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Evaluating Habitat Compensation in Insular Newfoundland Rivers: What have we Learned?

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

Habitat compensation is necessitated when a development project is expected to negatively impact fish habitat. The main goal of any compensation program is to offset the lost ‘productive capacity’ which stems from the ‘no net loss’ guiding principle outlined in the Policy for the Management of Fish Habitat. In Newfoundland, a number of compensation programs have been the subject to detailed scientific evaluations. An overview of these results will be presented and discussed with respect to the ‘no net loss’ principle. The lessons learned from these projects, as well as other habitat related research, have led to some generalizations about habitat population linkages within the freshwater habitats of Newfoundland. These will be outlined to allow a discussion on moving habitat compensation from a purely ‘physical habitat’ perspective to one that focuses more on ‘production’. The change in focus will be necessary as compensation plans become more complicated.

Évaluation des activités de compensation de l'habitat dans les rivières de l'île de Terre-Neuve : qu'avons-nous appris?

RÉSUMÉ

Des activités de compensation de l'habitat sont nécessaires lorsqu'on s'attend à ce qu'un projet de développement affecte négativement l'habitat du poisson. Le principal objectif de toute activité de compensation est de compenser la perte de la « capacité de production » qui découle du principe directeur d'« aucune perte nette » énoncé dans la Politique de gestion de l'habitat du poisson. À Terre-Neuve, un certain nombre de programmes de compensation ont fait l'objet d'évaluations scientifiques détaillées. Un aperçu de ces résultats sera présenté et fera l'objet d'une discussion en ce qui concerne le principe d'« aucune perte nette ». Les leçons retenues de ces projets et d'autres recherches menées sur l'habitat ont conduit à certaines généralisations en ce qui concerne les liens entre l'habitat et les populations au sein des habitats d'eau douce de Terre-Neuve. Celles-ci seront soulignées afin de permettre une discussion sur l'évolution de la compensation de l'habitat d'un point de vue de l'« habitat physique » uniquement vers un point de vue plus axé sur la « production ». Il sera nécessaire de changer de point de vue à mesure que les plans de compensation se compliqueront.

PREAMBLE

The information in this report was presented at a review meeting on habitat compensation effectiveness that was held in late 2011 (DFO 2012). Therefore the terminology used in this report is consistent with that used prior to the changes to the *Fisheries Act* that were introduced in 2012. Despite the change in terminology, habitat restoration and creation remain viable options for offsetting of productivity (DFO 2014; Loughlin and Clarke 2014) thus the ‘lessons learned’ in the examples outlined in this report are still of interest to the fisheries protection program.

INTRODUCTION

Freshwater systems in Newfoundland are usually dilute with low nutrient concentrations and a low primary production potential (Kerekes 1974, Knoechel and Campbell 1988, Ryan and Wakeham 1984). The fish communities themselves are simple with only hyposaline species recolonating the freshwaters of insular Newfoundland after the Wisconsian Glaciation (Scott and Crossman 1964). The most abundant and widespread of these are the Atlantic salmon (*Salmo salar*) and the brook trout (*Salvelinus fontinalis*). This low species diversity has been hypothesized to promote an expansion of useable habitat for these species (Gibson et al. 1993) which has created interesting ecosystems in which to study habitat population linkages.

A number of studies have described the unique aspects of salmonid habitat use within Newfoundland and how this might be important to the overall production in Newfoundland systems (Ryan 1986; Hutchings 1986; O’Connell et al. 1990; Ryan et al. 1993; Erkinaro and Gibson 1997; Dempson et al. 1996, Cote 2007, Cote et al. 2011). Coupled with these descriptive accounts there have been many directed habitat related research projects conducted in Newfoundland. A large number of these projects have focused on the biotic effects induced by manipulating habitat to ‘improve’ conditions for salmonid production (Clarke and Scruton 2002a). The habitat related projects have tended to focus on physical habitat alterations (Bourgeois et al. 1993; Clarke et al. 2001; Mitchell et al. 1998; Scruton et al. 1997; 1998; Van Zyll de Jong et al. 1997) although research on nutrient additions have also been conducted (Clarke et al. 1997, Knoechel et al 1998). Together the descriptive work and the evaluations of habitat manipulations form a significant body of knowledge on the functionality and effectiveness of habitat within insular Newfoundland.

A great deal of this knowledge has informed habitat compensation options under the Department of Fisheries and Oceans’ “Policy for the Management of Fish Habitat” (Department of Fisheries and Oceans (DFO) 1986). Under this policy any development that encroaches on fish habitat and harmfully reduces that habitat’s ‘productive capacity’ must supply a compensation plan. These plans try to adhere to the ‘no net lost’ guiding principle of the policy and thus the proposed compensation should, in theory, replace or exceed the productive capacity lost due to the alteration or destruction of habitat by the development (DFO 1986, DFO 1998). Several of these compensation projects have been the subject of detailed scientific investigation.

The main objective of this report is thus to provide an overview of these compensation/restoration projects conducted in stream habitats of Newfoundland. The main purpose of all the projects reviewed was to either offset losses or to increase productive capacity within systems studied. The surrogate measure of productive capacity used in this evaluation is salmonid biomass except in cases where this metric does not provide a good measurement against the projects stated objectives (e.g. Compensation Creek see main text). This review highlights the lessons learned in these intensively studied projects to both inform future compensation / offsetting projects and their monitoring programs.

METHODS

This paper is an overview of past work conducted within rivers of insular Newfoundland and most of the detailed methods can be found within the individual reports. The projects used in this analysis are well distributed throughout Newfoundland (Figure 1) representing a wide variety of ecological conditions. Three of the projects were compensation projects conducted as a result of HADD determinations, Seal Cove River, Compensation Creek and Rose Blanche River. The fourth project, Pamehac Brook, was a major restoration effort aimed at rehabilitating habitat that was destroyed as a result of dewatering associated with log driving activities during forestry operations in the 1970s. Three of the projects used changes in biomass as the productive capacity metric which can be considered a population level surrogate (see Minns et al. 2011) while research in the other project focused on the functionally of the habitat as designed.

SEAL COVE RIVER

Seal Cove River was one of the first compensation projects conducted under DFO's habitat policy (Scruton 1996; Clarke and Scruton 2002b). It was necessitated due to the destruction of 162 m reach of river for highway construction. The destroyed section of river was replaced with 195 m of compensatory habitat that was directed at producing older salmonids, specifically large brook trout. This directed approach involved the construction of four large pools with interspersed riffle sections, two of the pools had 'lunker' structures installed on the outside bend of the river channel to supply overhead cover.

Salmonid biomass estimates were determined via successive removal with a backpack electrofisher. These estimates were conducted in August of each year with baseline data being collected from the original stream reach and three upstream control sites in 1988 and 1989. Post construction estimates were conducted at 9 stations within the new habitat and the three original controls stations. Post construction sampling was conducted in consecutive years from 1991 to 1994, and then re-sampled in 1999 and 2007 to cover approximately three generations of the resident fish species. Population estimates (absolute density and biomass; # 100 m^{-2} and g 100 m^{-2} respectively) were calculated via the Microfish 3.0 program developed by Van Deventer and Platts (1989), which employs a maximum likelihood (ML) estimator (Burnham formula, Van Deventer and Platts 1983).

ROSE BLANCHE COMPENSATION

A compensation project was required on the Rose Blanche River due to a hydroelectric development which resulted in the dewatering of a part of the river post reservoir creation. As part of the compensation plan, a habitat channel with controlled flow was created (modified) to compensate for the habitat loss (Scruton et al. 2005). This channel had existed prior to the project but was only wetted during high flow periods, primarily in the spring during snow melt events. Furthermore, this high flow channel was extensively scoured and contained primarily coarse substrates. The compensation works involved excavation and installation of a controlled flow culvert to ensure a constant flow over a suitable range of discharge, installation of dykes to protect the channel during high flow events, and the addition of an extensive amount of gravels to provide high quality spawning habitat within the channel.

Monitoring of the project began in the summer of 2000 two years after the opening of the compensation channel. Resident salmonids, Atlantic Salmon and Brook Trout were not introduced to the channel but were expected to stray from the mainstem populations. Biological monitoring consisted of quantitative electrofishing in eight stations in the compensation channel and three additional sites within the mainstem. Sampling was conducted in the summer (late July) and fall (October) from 2000 to 2003. A 'no net loss' calculation was conducted by comparing the estimated fish biomass being produced in the compensation habitats during each of the monitoring years with that estimated for the destroyed habitat before project construction.

PAMEHAC BROOK

The restoration of Pamehac Brook entailed the re-watering of 11 km of river that was cut off from the mainstem to facilitate log driving activities in the early 1970s (Scruton et al. 1997, 1998). The project was conceived in 1989 as a partnership arrangement between the Environmental Resources Management Association (a local conservation group), Abitibi-Price Inc. (a pulp and paper company), the Environmental Partners Fund (of Environment Canada), and DFO.

The project underwent a scientific evaluation which included a quantitative assessment of juvenile fish populations before and after the project. Fish populations were sampled by quantitative electrofishing in 1990 (pre-project) and in 1991, 1992, and 1996 (post-project). A total of eight stations were electrofished, two above the diversion and six below the diversion in the newly restored habitat. Population estimates (absolute density and biomass; # 100 m^{-2} and g 100 m^{-2} respectively) were developed using the MicroFish 3.0 program.

COMPENSATION CREEK (GRANITE CANAL HYDRO DEVELOPMENT)

The construction of the Granite Canal Hydroelectric Development resulted in the destruction of salmonid habitat utilized primarily by land locked Atlantic salmon (ouanainche) and, to a lesser extent, brook trout. Pre-development surveys suggested that the habitat destroyed was used extensively for spawning, particularly by salmon. To compensate for habitat losses, Newfoundland and Labrador Hydro (now Nalcor Energy) constructed an engineered stream complex, subsequently named Compensation Creek, which consists of a main channel that is 15 m wide and 1,600 m long and two side channels, the east side channel is 4.5 m wide and 400 m long and the west side channel which is 4.5 m wide and 570 m long. The main channel was designed to primarily provide spawning and rearing habitat for salmon while the side channels were designed for brook trout.

This project differs from the others used in this review as the investigations to date have focused on evaluating the functionality of the engineered habitats. Investigations have included an early evaluation of salmonid habitat use within the newly constructed habitat (Enders et al. 2007) and colonization of the engineered habitat by benthic macroinvertebrates (Gabriel et al. 2010). More recently, efforts have focused on evaluating the importance of the engineered habitat as a spawning site for the salmon population using Maelpeg Lake, which is the adjacent reservoir, as this was an important function of the destroyed habitat (Loughlin et al. 2016).

The portion of spawning fish using the compensatory habitat and from which areas of the lake these fish where coming from was evaluated from 2006 to 2012. In the summer or late fall of each year Atlantic salmon were captured by Fyke nets from various locations throughout Meelpaeg Lake and implanted with a 23.1 mm passive integrated transponder (PIT) tag (Texas Instruments Model RI-TRP-WRHP). PIT readers/data loggers (Model series 2000, Texas Instruments Inc.) were installed at the inlet weir and outlet of Compensation Creek to record tagged fish moving into or out of the creek during spawning season. PIT systems were in operation from September to December each year.

RESULTS

Three of the projects reviewed here monitored salmonid biomass before and after habitat alterations. Two of these projects, Seal Cove River and Pamehac Brook, conducted before/after assessments *in situ*, i.e., the evaluation used the same area before the habitat alteration as after. The other project that evaluated biomass changes, Rose Blanche River, compared the biomass observed in the destroyed habitat with that being produced in the compensatory habitat that was physically located in a different part of the watershed. Table 1 provides an overview of the change in habitat area in these projects and the resultant change in biomass. All three projects resulted in a higher biomass after the habitat alteration. Two of the projects achieved this higher biomass with relatively small increases in overall habitat area, and the third actually achieved a higher biomass with a smaller habitat area (Table 1). The following sections discuss how these increases in biomass were achieved in each of the projects.

SEAL COVE RIVER

A fisheries management objective of increasing habitat for larger salmonids was made at the outset of the Seal Cove River compensation project. The main way in which this was to be achieved was to design the compensatory habitat with a higher pool to riffle ratio than the habitat that was being replaced. The original design aimed to change the habitat from an area with approximately 1 pool unit (1 unit=100^2) for every 6.7 units of riffle habitat to an area that had one pool unit for every 3 units of riffle habitat. Early monitoring results presented in Scruton (1996) show that this objective was met and longer term monitoring has indicated that this attribute of the compensatory habitat has remained relatively stable over time, being 1 pool unit to 2.7 units of riffle habitat in 2007, the last year a full habitat survey has been conducted in the stream (Table 2). Also, since larger brook trout where the targeted species for the new habitat, half of the new pools (2 of 4) had “lunker” structures installed to provide overhanging cover, an attribute preferred by larger brook trout. Pools with ‘lunkers’ were shown to average 2.6 times the biomass of large brook trout than those without ‘lunkers’ over the post construction period (1993 to 1999; Clarke and Scruton 2002b).

Before compensation approximately 10% of the trout population using the control sites were above 150 mm in length. This proportion was even lower for the habitat to be destroyed and no fish above 200 mm in length were observed in this area of the stream (Figure 2). In 2007, almost 25% of the trout using the new habitat were above 150 mm in length while the size distributions observed in the control sites were largely unchanged (Figure 2). These larger trout were the individuals that were targeted by the new habitat designed into the compensation. These larger trout would have a large impact on the overall biomass estimates of a small stream such as Seal Cove River. Since the designed habitat attributes have remained largely intact over time, the compensatory habitat remains functional and continues to produce more fish biomass than was observed in the destroyed habitat. This has been monitored for approximately three trout generations in Seal Cove River (Figure 3).

ROSE BLANCHE COMPENSATION

The compensatory habitat in Rose Blanche River was designed to provide high quality spawning habitat with a lesser amount of rearing habitat for older individuals. The habitat in the high flow channel was modified from an area that was heavily scoured by peak flows to an area where flow was provided constantly and gravels where added to provide spawning habitats (Scruton et al. 2005). While this design was initially observed to be completed as intended there was enough spring flow from the channels small catchment to flush and move some of the gravels. This resulted in a channel that had a more diverse habitat with isolated areas of spawning habitat interspersed with rearing and overwintering habitats (See Scruton et al. 2005 for details). This movement of substrate appeared to have stabilized by the third year of operation.

Both brook trout and Atlantic salmon were utilizing the compensatory habitat in the first year of monitoring, which was the second year of channel operation (Figure 4). Young-of-the-year (YOY) brook trout were the most abundant cohort in the channel and there was some indication from the October sampling that spawning fish were entering the lower parts of the compensation habitat from the mainstem (unpub data). As the habitat stabilized, brook trout YOY production remained strong but larger individuals were also observed to be using the habitat (Figure 4). This was in some contrast to observations in the mainstem where brook trout were always observed in low numbers. This indicates that the compensatory habitat was a more preferred habitat for brook trout than the existing mainstem habitats.

Atlantic salmon were slower to utilize the compensatory habitat than brook trout, with relatively few being observed in August 2000 (Figure 4). By 2001, however, reasonable numbers of salmon were observed with all size classes being represented in the compensatory habitat (Figure 4). The age class distribution of salmon in the compensation habitat during the final two years of monitoring was similar to that observed in the mainstem (Figure 4).

As can be seen from the age class analysis the habitat and fish community was changing in the compensation habitat during our monitoring period. This was also evident when the amount of fish biomass being produced by the compensatory habitat was calculated (Figure 5). It was not until 2002, the fourth year of channel operation, that the biomass being produced by the compensation habitat exceeded that estimated for the destroyed habitat (Figure 5). Incidentally because biomass estimates are so heavily weighed by larger fish (> 2+) it is questionable if the original habitat design would have been able to achieve ‘no net loss’.

PAMEHAC BROOK

While the Pamehac Brook project was not a compensation project it is another good example of how altering habitat quality can affect fish biomass. The habitat surveys and fish population data collected allowed an estimation of the 'habitat gain' and the increase in productive capacity associated with this project. Pre-restoration fish biomass and available habitat suggested a production potential for the fluvial habitat in the watershed (for 1990) of 18.01 kg excluding standing waters and steadies (Figure 6). The average fish biomass and available habitat in 1992, two years after restoration, indicated a potential production of 51.46 kg, a 2.9 fold increase and by 1996 the production potential was 263.94 kg, a 14.7 fold increase from pre-restoration levels (Figure 6; see Scruton 1998, Clarke and Scruton 2002a for more details). It is also important to note that the biomass estimates of the restored sites did not seem to increase very quickly in the immediate period after restoration indicating a lag time was required for fish to fully exploit the new habitats.

COMPENSATION CREEK (GRANITE CANAL HYDRO DEVELOPMENT)

The evaluations of habitat functionality in Compensation Creek have generally confirmed that the habitat is functioning as designed. Enders et al. (2007) investigated habitat use and swimming speed of adult brook trout and Atlantic salmon using the compensatory habitat. They found that trout selected habitats as expected by preferring areas with undercut banks and log debris structures while avoiding faster habitats such as runs and riffles. Atlantic salmon however used riffles, runs and pools in the same proportion as available (i.e. no obvious preference) but avoided areas with undercut banks and log debris structures.

Gabriel et al. (2010) evaluated how the benthic macroinvertebrate community, a main fish food, was establishing in the side channel habitats during 2006/07, three to four years after the compensatory habitat was opened. This was conducted by comparing the benthic communities to a nearby reference stream. They found that the benthic community was well established by 2006/07 with most of the major taxa being present in the compensatory habitats (Gabriel et al. 2010).

A total of 1811 salmon were tagged with Passive Integrated Transmitters (PIT Tags) over the course of the spawning study with greater than 48%, on average, of these fish entering Compensation Creek for spawning during the year of tagging (range 34-63% yr^{-1}). This is most likely a minimum estimate as some fish have been observed to spawn in alternate years (Loughlin et al. 2016). Salmon from all areas of Maelpeg Lake that were successfully sampled migrated to Compensation Creek (Figure 7). Thus, it appears that Compensation Creek is functioning as designed and is providing spawning habitat for a large proportion of the land locked salmonid populations.

DISCUSSION

The habitat compensation/restoration projects reviewed in this paper have, for the most part, attained their main objective of increasing salmonid productive capacity. This supports the idea that the 'no net loss' guiding principle of DFO's habitat policy (DFO 1986) is an achievable goal. In two of the projects, Rose Blanche River and Seal Cove River, the testing of this concept was a major objective. In both cases 'no net loss' was deemed to have been meet within a reasonable amount of time (Scruton 1998, Clarke and Scruton 2002a, Scruton et al. 2005). Continued monitoring in Seal Cove River has also shown that the habitat changes have persisted through time and are still functioning as designed, providing enhanced areas for larger salmonids and thus an increased biomass. This observation is relatively unique in the literature as long term studies on the effectiveness of habitat manipulations are rare (Roni et al. 2008, White et al. 2011).

These projects had many similarities which can inform future compensation efforts in the rivers of Newfoundland and elsewhere. It was apparent that habitat quality was very important to the overall success of these habitat compensation/restoration projects. This was most evident in the Rose Blanche example where a relative small area of high quality habitat was able to offset a larger area of low quality habitat. Habitat quality may be easier to ascertain in Newfoundland than in areas with a diverse fish assemblage as its waters are dominated by the relatively well studied salmonids (Gibson 1987, EFW paper). One potential way to include habitat quality into compensation planning in areas with diverse fish communities may be to target the larger species within the community. These species have a tendency to be better studied, be important from a fisheries management perspective and the proportion of large fish in a community is a good indicator of ecosystem health (see Greenstreet et al. 2011) and production (Randall 2002).

Another important aspect of the examples reviewed relates to site selection. The projects all maintained connectivity within their respective watersheds to the maximum extent possible allowing free movement between the compensation habitats and the rest of the watershed. For the most part the projects were conducted within natural channels, and even in Compensation Creek which was completely man-made, the project was used to connect two parts of the watershed that would have otherwise been disconnected by the Hydro development. Connectivity has been shown to be an important component of successful restoration projects as well (Roni et al. 2008). It is important to note that the project that had the single largest increase in biomass was the restoration of Pamehac Brook (Table 1). This observation points to the need to have a good overall understanding of the watershed in which the compensation is required. There may be areas outside the generally narrow project area that are degraded and would provide more benefit to the fish communities by conducting relatively 'simple' process based restorative activities (Beechie et al. 2010).

While restoration may provide the most benefit from an ecosystem perspective, these opportunities may not always exist in the affected ecosystem. As seen in the Newfoundland examples, habitat creation can also be effective to offset losses. When creating engineered habitats local hydrological and geomorphological conditions must be taken into account (Newbury and Gaboury 1993). The failure of engineered structures has most often been attributed to the failure to consider hydraulic principles and the need to consider long term stability under hydraulic extremes (Hunt 1988; Frissell and Nawa 1992). The projects reviewed here all had hydraulic controls built into their design. In both Compensation Creek and Rose Blanche these controls were physical control structures built by the hydro projects, in Seal Cove the compensation habitat was developed in a low gradient river section just 0.5 km from a pond that reduced hydraulic extremes. Even with these controls habitat changes can and will happen in some projects (e.g. Rose Blanche) and it may take additional time for fish populations to respond to these conditions. Thus, evaluation and monitoring of habitat projects must consider this temporal aspect and design assessments accordingly (Everest et al. 1991) and should also allow for adaption until the habitat stabilizes. This becomes even more important in large complex projects where uncertainty is high (Bradford et al. 2011; Minns et al. 2011).

Research conducted on habitat compensation effectiveness is still relatively rare in Canada despite the habitat policy being released in 1986 (DFO 1986). Including the examples listed here, there have only been a handful of directed compensation projects reported on in the literature (see Jones et al. 2008, and Minns et al. 2011). Additionally, evaluations conducted on the compensation program within habitat management program have not been overly encouraging (Harper and Quigley 2005). Thus, the single biggest opportunity to gain knowledge on the effects of habitat compensation lies with the monitoring programs that are associated with the HADD authorizations.

Monitoring in the Newfoundland stream examples relied heavily on before/after assessments or in the case of Compensation Creek investigated the functionality of the designed habitat. Before/after assessments while desirable in some cases are usually problematic in proponent driven monitoring programs and may only be possible in association with the largest development projects. Testing design functionality, however, is usually easier to achieve and if the compensation design targets one of the main rates of production (i.e., recruitment, growth or mortality) then the program should be consistent with the overall guiding principle of ‘no net loss’. Ideally the data generated by these monitoring programs would be available for additional purposes such as meta-analysis which could inform both managers and proponents.

In conclusion, the biological effects of habitat manipulations either through restoration or habitat creation are usually easier to detect when the habitat provided by the project supplies areas for all size classes within the target population(s). This has been observed in Newfoundland (Clarke and Scruton 2002a) as well as globally (Roni et al .2008). Even when one subcomponent of production is targeted (e.g. recruitment) as in the Rose Blanche and Compensation Creek examples the overall functioning of the compensation habitat from a population perspective benefitted from the addition of rearing and overwintering habitats. This again points to the need for detailed information on the existing ecosystem to both supply information with respect to compensation options and to inform on the functionality of habitats in the unperturbed ecosystem.

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TABLES

Table 1: Overview of habitat changes and resultant biomass changes in three projects that conducted before/after assessments of habitat compensation/restoration in Newfoundland Rivers.

Project	Change in habitat area (%)	Change in biomass by end of monitoring (%)
Seal Cove River	+ 12 %	+ 200 %
Pamehac Brook	+ 30 %	+ 1467 %
Rose Blanche River	- 82 %	+ 28 %

Table 2: Habitat characteristics in Seal Cove River before compensation (1987) and after restoration (1993 and 2007).

-	1987	1993	2007
Total length (m)	162	195.2	194
Mean width (m)	3.42	3.51	3.21
Total Area (units)	5.54	6.85	6.23
Total pool area (units)	0.73	1.69	1.66
Total riffle area (units)	4.81	5.16	4.57
Pool-riffle ratio	**1:6.7**	**1:3.0**	**1:2.7**

FIGURES

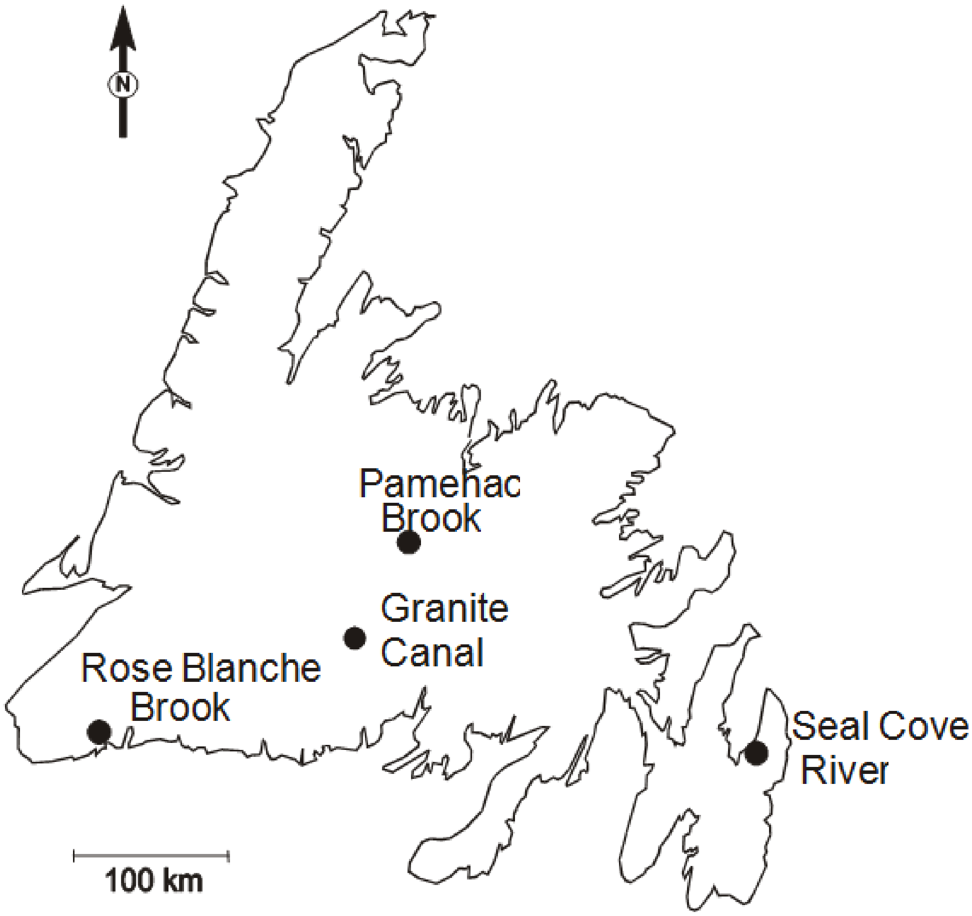

Figure 1: Location of the projects used in this analysis.

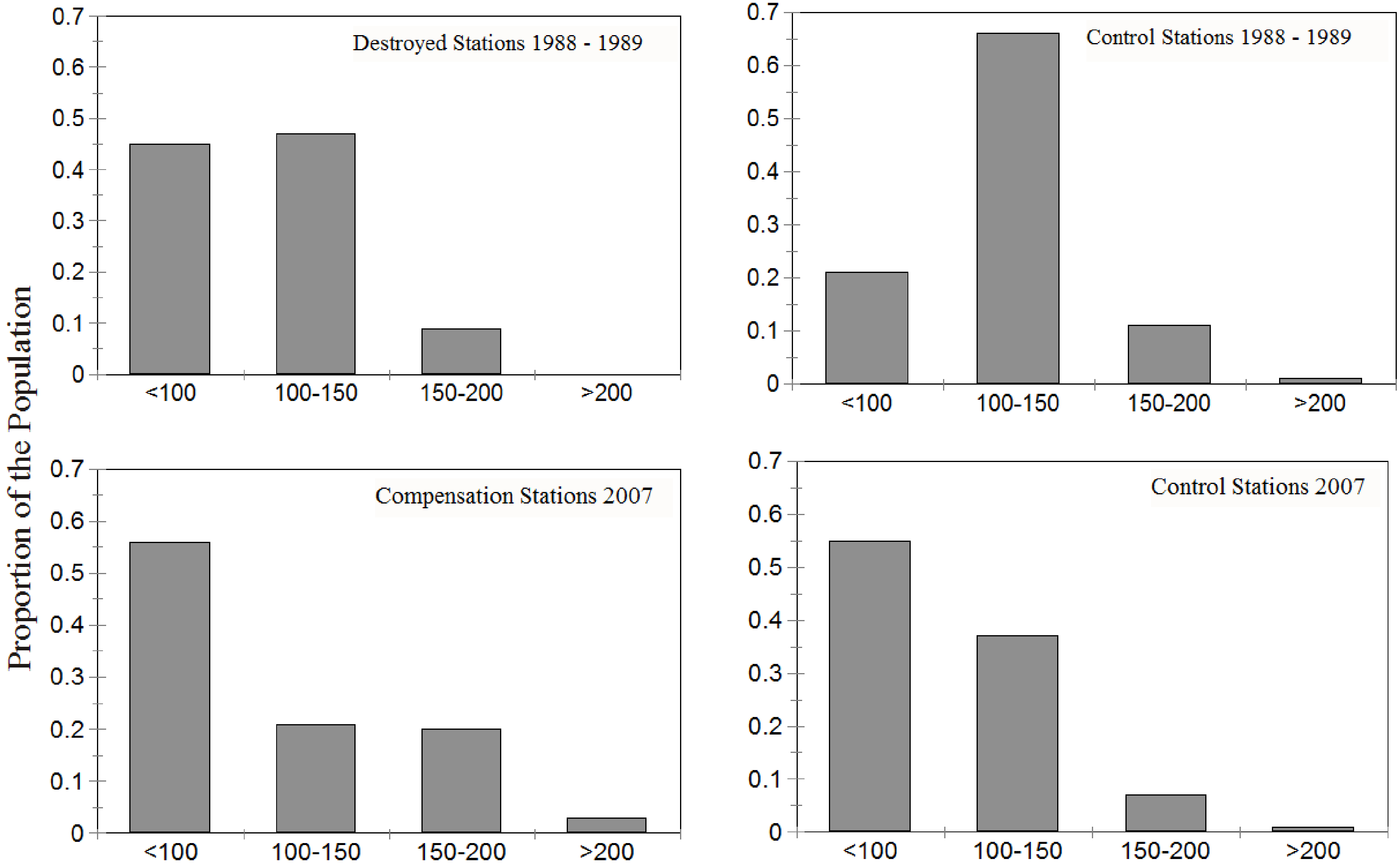

Figure 2: Brook trout size frequencies in Seal Cove River in the destroyed habitat and control station pre-compensation and in the new habitat and the same control stations during 2007.

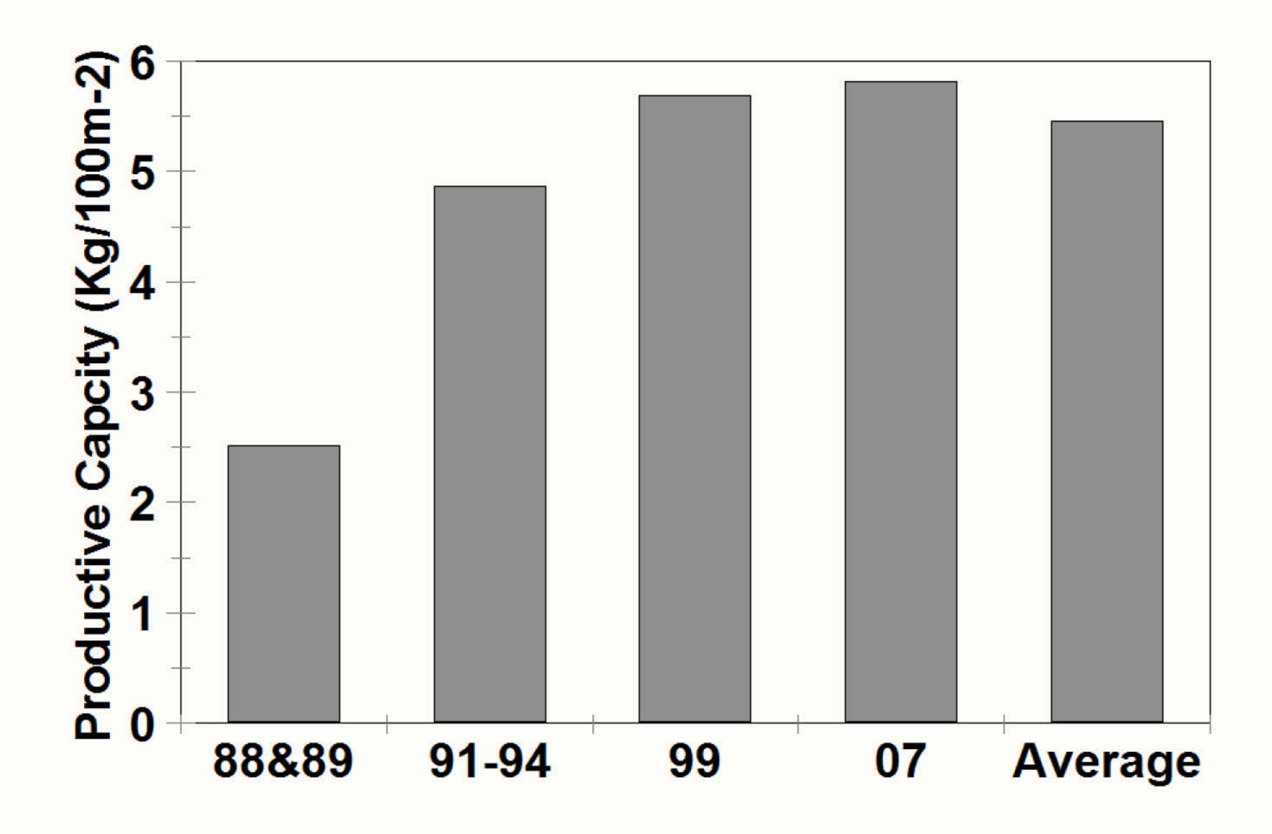

Figure 3: Productive capacity (measured as average biomass) in Seal Cove River before compensation (1988/89) and during post compensation monitoring that roughly equates to three generations of the native salmoinids.

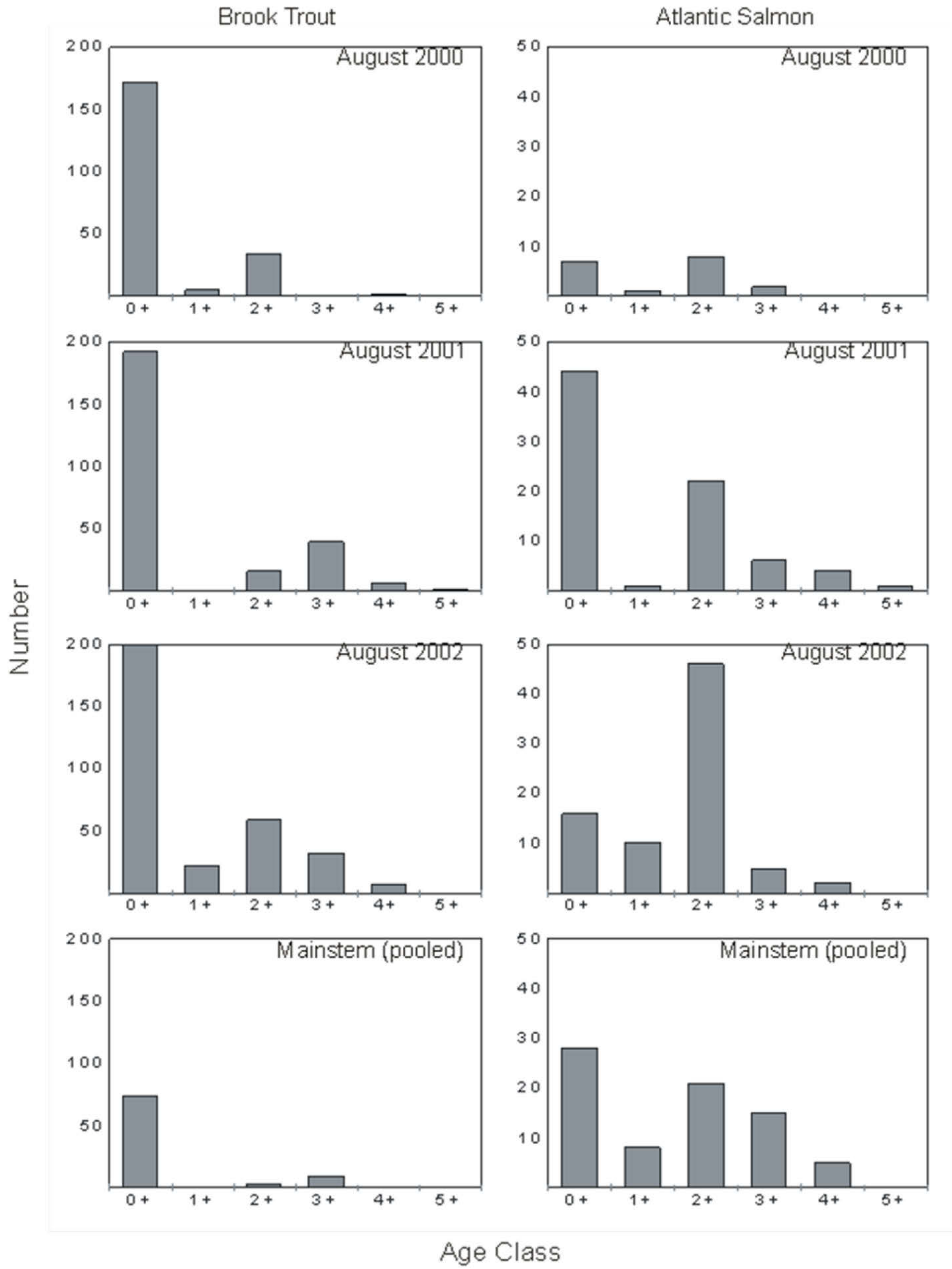

Figure 4: Age distribution of brook trout and Atlantic salmon using the compensatory habitat in August during the three years of monitoring (2000-2002) and a pooled control sample for the adjacent mainstem habitat.

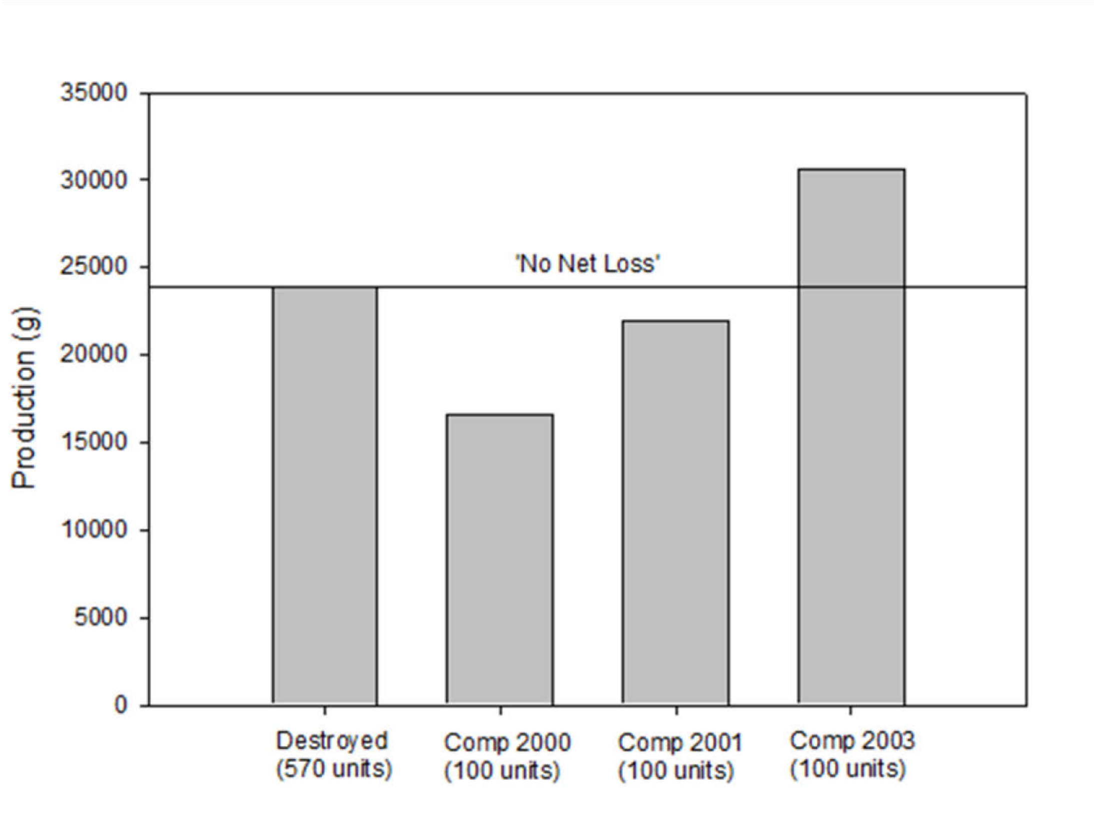

Figure 5: 'No net loss' calculation comparing the production (biomass produced) in the Rose Blanche compensation habitat in years 2, 3 and 4 of operation with estimated production from the destroyed habitat (after Scruton et al 2005).

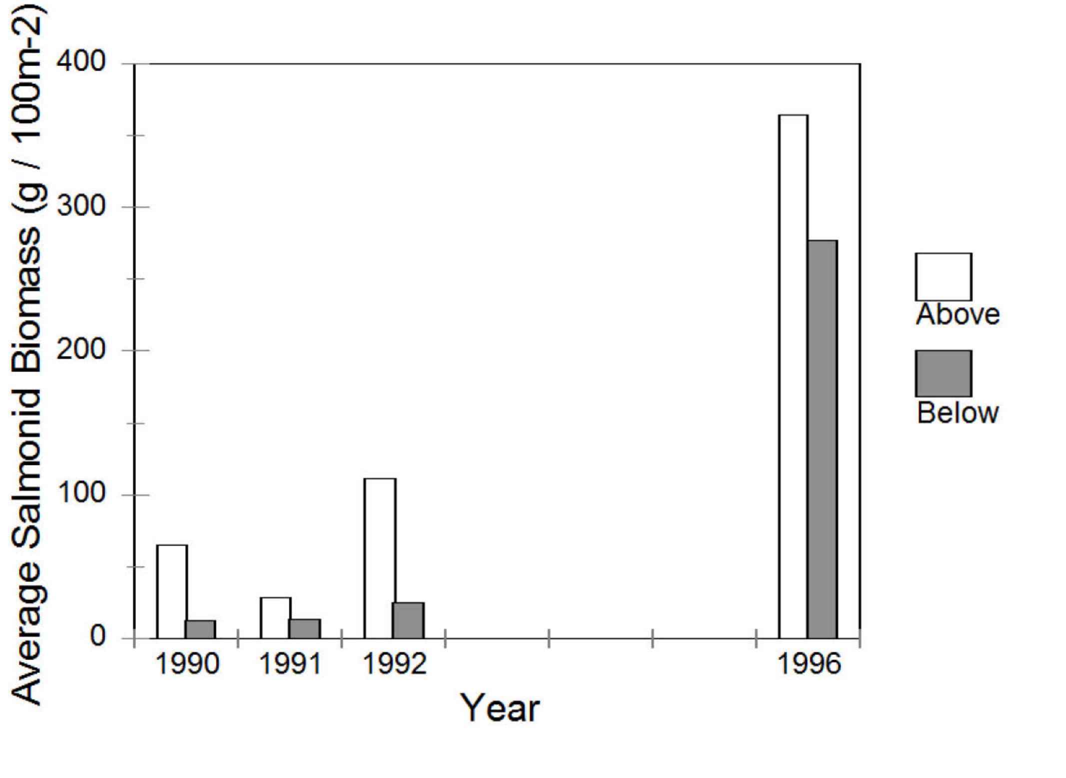

Figure 6: Average salmonid biomass in the restored (below) habitats of Pamehac Brook and the area above (control) the original diversion (see Clarke and Scruton 2002).

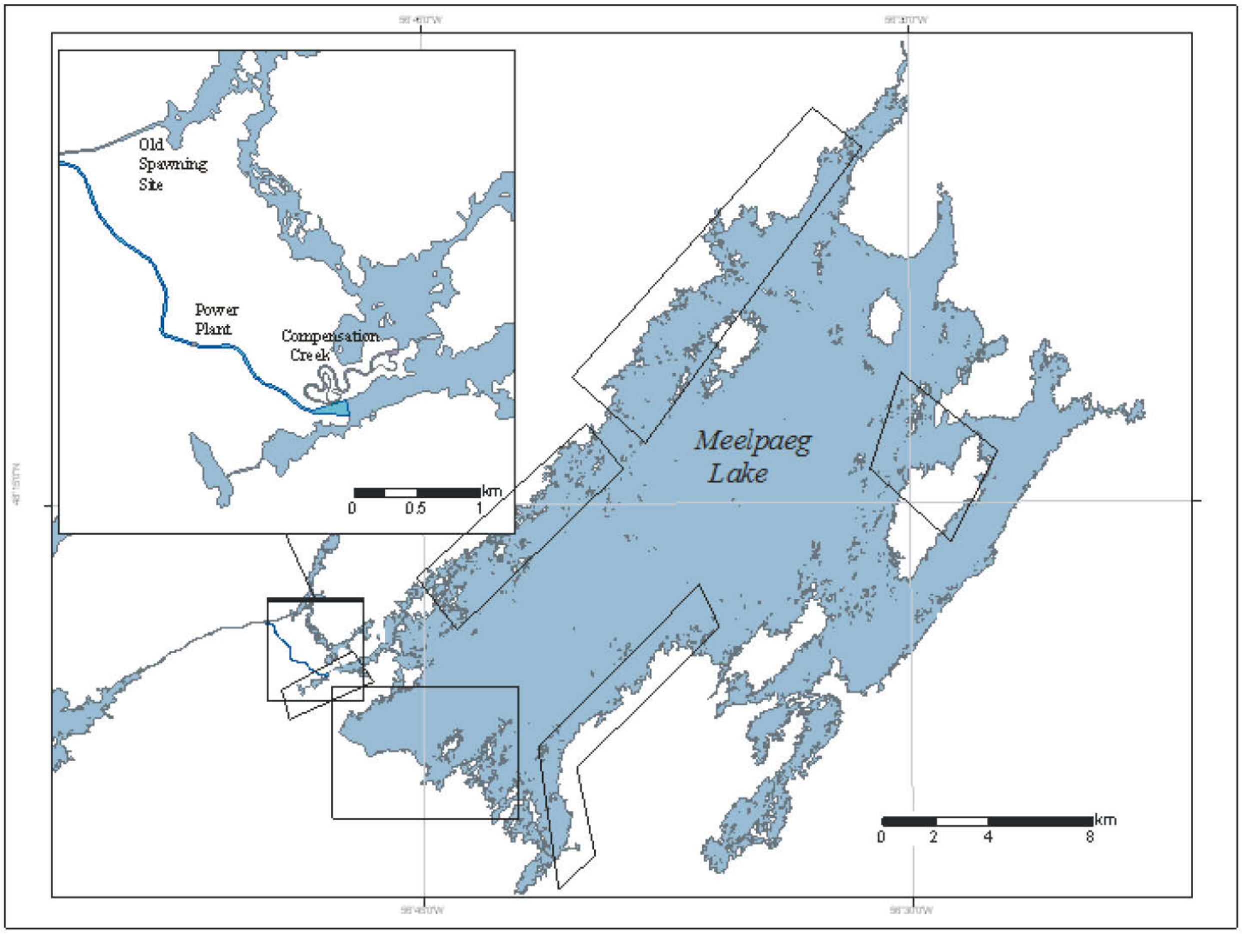

Figure 7: Map of Maelpeg Lake with insert of Compensation Creek entrance and net areas shown by the boxes.