Restoration of Stream Ecosystems

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INTRODUCTION

Maritime streams have had a long history of use as transportation routes, sources of power, waste removal and careless abuse due to poor land use practices. Almost every watershed shows the scars of numerous sawmills, grist mills, and water control dams constructed during the 1800s and early 1900s (Dunfield, 1985). Teams of horses pulling drags and later bulldozers worked streams and rivers to 'improve' them for log driving. Artificial freshets released from dams carried eight-foot saw logs and four-foot pulp logs, which scoured the beds and banks as the forest was harvested. The gravel flood plains were cleared to the banks; meadowland and marshes were dyked and drained for farmland. Power dams, many without fish passage, were constructed during the 1920s, blocking major watersheds. Even in recent years, streams have been straightened and moved to accommodate development, gravel removed for construction, gravel bars and riffles have been cleaned-out and channels straightened in the hope of improving flow and reducing damage due to ice jams and flooding.

In 1918 to 1920 and again in the 1930's, many farms were abandoned and grew up in softwoods and through the 1960s forestry turned away from log driving and water powered saw mills. Enhancement of streams for salmonids then concentrated on dam removal and the provision of fish passage at power dams and natural obstructions. Regional biologists and habitat managers felt that if they protected the fish habitats from current anthropogenic impacts, nature would quickly restore the streams to their former levels of productivity. Emphasis was placed on erosion control (during activities such as road construction), stream bank protection and land use guidelines. This approach remains the main thrust of fish habitat management programs, and with renewed public concern for the environment in the 1990s it is showing visible signs of success.

Despite improved habitat protection, salmonid populations are still under stress and are declining. The focus of stock managers remains on biotic factors such as low escapement, predation (including overfishing), competition, disease, and in some watersheds acidification due to acid rain. They hold to the view, that all things being equal, the salmonid habitat should have restored itself to historic production levels and current declines could not be the result of physical habitat degradation because of improved protection.

As part of the St. Mary's River Forestry Wildlife Project, salmonid habitats were surveyed in areas of proposed harvesting, so that the impact of modern industrial forestry on the water quality and physical salmonid habitats could be determined and mitigation measures, could be designed and implemented (Milton, 1990). The survey found that even though the streams were surrounded by sixty-year old or older forest, they were not very productive. They retained the habitat characteristics typical of degraded streams: a lack of pools, substrate embedded in silt and sand, shallow warm summer flows, ice build up during winter low flows, and a lack of summer escape cover and over wintering habitats. Habitat ratings for Brook trout (Salvelinus fontinalis) and Atlantic salmon (Salmo salar) indicated the physical habitat would support 10% - 15% of its potential, which was consistent or optimistic when compared with observed populations.

Subsequent investigations comparing highly productive habitats and those with poor production in gravel/cobble bed streams of similar size and flowing over the same geology found that the major difference was in the amount of large organic debris embedded in the substrate. Well-developed and diverse habitats had an amazingly regular pattern of embedded hardwood logs approximately six channel widths apart. This was the one ingredient that interacted with stable vegetated banks, gradient, substrate size and flows to sort gravels, develop bed forms and thalwegs (the deepest part of a stream channel cross section) needed for high productivity. Forest management practices and land use in general do not allow for this regular input of hardwood debris. The restoration technique developed from these observations is supported by extensive literature (Leopold, 1964; Hunt, 1969; Burton, 1972; Newbury, 1994).

CASE STUDY: BRIERLY BROOK

In 1992, a subwatershed restoration demonstration project was identified as a priority under the Canada/Nova Scotia Recreational Fisheries Planning Agreement. Brierly Brook, a tributary to the West River at the Town of Antigonish, Nova Scotia was selected for the project as almost a worst-case scenario. The brook was known to once have had a good population of Atlantic salmon and sea run Brook trout, which were currently in decline. Declines, in living memory, appeared to be coincident with a series of instream modifications (e.g., channelization, diversions), increasing ice jamming and flooding problems, urban development (e.g. subdivisions with little silt control, storm sewers, water pipelines, road crossings, drains, and a flow/flood control dam) all of which took place mainly during the 1960s and 1970s, but are still continuing to some extent. The watershed is 33.2 sq. km and the brook flows from the forested hills west of the town, through an area of mixed farming, subdivisions and finally through the center of town. This gave us a mix of all common land uses in the Maritimes in one small area. The riparian zone was small to non-existent along the lower half of the watershed. The forest through out is young and all significant dead wood was removed quickly especially in the lower reaches. With the exception of high-suspended solids and warm summer temperature, water quality was not a problem, and the flow regime was typical of the best streams along the Gulf of St. Lawrence shoreline. Rainfall patterns have shown a tendency toward longer dry periods in the summer and short higher intensity rainfall in storms. The study period has been characterised by extremes in weather ranging from the longest cold spell recorded in the winter of 1992/93 to the lowest rainfall over the summer in 1997.

The site is high profile, close to schools and universities, community groups, government offices and the general public; so it is an excellent education opportunity, which helps support the clean up of ongoing problems.

The project was implemented through a partnership between Fisheries and Oceans Canada, Nova Scotia Department of Fisheries, the Eastern Mainland Field Naturalist Society and Habitat Unlimited. The objective was to improve the productive capacity of the fish habitat for Atlantic salmon and Brook trout. The focus was on increasing juvenile habitat by providing low water refuges and lower silt loads. In achieving this we found that many other problems such as ice jamming, ice scour of banks, poor over winter survival of parr, poor escapement into the upper reaches and low wildlife populations were also mitigated. The objective has now broadened to restoring the health and function of the aquatic ecosystem.

THE RESTORATION PLAN

The plan was based on knowledge of the physical habitat features required by juvenile salmonids (Hynes, 1970; Raleigh, 1982); the previously mentioned observations on large organic debris and channel morphology (Leopold, 1964; Newbury 1994) which detailed how the desired pool riffle-sequence repeated every five to seven channel widths.

The brook was surveyed beginning at its confluence with the West River, which in natural watercourses represents a pool. The distances along the centre line, between noticeable changes in gradient, were noted and the channel width from the base of terrestrial vegetation on one bank, to the same position on the opposite bank, was recorded in areas where the brook had good thalweg development. Stream widths in this area averaged 8 m between vegetated banks, and the channel capacity was consistent with the one in two year flood channel. Breaks in gradient at the lower end of runs were approximately 48 m apart, the six channel widths expected. Since this time we have developed the ability to calculate the width and spacing of pools based on the one in two year flood using daily peak flows. This model works well for watersheds where we have hydrology as in Brierly, and it does confirm the size and spacing used.

The natural pattern was hard to find because of shifts created by human-made structures (exposed pipelines and bridges) and past realignment of the brook which had shortened the stream length and placed sharp turns out of pattern. However, once it was established, the pattern of a structure every six-channel widths, fit to the current natural pattern in the brook, was adhered to throughout the study section without modification to accommodate in-stream features. This spacing was adjusted as we moved up-stream to be consistent with the one in two year channel size at that point in the watershed.

IMPLEMENTATION

In the fall of 1992 the initial site at the mouth of the Brook in the town of Antigonish was installed as outlined below. Since then additional work, using the same techniques, has been undertaken on other badly degraded reaches extending upstream over 17 Km and bank rocking has been used to supplement the in-stream work at severely eroding sites.

To mimic large organic debris, which embeds itself at the change in gradient from a riffle/run to a pool, digger logs (Figure 1) were the most common device used. Where the brook was significantly wider than the design width, wing deflectors (Figure 2) were used alone, in pairs, or in combination with the digger log.

Digger logs were sized on site generally to be not more than ¼ of the bank height to the base of the vegetation. Logs averaged 15cm to 20 cm in diameter. They were placed across the stream on a preferred angle of 30° from the perpendicular. The upstream end of the log was set lower than the downstream end to concentrate low flows on the pool-side of the brook and allow for improved fish passage. Logs were drilled every 2 m to tightly accommodate a 1.5 cm rebar 1.25 m long, which was driven through the log. Fifteen centimetres of the rod was bent over to keep the log from floating up. Both ends of the log were well rocked with stream cobble and small boulder to non-vegetated channel height. A cobble/small boulder ramp was constructed on the upstream side of the log on a 2:1 slope using material from the downstream side where the pool was to form. This ramp protected the log from ice and debris damage and formed a base upon which gravels, sorted by the flow over the next couple of years, collected to form spawning and fry nursery areas. At many sites, in-stream rocks were so embedded they were unavailable, and rock had to be brought in.

Deflectors were used where the channel was over widened and were placed with the digger logs in seven locations; in pairs in four locations, and singly in seven. Twenty-five digger logs were place singly for a total of 43 locations over 2,064 metres of stream. Deflectors have a 30°-60°-90° triangle base with the 30° at the upstream bank and the 90° instream; and are shaped like the corner of a pyramid with the peak at bank height. The instream point is located so that the point-to-bank width is the design channel width. In combination with digger logs, deflectors are on the most downstream end. In the four cases where the deflectors are paired, the distance between the in-stream points is 8 m. This layout was used where the channel width was very wide (average 12.6 m) and both banks were eroding.

All devices were laid out to create pools on alternating sides of the brook to fit and emphasise the meander pattern.

In 1993 the devices were checked. Boulders and cobble which had appeared in the pool, as sands and silts moved out to the point bars, were used to improve the ramps or, in some cases, placed along the bank to allow the pool to scour deeper. These rocks were placed back in the pool to provide more in-stream cover after silts and sands have been flushed out a second time. A seed mixture of reed canary grass and 'highway mix' was placed on new bars and bare banks, along with willow cuttings. Minor bank rocking (using small boulder and cobble placed by hand) was done to protect bare banks unsuitable for planting.

DATA COLLECTION

Atlantic salmon and Brook trout habitats and populations were sampled for each life stage. These include migration, spawning, and each year class fry, one year olds (1+), two year olds (2+) and three year olds (3+).

Salmon spawn in the fall. In this brook they begin to move beginning in September and spawn in November, returning to sea before freeze up. They bury the eggs in the gravel bed of the brook up to 30cm deep in locations were the water draws down through the gravel. Young hatch the following spring remaining in the river usually changing into smolts and moving to sea the spring they turn two but some stay and leave in the spring when they are three or even four years old. Spawners return to the same brook after one, two or three years at sea.

Brook trout have a similar life history and may go to sea when they are about 10 - 15 cm in length and only for a few months at a time. If there are a lot of fish of this size in a small brook there will not be enough habitat during low flow periods or through the winter and the fish then move to sea. Some stocks appear to be more inclined to do this than others, but the objective in sea trout stream restoration is to develop habitats suitable to raise large numbers of trout to the 15cm size. This is also the same habitat needed for Atlantic salmon but with more instream cover.

A habitat survey was conducted,in the fall of 1992, prior to the installation of the devices to determine average maximum water temperature in the warmest summer period, average thalweg depth, percent in-stream cover, quality and quantity of spawning gravel, percent overwinter habitat, escape cover, dominant substrate type in riffle/run areas, percent pools during low flow, bank vegetation, pool class, percent fines in spawning and riffle/run areas, and percent shade (Hamilton, 1984). This survey was repeated in 1993 and observations on the changes of the habitat variables have been on an annual basis.

Electrofishing was conducted in each year from 1992 to 1998 using a Smith Root Mark 12 electrofisher, following the Schnabel method (Kaebs, 1989). This was initially done at two sites, then expanded in later years as more restoration was completed. A control site was established at the mouth of the brook, adjacent to and downstream of the restoration site. A second control site was chosen approximately 4.5 km above the uppermost structure. All fish captured were identified and measured. Electrofishing was repeated annually at the same sites.

Salmon redd surveys were conducted along the improved section and control sites. This survey was conducted by walking the stream and noting the location of spawners and redds on a bi-weekly basis throughout the fall beginning when the first signs of spawning were noted and continuing until no new activity was observed.

All data collection has been done or directly supervised by the authors to maintain consistency of methodology, technique, and observation quality.

RESULTS

Physical Habitat

Habitat survey information was interpreted using the Brook Trout Habitat Suitability Index (Raleigh, 1982), and a habitat suitability index for Atlantic salmon based on microhabitat studies in regional rivers (Morantz, 1987). These indexes rate the physical and chemical parameters, which commonly affect productivity, on a scale for 0.00 to 1.00. These variables were then combined to give suitability rating for each life stage. This rating is closely correlated to population but can not predict the standing crop of fish since the model does not include the biological factors, off site physical factors or predation. Never the less, it is a good indicator of a site's productive capacity or potential to produce these species.

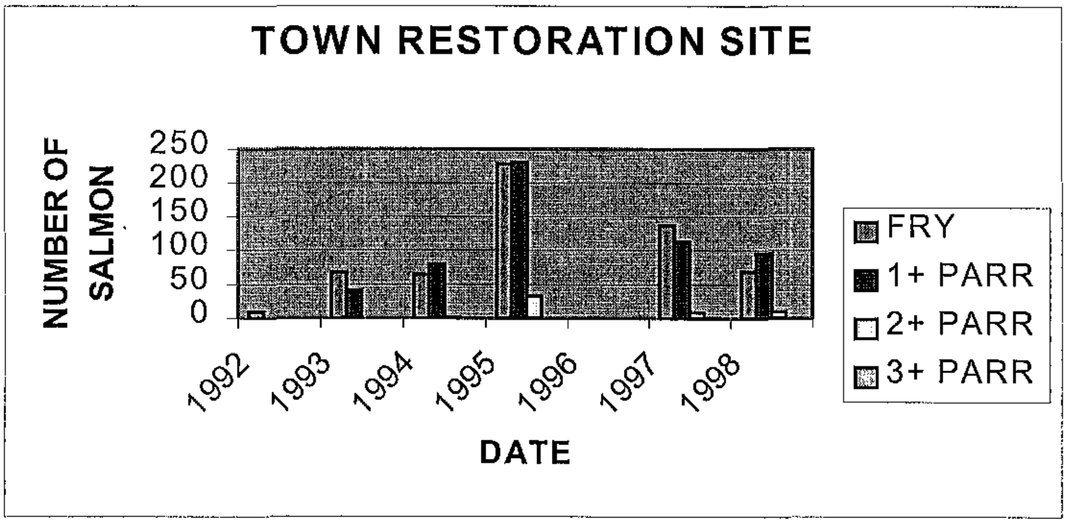
In 1992, adult trout habitat rated 0.20. The habitat was particularly weak in thalweg depth and percent cover, but also weak in percent pool and pool class. Juvenile trout habitat rated 0.30, with weaknesses similar to the adult habitat. Fry and spawning habitats both rated 0.00 due to the high percentage of silt and sand in the substrate, which ranged from 20% - 80% on the surface with all gravels and boulders fully embedded. Features common to all life stages were weak on summer temperature (0.20), and substrate quality (0.30), but were good for all other variables including vegetation, shade, oxygen concentration and pH. Atlantic salmon habitat had the same weaknesses, with large parr habitat 0.30, juvenile habitat 0.30, and fry and spawning habitat at 0.00. One year later in the fall of 1993, the survey was repeated with greatly improved results. Adult trout habitat rating was 0.72 with improvements in all variables but still limited by percent pool, pool class and cover. Juvenile habitat also improved to a rating of 0.79, limited by percent pool and pool class. Fry habitat improved to 0.85 limited by percent pool and spawning/embryo habitat improved to 0.83. Atlantic salmon habitat in 1993 showed even better improvement, with large parr habitat 0.77, juvenile habitat near optimum 0.96, fry habitat 0.85 and spawning/embryo habitat at 0.80. Improvements were also seen in summer temperature, which lowered to within the optimum range, and in improvements to substrate quality (0.60). This survey has not been repeated in subsequent years but observations on habitat quality indicate further improvements in pool quality affecting the trout population and overwinter habitat for older stages of salmon parr. Water temperatures have shown a further improvement as a result of restoration work upstream. Fish populations require a period of years to respond to such rapid increases in habitat quality. Initially there is a slight increase in population due to immigration then as the population grows it fills the stream habitat.

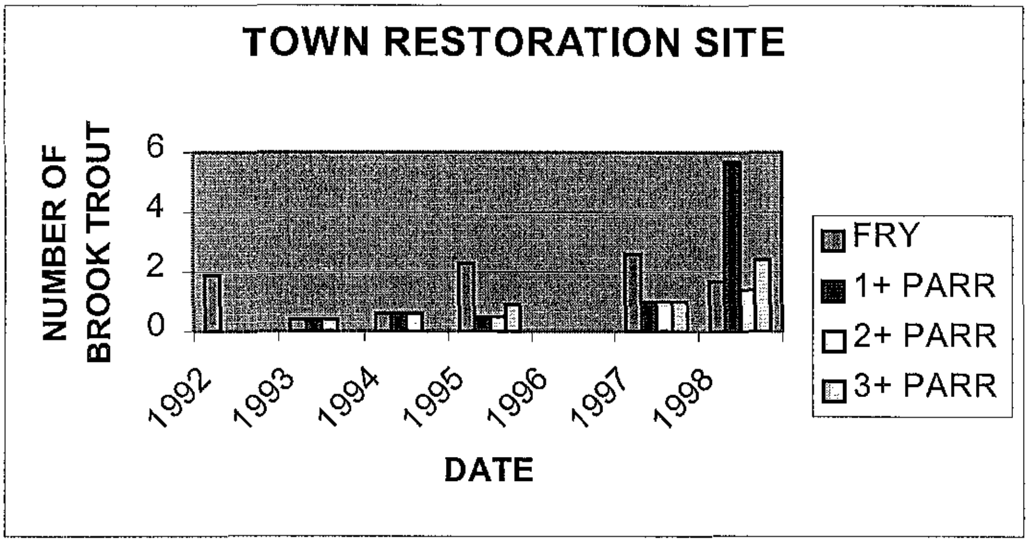
Electrofishing

The following tables and accompanying charts (note the changing scale on the y-axis) show the salmon and trout densities at the control and restoration sites in the Town of Antigonish.

In town restoration site densities in fish/ 100m^2

	1992	1993	1994	1995	1996	1997	1998
Atl. Salmon fry	9.5	67.9	64.3	228.7	N/D	136.5	69.4
1+ parr	0.0	40.7	79.8	230.8	N/D	112.5	96.0
2+ parr	0.0	0.4	1.7	32.1	N/D	8.1	9.1
3 parr	0.0	0.3	0.6	0.5	N/D	1.0	0.0
brook trout fry	1.9	0.4	0.6	2.3	N/D	2.6	1.7
1+ parr	0.0	0.4	0.6	0.5	N/D	1.0	5.7
2+ parr	0.0	0.4	0.6	0.5	N/D	1.0	1.4
3+	0.0	0.0	0.0	0.9	N/D	1.0	2.4





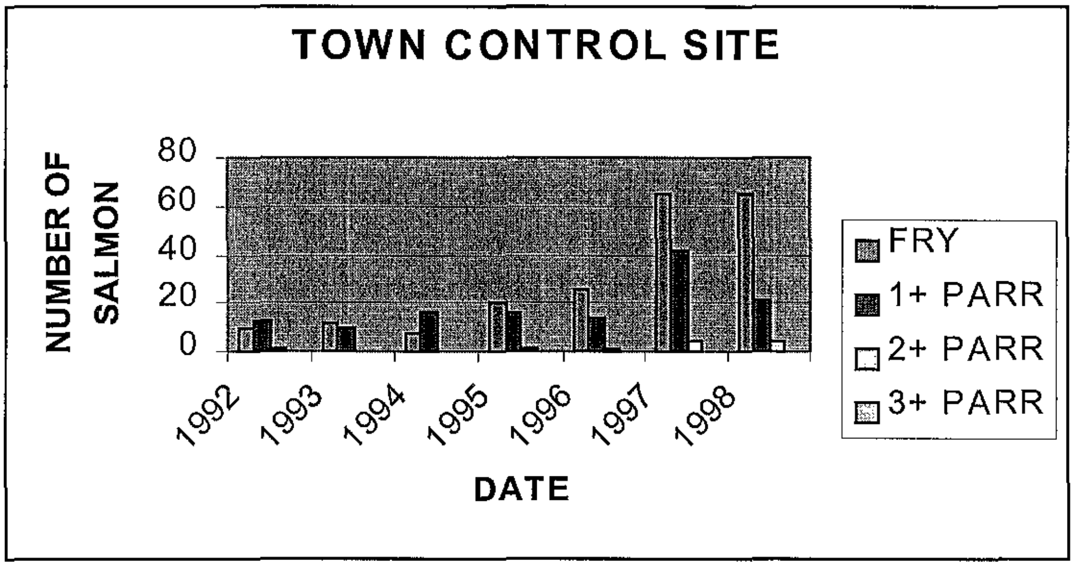
Electrofishing in the fall of 1996 was not possible due to high flows. All other 0's are actual counts

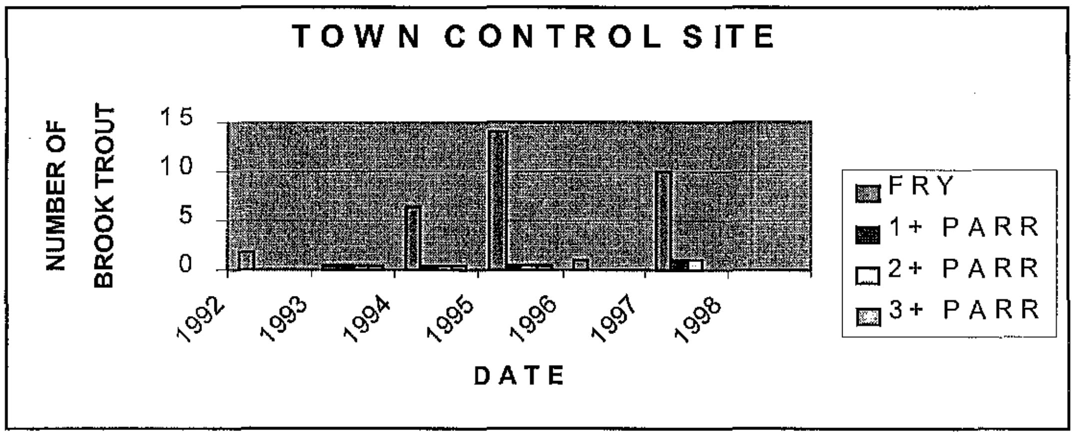
In the winter of 1996 the lower most structure and pool was partially buried by flows diverted by ice from the main river. This eliminated half of the restored electrofishing site and this can be seen in lower populations in 1997. There was a slight recovery of habitat features during 1997 but damage was caused again in the winter by flows from the main river plus mergansers beginning to feed in the site in 1998.

The in town control site changed in habitat quality each year as flows changed the bed form to give more or less water depth and small scour pools. The changes are reflected in the changing populations and age classes present. The productive capacity of this site remained low.

In town control site, poor habitat, densities in fish/ 100m^2

	1992	1993	1994	1995	1996	1997	1998
Atl. Salmon fry	9.5	11.5	7.1	20.7	25.7	65.0	64.7
1+ parr	12.4	9.5	15.5	15.9	13.6	41.4	21.2
2+ parr	0.7	0.5	0.5	1.0	0.9	4.0	4.7
3+ parr	0.2	0.5	0.5	0.5	0.0	0.0	0.0
Brook trout fry	1.9	0.5	6.5	14.1	1.0	10.0	0.0
!+ parr	0.0	0.5	0.5	0.5	0.0	1.0	0.0
2+ parr	0.0	0.5	0.5	0.5	0.0	1.0	0.0
3+	0.0	0.5	0.5	0.5	0.0	0.0	0.0



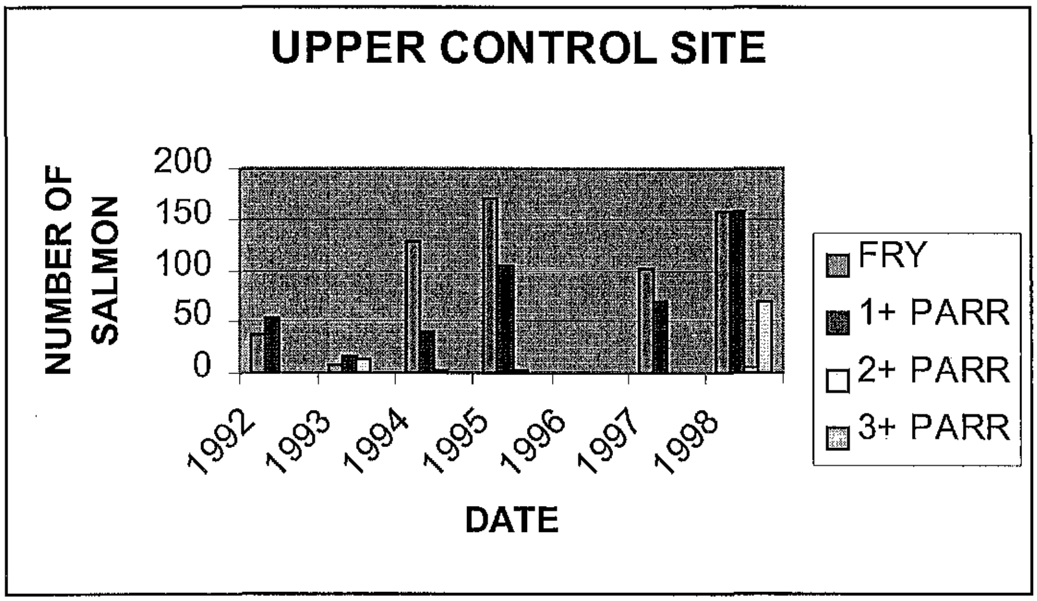


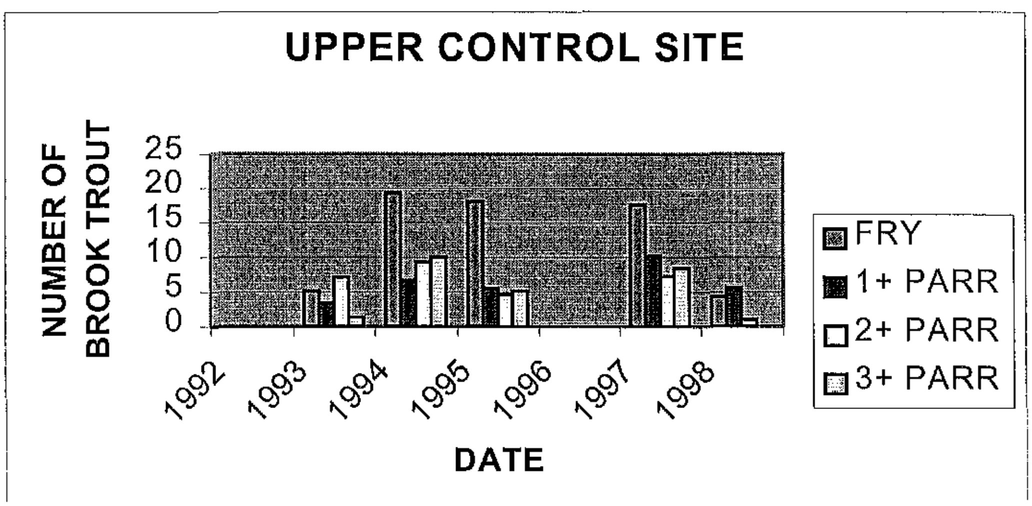
The upstream control site was considered to be good habitat but was not supporting a population that would be expected. The number of fish in the site in recent years reflects expected densities because restoration below allowed access by spawners. The drop between 1995 and 1997 reflects the improvements upstream that allowed spawner to move up further. Populations in this area have not stabilised yet and will likely move back to 1995 levels when the brook is fully stocked.

Note the increases in the trout population. These densities are among the highest in the Maritimes even though they are combined with high densities of salmon.

Upstream control site, good habitat, densities in fish/ $100m^2$

	1992	1993	1994	1995	1996	1997	1998
Atl. Salmon fry	36.1	6.7	126.8	170.8	N/D	102.0	156.7
1+ parr	54.4	16.1	41.1	104.3	N/D	70.0	63.0
2+ parr	1.0	13.5	4.0	1.5	N/D	1.0	5.9
3+ parr	0.3	0.2	0.3	0.3	N/D	0.0	68.9
brook trout fry	0.0	5.1	19.3	18.1	18.9	17.6	4.3
1+ parr	0.0	3.5	6.7	5.5	25.6	10.2	5.6
2+ parr	0.0	7.2	9.3	4.6	16.7	7.3	1.0
3+	0.0	1.3	10.0	5.1	1.3	8.5	0.0



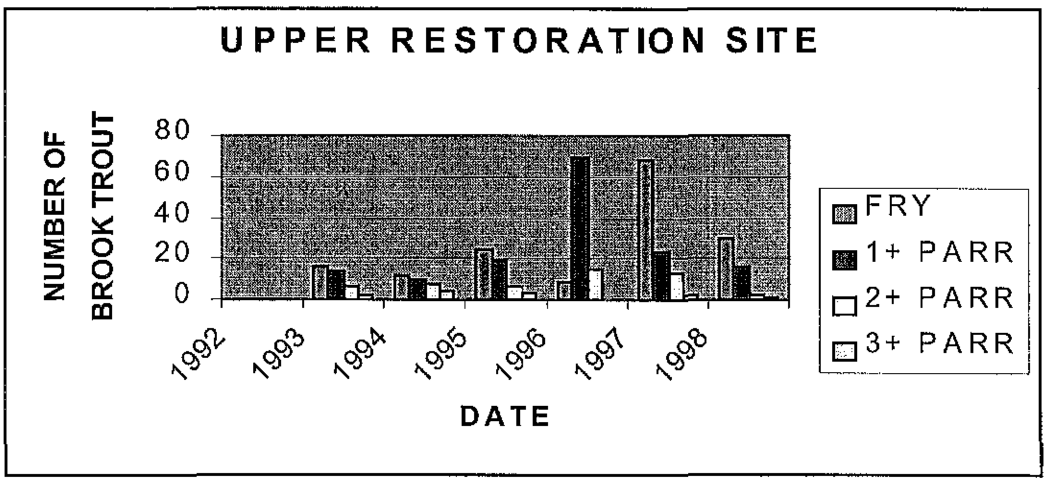


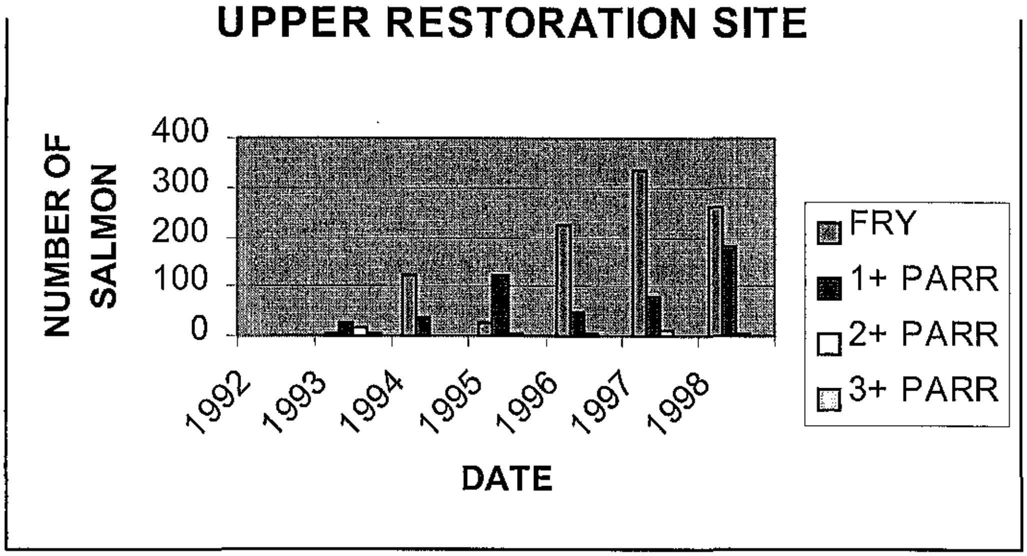
This site, located 13.4 km from the mouth of the brook was restored in 1993 and is in a steep forested section. The stream is typically described as a trout stream and many salmon biologists have been surprised to find salmon in this reach. Salmon densities have fluctuated with access though the lower sections.

Again like the control site below we have high trout populations with the salmon.

Upper Brierly Restoration Site

	1992	1993	1994	1995	1996	1997	1998
Atl. Salmon fry	N/D	4.7	120.6	24.2	224.0	335.0	260.0
1+ parr	N/D	27.4	38.1	123.5	47.3	79.0	182.0
2+ parr	N/D	16.1	0.4	5.0	5.9	11.7	7.2
3+ parr	N/D	3.0	0.4	0.4	0.5	1.0	0.0
Brook trout fry	N/D	16.5	11.7	24.8	8.7	68.7	29.8
1+ parr	N/D	13.6	9.4	19.4	69.0	23.2	16.4
2+ parr	N/D	6.9	7.0	6.0	15.3	13.1	2.5
3+	N/D	2.0	4.0	3.3	0	2.2	1.1

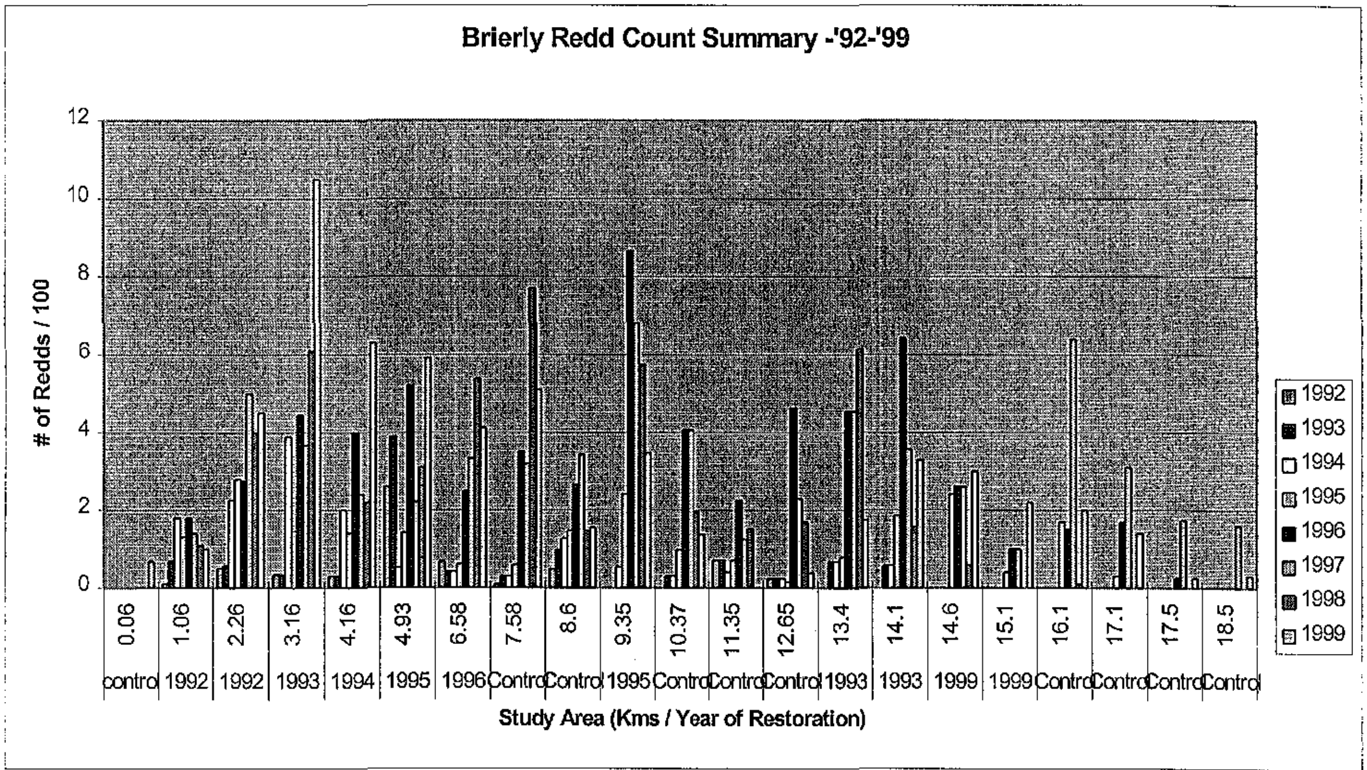




Redd Survey

NUMBER OF REDDS PER 100 LINIEAR METERS OF STREAM

Control restored	distance	Length	1992	1993	1994	1995	1996	1997	1998	1999
Control	0.06	0.06	0	0	0	0	0	0	0	0.67
1992	1.06	1	0.1	0.7	1.8	1.3	1.8	1.4	1.1	1.0
1992	2.26	1.2	0.5	0.58	2.25	2.8	2.75	5	4.0	4.5
1993	3.16	0.9	0.34	0.34	3.89	1.45	4.45	3.67	6.1	10.5
1994	4.16	1	0.3	0.3	2	1.4	4	2.4	2.2	6.3
1995	4.93	0.77	2.6	3.9	0.52	1.43	5.2	2.21	3.1	5.9
1996	6.58	1.65	0.67	0.42	0.42	0.61	2.49	3.34	5.39	4.12
Control	7.58	1	0.1	0.3	0.3	0.6	3.5	3.2	7.7	5.1
Control	8.6	1.02	0.49	0.98	1.27	1.47	2.65	3.43	1.47	1.56
1995	9.35	0.75	0	0	0.54	2.4	8.67	6.8	5.74	3.47
Control	10.37	1.01	0	0.3	0.3	0.99	4.06	4.06	1.97	1.37
Control	11.35	0.98	0.71	0.71	0.41	0.71	2.25	1.25	1.53	0
Control	12.65	1.3	0.23	0.23	0.23	0.15	4.62	2.31	1.69	0.39
1993	13.4	0.75	0	0.67	0.67	0.8	4.54	4.54	6.14	1.74
1993	14.1	0.7	0	0.57	0.57	1.86	6.43	3.57	1.57	3.29
1999	14.6	0.5	0	0	.0	2.4	2.6	2.6	0.6	3.0
1999	15.1	0.5	N/D	N/D	0	0.4	1.0	1.0	0	2.2
Control	16.1	1	N/D	N/D	0	1.7	1.5	6.4	0.1	2.0
Control	17.1	1	N/D	N/D	0	0.3	1.7	3.1	0	1.4
Control	17.5	0.4	N/D	N/D	0	0	0.25	1.75	0	0.25



Control	18.5	1	N/D	N/D	0	0	0	1.6	0	0.3

At the lowest control site, no spawning has been observed from 1991 to date. Salmon and trout juvenile populations in this area are emigrants from upstream areas. At the downstream experimental site (2,200 m long) there were no redds in 1991. The improvement devises were installed in October 1992, just prior to salmon spawning. That year, there were immediate results (0.6 redds/100m) and continuing yearly increase to 6.4 redds/100m in 1997. Similar patterns can be seen in other areas restored in later years. There is an immediate increase followed by a regular increase over the years.

The upper control areas are also showing increased spawning due to better access through formerly degraded habitats in the lower sections of Brierly Brook. This increase is not uniform with fish showing a preference for sites with large organic debris. It is important to note that prior to this instream work we did not consider the brook to have any partial barriers to migration. The immediate colonisation of the middle control area shows that spawners were returning to the brook in greater numbers than those that were reaching the spawning beds. To fully utilise the productive capacity of salmonid streams the spawners must be able to get as far up the system as possible. Fry, emerging from the redds, do not move far and must have suitable habitat. If an optimum density is exceeded then the survival of the fry could even be reduced below the optimum carrying capacity. This is a critical or limiting density dependent life stage of salmonids. If the redds are not well distributed throughout the system, fry to parr survival may limit the total population. In the other stages they are much easily distribute themselves to fill the available habitat throughout the system. Fry emerging from the redds move predominately downstream with very little upstream colonization until they are 1+. If the spawners do not move well up into the system then the rearing habitats are not fully utilized.

DISCUSSION

Brooks, like Brierly Brook, have been impacted by direct human intervention such as diversions, channelization, ice jam removal, road crossings and log driving; as well as the indirect impacts of poor land use, which results in increased sand and silt loads. Individually or in combination, these impacts have left Maritime streams approximately 20% over widened, and dominated by runs and flats with poorly sorted and embedded substrates. These brooks consistently rate poorly on salmonid habitat models, and better on white sucker (Catostomus commersoni), sculpin (Cottus cognatus) and American eel (Anguilla rostrata) models. The result is reflected in the fish populations. In the case of Brierly Brook, there were white suckers, creek chub (Semotilus atromaculatus), and sticklebacks (Gasteroteus aculeatus) present in the experimental site during the 1992 electrofishing but none were found in 1993. Chub came back in later years with much larger spawning individuals than previously seen

Restoration of the site, using digger logs to imitate the missing component of large organic debris, required these logs to be carefully placed where flows had created breaks in the gradient. This pattern was established in reaches with narrow bank widths and followed without change through the wider reaches. In our past experiments with digger logs, we found that if this pattern of six channel widths is not followed, the effectiveness of the logs is reduced, some wash out and others are buried. In the case of Brierly Brook, none of the logs were lost to natural physical causes (two were removed by vandals and three were damaged by beavers) and all are working to improve habitat. This approach works with nature to form a stable brook with more diverse habitats.

Electrofishing results are consistent with the habitat ratings and with the observed spawning. The improving conditions meet with an early response with increased number of redds although survival from these redds is likely low: the first year due to conditions which were still marginal and the sorting of gravels during this first winter. The increased fry counts are due in part to these redds, plus increased survival of migrants in the improved habitat. In the first year of a restored site large increases in parr counts is due to increased survival of migrants.

The wide shallow channel was a major factor in the warm, rapidly fluctuating water temperature which lowered habitat quality prior to 1992, and caused numerous fish kills. This channel now has a good thalweg and pools acting to stabilise temperatures. There were no fish kills in the improved sections. Previously poor thalweg development caused problems in winter, when low flows would freeze to the bottom, and minor thaws would flood over the ice and freeze, causing a thick ice build up. This created a nice skidoo trail through town, but the spring thaw lifted the ice cakes and surface gravels, skidding them downstream scouring the banks and bottom, and jamming at turns. The resulting floods brought heavy equipment, which did additional damage. The improved thalweg has made significant changes. In one of the worst winters on record in 1992/93, the brook had very little ice build up and several sections stayed open, to the disappointment of skidooers. Ice jamming has been minimal since the work was done but ice still backs up from the main river affecting the lower part of the restoration. Nearby tributaries of the West River continue to have ice jamming problems. In all restored sites the brooks never completely freeze over, preventing ice build-up, ice jams and scouring of streambeds and banks. Many eroding banks vegetated themselves naturally. (quote TUNS

In one example, 140 m of bank was proposed for riprap adjacent to a local campground. During the spring of 1993, there was no further erosion without the rip rap. Over the summer, all but 30 m revegetated naturally. The remaining 30 m was rocked by hand with small boulders and cobble, then planted.

The cleaner substrate creates a rougher bottom that will also allow the deposition of organics from the surrounding vegetation to deposit in the bottom and compost to feed the food chain. This is very important in Maritime streams which tend to be nutrient poor. Primary productivity comes mainly from leaf fall in the riparian area. This enhanced food chain is needed to support the increased fish population.

Great blue herons were a common sight along the brook in past summers, feasting on salmon parr. With improved water depth and instream cover, the fish are harder to catch and the herons have moved elsewhere.

Digger logs are more effective in a stream with this width and substrate size than deflectors at improving habitat, especially when placed at a 30° angle from the perpendicular. There is no evidence that placing them at this angle will cause bank erosion. In the work done in subsequent years, all logs were placed this way regardless of the bank condition. The digger logs cause water to scour the bottom with a plunging flow during low flows digging outward as the flows increase, producing two to four standing waves downstream during bank full flows. Fine gravels, sands and silts are layered with each freshet on the point bar which forms to narrow the channel along the bank adjacent to the downstream end of the log. During low flows, these areas can be seeded with grasses, as mentioned before, to speed up deposition. Pool and thalweg development continues throughout the year with each freshet. Fluctuating flows do the sorting, rather than just high flows. Very little material is flushed downstream; most of it is redistributed to form new banks, or the sands and silts are deposited on the flood plain. The hardwood digger logs remain wet throughout the year and do not show significant damage due to ice or moving gravels if the upstream rock ramp is well installed. The rock ramp area fills in with gravel, which is suitable for spawning. With the head difference over the log, seepage through the gravel is ideal. These areas were used by both salmon and trout, as were more traditional sites at the tail of pools. Digger logs are expected to remain for at least 25 years. The new channel should be able to handle moderate suspended silt loads, depositing them out of the main channel.

Changes in habitat quality are initially rapid, but slow as they approaches optimum levels over the next two to three years. Fish populations will follow, based on improved survival. For example Atlantic Salmon fry which hatch in 1994 will return in 1999 as grilse (one sea year salmon) and in 2000 as adults. Sea run brook trout from the 1994 hatch are expected in 1999. However the population also increases due to improved survival of the fish already in the brook when restoration is done. So adult returns begin to rise in the first few years. We have found that the brook was first fully stocked with salmon eggs in 1996 so full spawning returns are not expected until 2003.

The success of this project has acted as a catalyst for work across the Maritimes and there are now over 60 watershed projects directly restoring over 240km of stream. Each project is unique in terms of the land-use problems to be solved, stream ecosystem restoration plan, community involvement and the sources of support. Most projects are completed through partnerships between several federal, provincial and private sector funding sources, inkind support and a lot of volunteer time.

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