment was being generated within the Provincial Fish Sanctuary. Cartier (1989) identified 19 specific erosion or migration impairment sites between the mouth and the Highway No. 63 crossing. Several unstable and eroded banks were observed. Six sites were considered to be of top priority with rehabilitation required as soon as possible. In addition, due to the poor vegetative growth, the ONR derailment spill area was a source of ongoing sediment loadings. Cartier (1989) indicated that Four Mile Creek has a "natural sedimentation problem within its lower reaches, which has been exacerbated by streambank erosion". As a result, substrate that is suitable for salmonid species has been silted over with finer material. It was concluded that erosion control work and the elimination of sources of sediment loadings were the major priorities in rehabilitating Four Mile Creek.

As part of the present study, a number of other sources of sediment loadings to Four Mile Creek and its tributaries were identified, including discharges of agricultural drainage ditches to the northwestern tributary (see Figure 4), particularly at Sampling Location F2h; surface runoff from Four Mile Creek Road near Sampling Locations F2a, F2j and F2k; major erosion gullies at the Highway No. 63 crossing associated with the guard posts; and a commercial topsoil operation near Feronia (see Figure 1). Because of the nature of the surficial deposits (i.e., soft sands and gravels), any new land development in the Four Mile Creek drainage basin, particularly near the watercourse and its tributaries, will be a potential source of sediment loadings.

A number of studies have concluded that beaver ponds on small streams are generally beneficial to resident salmonid populations (e.g., Gard 1961; Hale 1966). Following the construction of a beaver dam on a watercourse, the substrate typically changes from gravel and rubble to silt, water velocities decrease, ice conditions become less severe, and the depth and area of the aquatic habitat increase. These changes in physical environment result in profound changes in the benthic macroinvertebrate community. Although species composition changes to those less preferred by salmonids and there is decreased species diversity, much greater standing crops are present in ponds relative to the stream. The greater standing crop of benthic fauna and the unique physical environment in the pond generally result in higher salmonid populations and larger fish. However, Hale (1966) cautioned that beaver populations should be kept within reasonable numbers to optimize the production of preferred species of bottom fauna, to minimize extensive flooding and development of beaver meadows after dam wash-out, and to maximize spawning habitat. Beaver activities can negatively affect ouananiche production in Four Mile Creek in two ways. First, beaver dams can block upstream fish migration. A number of dams were observed in the fall of 1992 and 1994 in the lower reaches of Four Mile Creek and reported to OMNR North Bay District. These were subsequently breached by the OMNR to permit fish passage. Secondly, beaver dams result in upstream siltation of gravel beds, thereby eliminating spawning habitat, or burying incubating eggs. Moreover, when dams are breached by the OMNR (generally during low flow conditions) or naturally by high flows, the resultant sediment loadings may result in the siltation of spawning habitat downstream.

Finally, there is the ongoing risk of hazardous materials spills due to derailment or road accident. Three derailments have been tentatively documented in the last 35 years for the Trout Lake drainage area, which have affected water quality over an extended period of time. Elevated zinc concentrations have been recorded in Four Mile Creek and Hogan Creek due to ore concentrate spills associated with ONR derailments in 1967 and 1970, respectively. Elevated levels of copper have been consistently measured in Lees Creek possibly due to an ore train spill in the 1960s (Northland Engineering Limited and Beak Consultants Limited 1992).

Although it appears that ouananiche may once again be established as a self-sustaining population in Trout Lake, its status in the future will be dependant upon the implementation and continuation of proper regulatory enforcement, monitoring and appropriate habitat restoration and management.

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