THE VIABILITY OF LIME DOSING IN NOVA SCOTIA: A COST BENEFIT ANALYSIS

Exploring the concept of using in stream lime dosing technology in Nova Scotia from a scientific, economic, and social perspective.

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The Nova Scotia Salmon Association's lime doser on the West River, Sheet Harbour in Nova Scotia

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Executive Summary

The wild Atlantic salmon is a graceful and historic species that is a part of Nova Scotia's rich culture and history. The species has a special place in the heart of thousands of people who have a cultural and social connection to the species. This emotional connection of Atlantic salmon also inevitably results in an increased social and economic value of the species to the residents of Nova Scotia. Unfortunately, due to human activity, the number of Atlantic salmon in Nova Scotia's rivers has been generally decreasing for over two decades (Clair, 2007). This effect is especially true in the Southern Uplands region of Nova Scotia where due to the decrease in the abundances of Atlantic salmon in the rivers, the recreational salmon fishery in the region has been closed. A considerable amount of research on the cause of the decrease in the numbers of Atlantics salmon has been done and several potential causes have been identified. One of these causes is known as acid rain.

Acid rain is when nitric and sulfuric gasses from pollution sources precipitate from the atmosphere onto soils and water courses. Acid rain has the effect of decreasing pH levels and increasing aluminum levels in a watercourse in Nova Scotia. This causes the decreased quality of habitat for all salmonid species including the wild Atalntic salmon. It affects the overall population of Atlantic salmon within the river by decreasing survival rates. Acid rain in Nova Scotia is expected to be one of the main drivers of the decreased salmon populations; particularly in the Southern Uplands region of Nova Scotia. The characteristics of the soil and geology of the region make it vulnerable to impacts from acid rain. The region has had its capacity to buffer out acidity diminished significantly. Acid rain is not only an issue in Nova Scotia but also in other places in the world such as Norway. Norway has historically had issues with the impacts of acid rain on Atlantic salmon populations. Norway began a salmon restoration program in the 1980s using lime dosing techniques including in-stream lime dosing with salmon stocking activities and were successful in increasing the salmon populations in their rivers back to levels where the recreational fisheries were again viable. Norway now has annual recreational catches comparable to those before acid rain had an impact on the region.

In-stream lime dosing is when lime mineral is dissolved into a watercourse via an electronic device called a lime doser. Its effects are increased pH levels and the lowering of aluminum levels into salmonids tolerance zone. If a river is acid impacted and the limiting factor of the salmon population is the pH and aluminum levels then a lime doser will increase the population of salmon in the river.

In attempt to investigate the acid rain mitigation technique using lime dosers the Nova Scotia Salmon Association began a project to purchase and install a lime doser from Norway in Nova Scotia. In 2006 the lime doser was installed on the West River Sheet Harbour. Since then data on the West River Sheet Harbour has been collected to evaluate the effectiveness of the

technology in increasing the salmon populations as well as its effect on the overall ecology of the river.

The results from statistical analysis of the data from the West River Sheet Harbour yield promising, yet anecdotal results. The evidence from the river is not scientifically conclusive; however, results remain positive. The reasoning for the lack of significance is largely due to the size of the time series as well as the standard error associated with the data. The trends from the limed and unlimed sections of the river are divergent, with the limed section showing increased outward migration of smolts and juvenile salmon density. Since the introduction of the lime doser the estimates for the outward migration of smolts has increased by 300%. Also, juvenile salmon densities have been recorded using electrofishing techniques that have not been recorded on the river since 1971 (Ferguson, 2012).

Data from Norway is however conclusive and there has been research that shows the positive impact of lime dosing in increasing salmon populations in an area impacted by acid rain. There is evidence that shows significant increases in salmon densities on rivers that are limed without stocking with a previously “lost” salmon population. In Norway on rivers that have been limed there has been increases in fry densities, parr densities, outward migration of smolts, inward migration of adults, and recreational catches (Hesthagen, 2003)(Hindar, 2007). The conclusive data from Norway and the anecdotal evidence from Nova Scotia combined makes it reasonable to say that Lime Dosing has a positive effect on Atlantic salmon populations in acid impacted streams. For the cost benefit analysis within this report the assumption is made that any acid impacted stream in the Southern Uplands that has a lime dosing program implemented will have salmon population increases at a level where after 10 years of implementation, a recreational salmon fishery would be viable.

Typically in situations where a project calls for government funding, the government will complete some form of cost benefit analysis to assess the practicality of a project. To assess this projects practicality and whether governmental investment is warranted this report has completed a cost benefit analysis weighing the costs to the economic and social benefits of lime dosing in Nova Scotia. The results of the analysis showed that lime dosing from a purely economic stand point on a typical river in the Southern Uplands was not self-sustaining. That the resulting increase in economic input from the recreational fishery that would be created by lime dosing did not offset the total costs of lime dosing over a thirty year period. However, from an analysis including both a social and economic perspective it is believed that investment in a lime dosing program would result in an overall net benefit to society. Assuming that a lime dosing program has an expected chances of success of above 80% in increasing salmon populations to at least 40% of historical highs then a lime dosing program would be expected to have a net benefit to society. Based on data from the West River Sheet Harbour and Norway it is reasonable to assume that a lime doser project would have a chance of success of above

80%. This means that a lime dosing program have an overall net benefit to Nova Scotia. The results of the analysis give grounds for a re-allocation of governmental resources or increased taxation to support a lime dosing program.

Introduction

Research Premise

The purpose of this research is to evaluate the viability of the use of lime dosing technology in Nova Scotia from an economic and social perspective. This report will weigh the benefits and costs of lime dosing against each other. Using a cost benefit analysis, the viability or practicality of government investment will be assessed. If there is a net benefit to society indicated by the cost benefit analysis, this would give grounds for government investment in lime dosing.

Atlantic Salmon in Nova Scotia

Nova Scotia is a province with a rich history of angling, being almost completely surrounded by ocean, the rivers and streams are seemingly endless along Nova Scotia's coastline. The beautiful scenery of the provinces rolling hills, the picturesque rivers, and the big runs of Atlantic salmon attracts salmon anglers from all over the world to fish these rivers. Fir many people in Atlantic Canada there is an emotional connection between them and wild Atlantic salmon. However, now most of these river's salmon populations have been affected by human activity, particularly in the Southern Uplands and Bay of Fundy.

The population trend for the returns of Atlantic salmon to Nova Scotia has been generally negative since the 1980s (Clair, 2007). The recreational salmon fishery has been closed in the Inner Bay of Fundy and the Southern Uplands since 1990 and 1998 respectively (DFO, 2011). All of the rivers in the Southern Uplands region of Nova Scotia have salmon populations that are either extinct, have remnant populations, or have been depleted (Ferguson et al., 2007). In the summer of 2011 the Southern Uplands region salmon population was recommended to be listed as an endangered species under the Species at Risk Act by the Committee on the Status of Endangered Wildlife in Canada (Adams et al., 2011). The current situation for Atlantic salmon in Nova Scotia is dire, the survival of specific genetic strains of salmon is at risk. The governmental body in charge of the conservation of these species is the Department of Fisheries and Oceans (DFO). This governmental body has been slow to respond to the issue and federal budget cuts have hindered their ability to fund projects to encourage the conservation of wild Atlantic salmon. In Nova Scotia it appears government funding is not reacting on the same scale as the urgency of the situation for Atlantic salmon. Much of the responsibility of protecting the salmon in Nova Scotia is resting on the shoulders of environmental non-government organizations (ENGOs) who rely heavily on volunteer work. Organizations like the Atlantic Salmon Federation, the Nova Scotia Salmon Association, and all their regional affiliates. If the current population trends for Atlantic salmon were to continue without human intervention to conserve this species the recreational salmon fishery in Nova Scotia could be at risk.

There is some debate on what the main cause for the decline of salmon populations in the Southern Uplands Region. Possible explanations include low marine survival, aquaculture, habitat loss, and acid rain (Adams et al., 2011). There is currently ample research being done in all of these areas from around the Atlantic. It is likely that it is a combination of all these factors that is causing the decline of salmon populations in Nova Scotia with acid rain and marine survival being two of the more significant sources of mortalities in the Southern Uplands region. Acid rain has its largest effect on the Southern Uplands region of Nova Scotia where the geology is more vulnerable to the known impacts from acid rain.

Acid Rain

Acid rain is the result of pollution released into the atmosphere by industrial activities. The majority of the pollution that causes acid rain in Nova Scotia comes from Eastern United States, and central Canada. The pollution from these regions makes its way to Nova Scotia via the Jetstream and prevailing weather systems and releases sulfuric and nitric acids in Nova Scotia in the form of percepitation (Clair, 2007). As acid rain falls in Nova Scotia it has two main effects on the rivers which in turn have several effects on the salmon and trout. These two effects are the lowering of the overall pH levels within the river and the increase in the heavy metal toxicity of the river (McCormick et al., 2007) (Farmer, 2000) (Schindler, 1988) (Marshall et al., 2005). These two effects of acid rain on the chemistry of Nova Scotian rivers have several effects on Atlantic salmon. Some of the known negative physiological and embryotic effects on salmon from the acidification of the include:

- The reduced egg quality prior to spawning
- Reduced spawning activity and fertilization in adult salmon
- Negatively affect embryonic development
- Slower development during embryonic life stages, resulting in greater mortality and reducing hatching success.
- Potentially mortal effects on the circulatory system of salmon particularly during the smoltification stage of the salmons life-history.
- Decreased invertebrate abundances resulting in a reduction to the available food sources
- Reduced chemical alarm capabilities during predator prey interactions.

(Aas et al, 2010)(Leduc et al., 2009)(Mcormick et al., 2007)(Roy et al., 1995)

The effects result in an increased mortality rate in juvenile salmon, especially during the smoltification stage of a salmon's life, as well as incur negative effects on the spawning efforts of adult salmon. These combined affects leads to an overall decline in the populations of salmon in rivers affected by acid rain. This impact is only compounded by the low marine survival rates currently observed in the Southern Uplands.

Acid Rain Mitigation Techniques

Acid rain is a problem that can be difficult to manage because it affects the chemistry of the water which can be more expensive to correct then physical restoration techniques to improve fish habitat. A natural pH level for rivers without the effects of acid rain is considered to be around 5.0. This pH level is suitable for both salmon and trout species who can tolerate pH levels of above 4.7 and 4.1 respectively (Amiro et al., 2007)(Karas, 2002). However acid rain has been known to lower pH to levels far below 4.7 in many areas across Nova Scotia especially in the Southern Uplands region (Amiro et al., 2007).

Liming of rivers as an attempt to mitigate this effects is not a new concept and has been in use in various regions in Nova Scotia for many decades as a way to mitigate acid rain. There are various forms of "low tech" liming such as lake and terrestrial liming that have been in use in Nova Scotia in the past.

The most apparent technique to reduce the effects of acid rain is to reduce the source of pollution that causes the acid rain itself. The reduction of these pollution sources has seen much progress over the past several years with the introduction of key legislation outlining the reduction of total greenhouse gas emissions. Acts such as Canada's Environmental Protection Act and America's Clean Air Act have facilitated the reduction of total emissions. However, the complete elimination of pollution sources is not in the foreseeable future for North America. North America is still heavily dependent on fossil fuels and the emissions that are associated with them. The elimination of emissions that cause acid rain is not an overly realistic solution for the near future. Even if pollution activities were successfully reduced to the goals set by the Environmental Protection Act and the Clean Air Act today the buffering capacity in the Southern Uplands region has already been depleted and the reduced amount pollution will not be an immediate fix. The soils in this region may require up to 50-100 years to recover (Ferguson et al., 2007). At which point there could be overwhelming losses to the specific genetic strains of salmon and recovery to a truly natural system may be impossible.

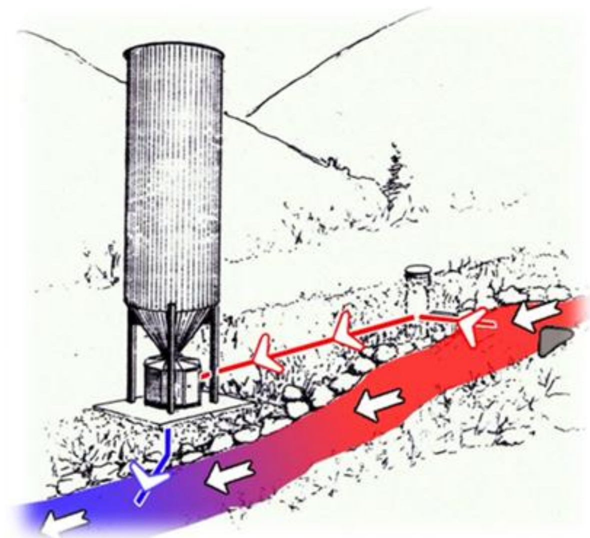
Another common acid mitigation technique is lake liming. This is when a catchment of water has limestone dumped into it where it is left to dissolve into the water course over time and consequentially increase the pH level of the outflowing rivers associated with the lake. Typically the lime is dumped into the lake either by helicopter, liming boat, or trucked out onto the ice during the winter. This technique is useful in many situations, and can be effective in increasing the pH of a watercourse (Hindar, 2007). However the costs associated with this are high and also take place over a short time period which can make funding difficult. This technique has a low amount of accuracy in controlling the pH levels within the watercourse and can not adjust the dosage based on changing conditions. The useful effective life span is also relatively short. Depending on the retention time of the catchments lime mineral may dissolve too quickly or not quick enough and so the usefulness of this technique varies depending on the river (DFO, 2004).

Terrestrial liming is a technique where the area surrounding a watercourse is limed, similar to what is done on residential properties lawns with lime pellets. This technique benefits the water course as well as the surrounding forest and can have a useful life that lasts decades. Again the accuracy of this technique to regulate the pH level of the stream is low however it is an effective technique in mitigating against acid rain impacts on terrestrial and aquatic habitats. Although these techniques can be effective in some situations it is unreliable and is not overly accurate in obtaining the desired pH level consistently (Halfyard, 2007) (Brown, 2003).

In stream lime dosing although a relatively expensive river restoration technique is very effective in accurately controlling pH levels on a river. The in-stream lime dosing technology is based on a relatively simple concept of mixing lime into the river accurately and electronically to increase the availability of base cations and consequentially raise the pH and lower the aluminum levels. The actual lime doser itself resembles a small barn silo installed next to a river. There is a pipe that takes water from upstream into a mixing well underneath the silo. The well creates turbidity in the water which when lime mineral is added from the silo above helps dissolve the lime completely into the water. After this process, the water with its dissolved lime is then transported downstream from the silo through another pipe where it is deposited back into the river carried further downstream and further diluted into the river via the rivers natural current.

The lime dosage is controlled electronically via phone lines and can be controlled remotely from anywhere in the World. Information like the pH levels, lime mineral levels, temperature, water level, velocity, etc can be monitored by the doser and it automatically regulates the dosage of lime depending on the changing conditions in the river. Future weather patterns can also be monitored and liming can take place in anticipation of heavy rainfalls in order to compensate for the predicted runoff. All of this data can also be sent electronically to the lime doser controller via computer or phone, and based on this information the controller can select adjust the settings as he/she desires as well as order lime mineral to be delivered to the machine as required. The lime doser is designed to deliver the exact amount of lime required to the river which maintains the pH levels more accurately as well as saving economically by avoiding the overuse of the lime mineral. Typically lime dosers maintain a eiver pH of 5.5 during the non-critical time periods and 6.0 during the critical time periods such as the late spring and early summer when smoltification occurs.

Figure 1: Lime Dosing Technology Function



Lime Dosing Consultants, 2010

Some of the issues with in stream lime dosing is that there are electronics and moving parts that require maintenance. It is not a "set and forget" method and requires management over the 30 year period. The difference between in-stream lime dosing and other "low-tech" liming techniques is that in stream lime dosing can accurately control the pH levels in the river and adapt to changing conditions such as water velocities and upstream pH levels. It is very accurate in increasing pH to desired levels. The costs of in stream lime dosing are high, however they take place over a longer time period as a typical lime dosers life span is around 30 years.

Liming programs in countries with developed liming programs such as Norway often use a combination of several of the above mentioned techniques as an overall strategy to acid rain mitigation. This model has proven effective in raising pH lowering Al levels and increasing the overall Atlantic salmon populations in the associated rivers (Hesthagen, 2003).

The Nova Scotia Salmon Association's Lime Doser Project

In an attempt to investigate techniques to mitigate the harmful effects of acid rain in Nova Scotia in 2000 the NSSA investigated potential use of the in stream lime dosing technology widely employed by Norwegians with high levels of success. They began investigating the concept with consultation of Norwegian experts. There were four proposed sites for the project with the West River Sheet Harbour eventually being selected as the most suitable candidate.

In 2005 the lime doser was purchased from Norway and installed on the West River Sheet Harbour. After the beginning of the operation of the lime doser there was a practically immediate increase of the pH levels on the river into the tolerance zone for salmon and trout.

Since the installation of the lime doser data has been continuously collected in order to measure the effects of the technology. The initial results show promising trends for the salmon populations on the river, and currently the West River Sheet Harbour is the only river system in the Southern Uplands with a known increasing salmon population and has juvenile salmon densities that have not been recorded on the river since 1971 (Furgusson, 2012).

Funding for this project is mostly from fundraising activities conducted by the NSSA. There is an annual golf tournament which raises the majority of the funds that go towards the annual costs of the lime doser including the powdered lime. There are several public organizations that help the NSSA in funding this project, and without funding from the public sector, this project would be impossible.

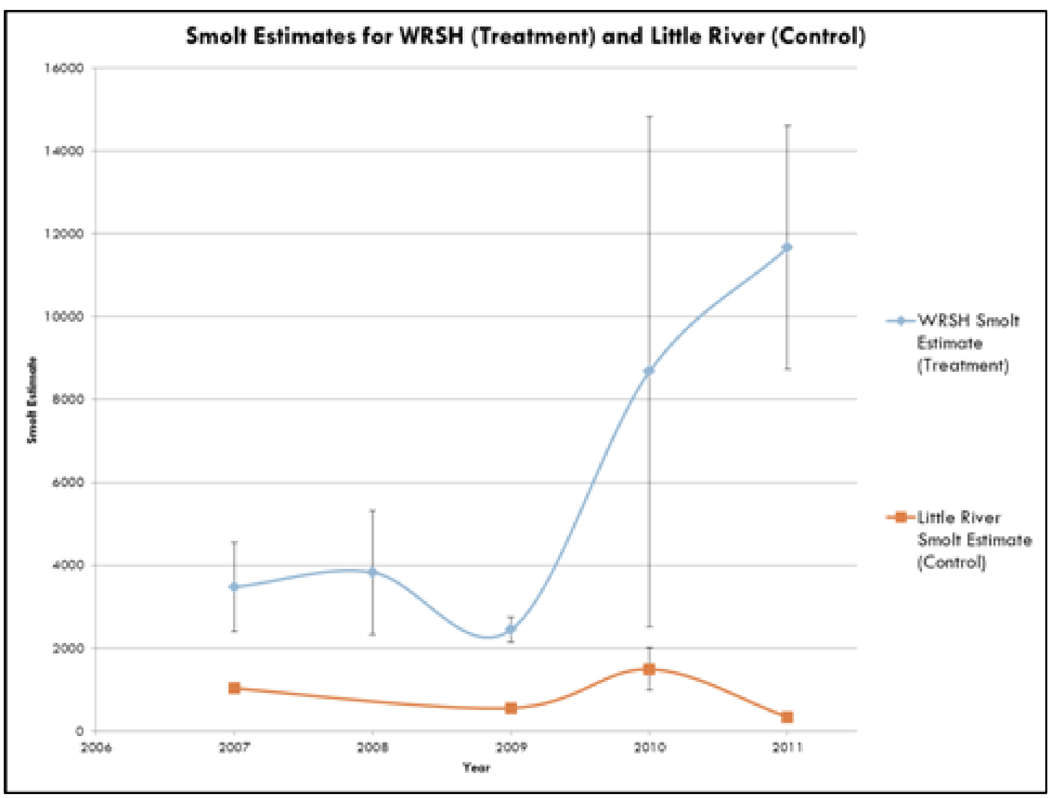
Scientific Evaluation of the Effectiveness of Lime Dosing

Nova Scotia Lime Dosing Project

The Nova Scotia Salmon Association's Lime Doser project has been in operation since 2006. Data on the West River Sheet Harbour regarding pH, flow velocities, smolt migrations, juvenile salmon densities, plant growth, and invertebrate populations has been collected since the beginning of the project to estimate the effect of the lime doser on the salmon populations as well as the effects on the overall ecology of the river. Thus far, the results have been promising and there have been many indicators of success.

The West River Sheet Harbour experiment has a control and treatment site. The main stem of the West River has been treated with lime and represents the treatment site. The tributary called Little River is unlimed and serves as a control to the experiment. The Little River tributary is in fact one of the least acid impacted streams in the West River Sheet Harbour watershed (DFO, 2011). In comparison of the outward smolt migration estimates for the West River main stem and the Little River tributary over a 5 year time series we can see a major visual difference. We can see an anecdotal divergent trend from viewing the data between the two rivers indicating a difference in outward smolt migration trends over time.

Figure 2: Smolt Estimates for WRSH and Little River



Another comparison that can be made is the outward migration of smolts between the West River Sheet Harbour and other acid impacted rivers in the Southern Uplands region. When comparing these rivers there is again a visual difference between the linear trends.

Figure 3: Southern Uplands Rivers Smolt Estimates

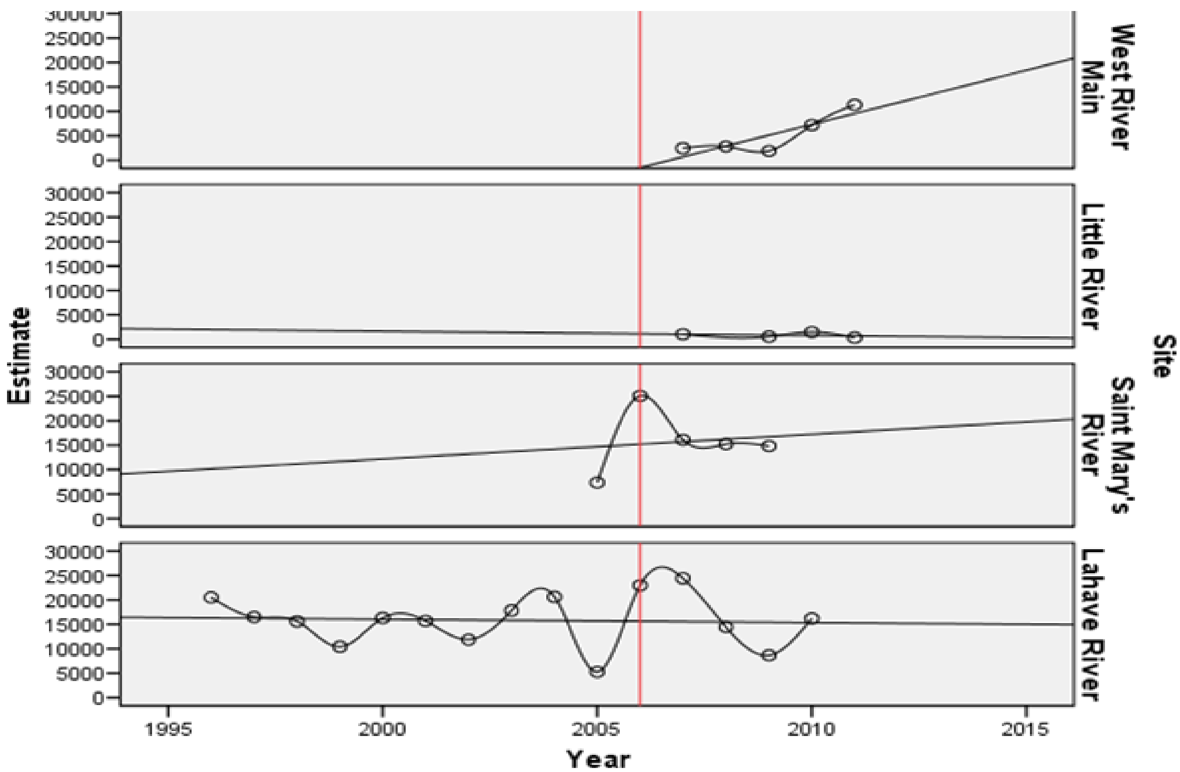


Figure 3: Divergent outward smolt migration trends in the Southern Uplands. Red line represents installation of the lime doser on the West River Sheet Harbour.

When completing a statistical analysis using log transformed data between the West River Sheet Harbour and the Little, Lahave and Saint Mary's Rivers there is a significant ($P \leq 0.05$) difference between the river systems. The results of this analysis are included in Appendix A. This is a rudimentary method of analyzing the effectiveness of the lime doser due to the various other effects that could be taking place on the rivers. However, it is another anecdotal method to show the divergent trend between the West River Sheet Harbour and other unlimed rivers that are acid impacted. The most insightful of these comparisons is the comparison between the West River main stem and the Little River Tributary because of their location on the same watershed system and shared outlet estuary.

The significant difference between the smolt counts on these two rivers shows that there is a difference between the treatment and control sites, or the limed and unlimed sites. This difference suggests that the West River Lime Doser Project has been successful in increasing juvenile salmon populations in the river and that this could be a viable river restoration technique on other acid impacted rivers in the Southern Uplands region of Nova Scotia in the future. All evidence is anecdotal and continues research and data collection is required on the West River Sheet Harbour.

Norwegian Evidence of Lime Dosing Effectiveness

The short time series and large levels of standard error prevent the ability to provide conclusive evidence of significant increases in salmon populations from the West River Sheet Harbour lime doser example. Due to this, much of the evidence of an increase in salmon populations from the West River experiment is anecdotal and not conclusive. In order to supplement the West River data in the ability of lime dosing to increase salmon populations in a river to levels where recreational salmon fisheries are viable, additional data from Norway will be used.

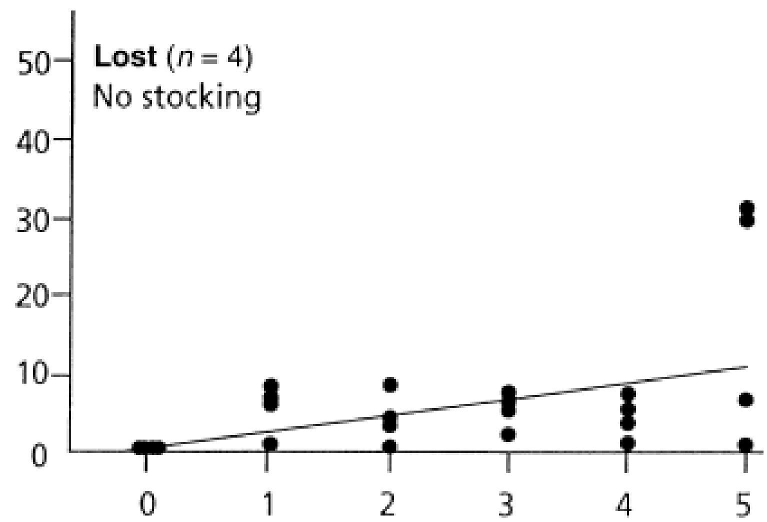
In the 1960s people in Norway were being confronted with a noticeable decrease in annual salmon catch numbers. They were experiencing a decrease in salmon populations in acidified rivers similar to what Nova Scotia is confronting now. Over the following years the country lost 25 unique genetic classes of Atlantic salmon and several of the rivers were classified as extinct (Hindar et al., 1998). Public attention was raised and the government began to fund research in the area of acid rain mitigation. In 1985 the first lime dosers were installed in Norway, since then there are over 20 rivers being limed and the technology has seen great success both from an environmental perspective in improving the quality of the ecosystem as well as improving the economy (Hindar, 2007).

Nova Scotia and Norway are two regions that are relatively similar. Both regions lacks buffering capacity and have acidified watercourses that is caused by long range pollution sources. Both regions geology is simmular, both with decreased buffering capacities. Both regions also share similar hydrological characteristics. Due to the similarities of the two regions in these capacities it is reasonable to use some data to project potential effects of lime dosing on acid impacted streams in Nova Scotia.

Hesthagen (2003) conducted a study to evaluate the growth of salmon fry and parr densities in rivers that had been limed with in stream technology. He surveyed 12 rivers using electrofishing techniques for a period of 5 years after the introduction of a lime doser. The rivers were classified into four subcategories; rivers with “lost” salmon stocks that underwent stocking activities, rivers with “lost” salmon stocks that did not undergo stocking activities, rivers with “remnant” salmon stocks that underwent stocking activities, and rivers with “remnant” salmon stocks that did not undergo stocking activities.

All 4 categories showed increasing linear slopes over the 5 year period. The two categories with formally "lost" salmon stocks showed significant ($P < 0.05$, $N=7$) growth of 0+ and ≥1+ salmon age classes. One of these rivers had not undergone any stocking activity and had a significant ($P=0.011$, $N=4$) linear growth function of $D = 2.33YL - 0.046$. These rivers were not stocked. Therefore, the increase in salmon Fry and Parr densities can be attributed to lime dosing. Below is a graph depicting the linear growth of the Fry and Parr densities in the rivers sampled.

Figure 4: Linear Growth of salmon on extinct river with no stocking



HESTHAGEN, 2003

There is also evidence that shows increases in the annual catches in the recreational fisheries since liming (Hesthagen, 2003)(Kroglund, 2007). The River Audna at one time had an extinct salmon stock and now the catches that in 2001 reached 2.1 metric tons after only 16 years of liming and stocking activities (Hesthagen, 2003).

Another benefit of lime dosers that has been shown in Norway is an overall benefit to the general quality of the ecosystem. Atlantic salmon are not the only species that are acid-sensitive and as the natural pH and al levels are restored many other species are seen to have been positively impacted including many other fish, invertebrate, bacterial, and vegetative acid sensitive species (Hindar, 2007). This has a positive effect on the overall biodiversity of an ecosystem which is an added bonus effect of this Atlantic salmon conservation technique and using salmon as a bio-indicator for our watersheds.

There is evidence to conclude that the implementation of lime dosers in Norway in conjunction with their stocking programs is directly attestable to the return of the Atlantic salmon to the region. Where lime dosing technology was used there have been increases in the fry densities, parr densities, outward migration of smolts, inward migration of adults, and recreational catches (Hesthagen, 2003)(Hindar, 2007). Although the implementation of lime dosers had often been done in conjunction with heavy stocking, there is still evidence that shows that in rivers where stocking activities did not take place and solely lime dosing was employed as a restoration technique the Atlantic salmon populations still increased significantly (Hesthagen, 2003). This evidence suggests that lime dosing does work in Norway in increasing the population of Atlantic salmon in rivers with or without stocking. Liming has been proven an effective technique in Norway for restoring and re-establishing Atlantic salmon to rivers that have been negatively impacted by acid rain.

With this evidence in combination with the anecdotal evidence from the West River Lime Dosing Project it is reasonable to say that lime dosing has a positive on rivers affected by acid rain. For the remainder of this report the assumption that results similar to what has been seen in Norway would be seen in Nova Scotia with the implementation of a lime doser. This assumption will include the notion that a recreational salmon fishery would be viable on a river after ten years of a lime dosing program using in stream technology.

Cost Benefit Analysis

In most situations that call for government investment typically some form of cost benefit analysis is to be completed to evaluate the practicality of a project. The purpose is to understand what the benefits will be to a region from a project that requires investment of resources. Completing this analysis will yield results that show if the project is worth investment. Cost benefit analyses involving public funds should be done from an economic, social, and environmental perspective to fully understand all of the total benefits and costs of an investment. Theoretically if the returns to the region are equal to or greater than the cost of investment over a reasonable time period then the government has grounds for investment. This is particularly true if the investment promotes sustainability and environmental protection.

In this section a cost benefit analysis on the theoretical implementation of lime dosers in Nova Scotia will be completed in order to assess whether there is grounds for government investment. This will be completed on a per-lime doser basis, analyzing the benefits per lime doser and then this number can be extrapolated to understand costs and benefits of multiple lime dosers.

In order to do this, an important assumption must be made. The assumption is that lime dosers will improve salmon habitat to a state where the salmon populations would reach a level where a recreational salmon fishery is viable on all rivers where the doser technology is implemented. This is assuming that results similar to what has been seen in Norway will be realized in Nova Scotia. This assumption will take effect throughout the remainder of the economic evaluation.

In the winter of 2011 the ASF commissioned a report to be completed by Gardner Pinfold consulting. This report was appointed to evaluate the total economic value of wild Atlantic salmon to Atlantic Canada. The report evaluated both the economic and social value of Atlantic salmon represented in a monetary form using a contingent evaluation method. Both the economic impact as well as the non-use values within this report will be taken from the Gardner Pinfold study (2012). These values will be used extensively in the economic evaluation section of this report.

There is some controversy over the value of contingent evaluations in representing the value of environmental assets (Diamond and Hausman, 1994) it is important to include the social perspective of the value of Atlantic salmon in the evaluation because of its profound importance to Atlantic Canadians. Currently the only viable way of evaluating this is through a contingent evaluation such as the one completed be Gardiner Pinfold.

There are some potential benefits that will be excluded from the evaluation due to their complex nature and difficulty in evaluating accurately. They are however worth identifying.

The first is the potential consequential cost of not implementing a lime dosing program, or other Atlantic salmon conservation effort. In the summer of 2011, there were several pool closures on different river systems in the Southern Uplands region because of alleged salmon fishing on trout licenses. These closures resulted in a reduction in trout related spending activity in Nova Scotia. Another benefit of lime dosing is that it has a positive impact on all salmonid species including trout. This means that with the implementation of lime dosing, there would also be increases to economic input from the recreational trout fishery.

Another economic aspect that is important to consider is the effect of economies of scale on the costs side of the analysis. If there was a purchase of more than one lime doser for a lime dosing program in Nova Scotia there would be potential savings that could be realized through economies of scale. As the number of purchased dosers increase, the cost per doser decreases. Also, if enough investment is made into lime dosing, then investment in the manufacturing of lime dosers in Nova Scotia may be warranted, which would contribute more jobs and economic benefits to the economy of Nova Scotia.

Lastly, the figures for social non-use willingness to pay only account for Nova Scotia's and does not account for other potential international and non-Atlantic Canadian users of the recreational salmon fishery. Nor does this value account for the benefit outside of the salmon population perspective. This value does not include the social value of healthier trout populations and more natural river ecosystems. These values are not included in this report, however are potentially important values that should be considered when viewing the final economic analysis.

Costs Evaluation

The costs of the Lime Doser are relatively easy to evaluate because many of the costs are currently being incurred on a yearly basis. The costs are estimated based on Strains article (2007) and on individual account from NSSA board members.

Some of the labor costs of lime dosing are not included in the West River Sheet Harbour example because of volunteer work that went into the purchasing, coordination, and installation of the doser. If lime dosers were to be implemented on other rivers in Nova Scotia, we would not be able to count on the charitable donations and volunteer work of others as was exemplified in the West River Sheet Harbour example. In this report the assumption that all labor and materials that go into the purchase and installation of a lime doser will require funding and all of these costs will be added in the evaluation. Conversely, many of the scientific monitoring costs of the West River Sheet Harbour example are not included in this analysis because they are not critical to the operations of the lime doser in increasing the salmon populations. Only the costs considered critical to the operation of the lime doser will be included in this analysis.

The costs will be categorized into two main sections, start-up costs, and operational costs. Start-up costs being one-time payments associated with the purchase and installation of the lime doser and operational being annual payments associated with the operations of the doser. It is important to note that costs could vary based on location and specifics regarding the unique characteristics of an installation site however these estimates are intended to serve as a base line average of costs on a per lime doser basis.

Start-Up Costs

Included in start-up costs are wages for project coordination. Wages are estimated using a base line of $15 per volunteer hour and totals to $1600 for project coordination. Additional labor costs total to an estimated at $13,500. The legal fees for the lease development are an estimated $645. The required pre-installation water chemistry analysis is $5000. Purchase of the lime doser from Kemira was $111,000 and the shipping costs associated with this purchase were $1,613. The construction of the foundation of the lime doser cost $5,375. The installation of the doser onto the foundation cost $2,000 and the surveying costs associated with this was $1,000. The installation of the power and telephone lines to the site was one of the larger costs equating to $75,160 combined. The combination of all these costs leaves a total for start-up costs of $201,148. These start-up costs are represented in the table below.

Table 1: Start-Up Costs

Cost Activity	Amount
Project Coordination	$1600
Lease Development	$645
Water Chemistry Analysis	$5,000
Doser Purchase	$111,000
Doser Shipping Costs	$1,613
Doser Pad Construction	$5,375
Doser Installation	$2,000
Dosing Level Determination	$1,000
Electrical Power Installation	$70,000
Telephone Service Installation	$5,160
Labor	$13,500
Total	**$201,148**

Operational Costs

Operational costs are estimated on an annual basis. Within these annual costs wages are again based on a $15 per hour base line value. This makes the project management labor cost of $3,500 per year. Maintenance costs, including road and doser maintenance is $3,000. The cost of the raw material of lime including the transportation of the lime costs $14,500. This is the largest annual expense of the doser. The remaining miscellaneous expenses equate to a total of $4,250. The total annual costs of a lime doser equate to approximately $25,250. Over the 30 year estimated life span of a lime doser this total is $757,500. A summary of these costs are shown in the table below.

Table 2: Operational Costs

Cost Activity	Amount
Project Management	$3,500
Road Maintenance	$2,000
Doser Miscellaneous Expenses	$900
Doser Routine Maintenance	$1,000
Doser Operating Expenses	$750
Limestone Purchase	$8,000
Trucking	$6,500
Electrical Power	$500
Telephone	$500
Insurance Premium	$600
Water Chemistry	$1,000
Total	**$25,250/Year**

Benefits Evaluation

Benefits of lime dosing can be difficult to evaluate in terms of monetary value because of the intangible nature of some of the benefits involved with the restoration of habitat. Habitat evaluation in terms of economic value is a difficult and controversial process. The economic evaluation is easier to complete, more accurate, and less controversial. In this section benefits from lime dosing will be evaluated through two main perspectives. Firstly, an economic, “market” benefits approach using values found in the Gardner Pinfold report (2012). Secondly, a social non-use willingness to pay value based on the contingent evaluation also conducted by Gardner Pinfold (2012) to evaluate the potential social benefits from lime dosing in Nova Scotia. The benefits will be incurred over a 30 year time period, which is the estimated life span of a lime doser.

The benefits will be calculated on a per lime doser basis. This value can be extrapolated to understand values for larger investment into a lime dosing program. All benefits are calculated based on the increase in recreational salmon angling opportunities from the 2010 level of one lime doser over a 30 year period.

Economic Benefits

Every year in Nova Scotia millions of dollars are spent in the recreational fisheries. The purchases of licences, fishing gear, travel costs, accommodation costs, and others expenses. The recreational salmon fishery is typically one of the more profitable fisheries on a per fish caught basis. In Inverness, Nova Scotia where some of the provinces most productive salmon rivers are located, the catch per effort rate is approximately 5 days fishing to one salmon caught, and 91% of the time, the salmon is released. The average spending for an angler for every salmon caught in Inverness is $1082 (Gardner Pinfold, 2012). This is the equivalent of five days spent fishing and all the gas, food, accommodation, and other costs that are associated with this.

In Nova Scotia the total salmon related spending activity from resident and non-resident anglers equated to $4.3M in 2010 (Gardner Pinfold, 2011). This value is the total amount of spending with the current level of recreational salmon angling opportunities available to anglers. Every lime doser that is installed on acid impacted rivers in the Southern Uplands of Nova Scotia would theoretically restore the salmon populations on that river to a level where a recreational salmon fishery would be viable. Thus increasing the total amount of recreational salmon opportunities available. This report will assume that this restoration will take ten years before the river could be re-opened for recreational angling and therefore economic impacts will not be recorded until the tenth year after the lime dosers installation. Assuming that spending increases linearly with the increase in angling opportunities in Nova Scotia then the percentage increase in salmon angling spending would match the percentage increase in angling opportunities opened by lime dosing. The calculation method used to calculate the total economic benefit of lime dosing in Nova Scotia is included in Appendix A.

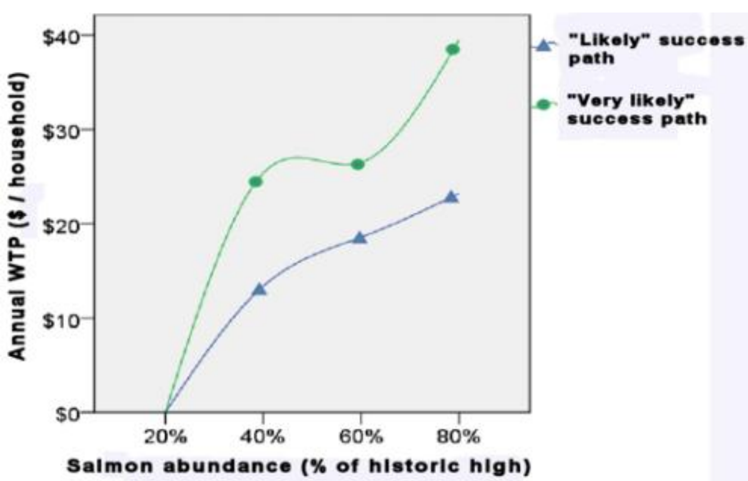
In 2010 the recreational salmon fishery accounted for approximately $4.3M worth of salmon related spending. There were a total of 49 open recreational salmon angling rivers visible at the 1:1000000 map level (Toporama, 1945). These rivers are located along the Northumberland Strait on the North shore of Nova Scotia (SFA 18) as well as some in the Inverness and Victoria region of Cape Breton (SFA 19) (DFO, 2011). These rivers currently account for the total amount of recreational fishing opportunities in Nova Scotia. We will assume that the average river in Nova Scotia would require 3 lime dosers to completely mitigate the main stems. As mentioned, we will also assume that rivers where lime dosing was implemented would require 10 years to restore the rivers to a level where a recreational salmon fishery would be viable and that the life span of the lime doser would be 30 years. With all of the variables set can say that each lime doser would increase the amount of available salmon angling opportunities would be by 0.41% per lime doser installed. The total economic benefit over a 30 year period is calculated to be $585034.

Social Benefits

It is important to account for the social benefits in addition to economic benefits in order to fully understand the total value of the restoration of Atlantic salmon to Nova Scotians. The social "non-use" value shown in dollar terms from the Gardner Pinfold contingent valuation will show an amount that survey respondents suggest that they would be willing to pay for a 20 year salmon restoration program that would increase salmon populations. This value is an amount that is a justifiable taxation or reallocation of tax dollars to fund a project such as lime dosing.

Social benefits of a lime dosing program are evaluated using data from the Gardner Pinfold Contingent evaluation and combining it with other data to understand the social benefit on a per lime doser basis. The Gardner Pinfold report (2012) conducted a survey with 1,000 survey participants from across Atlantic Canada including anglers and non-anglers assessing their willingness to pay for salmon restoration programs with varying degrees of population increase and chances of success. On the following page is a chart that depicts these values on a per household basis.

Figure 5: Gardner Pinfold Willingness-To-Pay Values



Gardner Pinfold, 2012

The potential effects in the southern uplands of any restoration program including a lime dosing program are not accurately predictable. However, the social willingness to pay is dependent on the predicted level of increase in the salmon populations relative to historic highs and the probability of the program succeeding in achieving these levels. In order to show the potential benefits of a lime dosing program at all levels of predicted increase in salmon populations and chances of success this report will analyze the potential benefits at all the points outlined in the Gardner Pinfold report (2012).

We then must multiply this value by the desired payment period divided by the lime doser life span. We must do this because we wish to represent the desired 20 year payment period for the salmon restoration program which was described in the Gardner Pinfold report over the total life span of the lime doser. One these calculations are completed we will have our total social benefits represented by willingness to pay in terms of monetary value. The calculation method used is included in Appendix B.

In Nova Scotia there are approximately 376,845 households (Statistics Canada, 2001). The desired payment period described in the Gardner Pinfold report is over 20 years. Applying the calculation method found in Appendix B to all of the willingness to pay values identified in Figure 5 we get the following social benefits values outlined in the table below.

Table 1: Total Social Benefit Values

Total Social Benefits					
80-100% Chances of Success			50-80% Chances of Success		
40%	60%	80%	40%	60%	80%
$392,292	**$502,918**	**$610,609**	**$207,348**	**$287,227**	**$379,468**

Overall Benefits

The two equations shown above are the calculation methods used to evaluate the potential benefits from both the economic and social perspective. The combination of these two calculation methods yields the equation shown in Appendix C which is the calculation method used to evaluate the overall benefits from both perspectives.

In applying this formula to the various willingness to pay values that were identified in the Gardiner Pinfold report (2012) we can obtain the value for overall benefits from both economic and social perspectives of lime dosing in Nova Scotia over a 30 year period. The overall value is dependent characteristic's associated with the lime dosing program related to chances of success and expected change in abundances of salmon relative to historic highs and therefore there are 6 total possible total benefits values. These six points are shown in the table below.

Table 2: Total Economic and Social Benefits

Total Economic and Social Benefits					
80-100% Chances of Success			50-80% Chances of Success		
40%	60%	80%	40%	60%	80%
$977,326	**$1,087,952**	**$1,195,643**	**$792,382**	**$872,261**	**$964,502**

Alternative Calculation Method

An important note is that the above model does not account for variables such as population, location, and the specifics of the river where lime dosing is installed. This is a general model for any river in the Southern Uplands Region of Nova Scotia. If we were to calculate this using a comparison of size of the watershed to another we could say that the Lahave River in Lunenburg County is of comparable size to the Margaree River in the Inverness County of Cape Breton, Nova Scotia which generates approximately $2.3M per year in salmon related spending (Gardner Pinfold, 2012). Applying this calculation method would lead us to a higher profit margin. The location of the river and the characteristics of the river involved will greatly affect the social and economic benefits of a lime dosing program in that area and thus also affects the overall net margin of benefits that are gained from the lime dosing program. It is most likely that the opening of a river such as the Lahave river over other smaller rivers in more rural areas could yield more salmon related spending per lime doser then the typical Southern Uplands river. This means that the ratio of benefits to costs could vary from river to river, and the implementation of lime dosing on one river could yield more benefits then on another. This deliberation should be considered when evaluating the net benefits of lime dosing as it is likely that lime dosing would take place on a river with the highest possible margin of benefit.

Net Cost Benefit

When combining the costs and the benefits of a lime doser we can then then get a number that represents the total net benefits of a lime doser to Nova Scotia. This is the most important number in the cost benefit analysis because it shows weather the project is worth investment or not, and if the investments "break even". The total potential net benefit value ranges from approximately $237,000 to -$166,000 dependent on the success levels of a lime dosing program. The calculated net benefit values are shown in the graph and table below.

Figure 8: Net Benefits from a Lime Doser

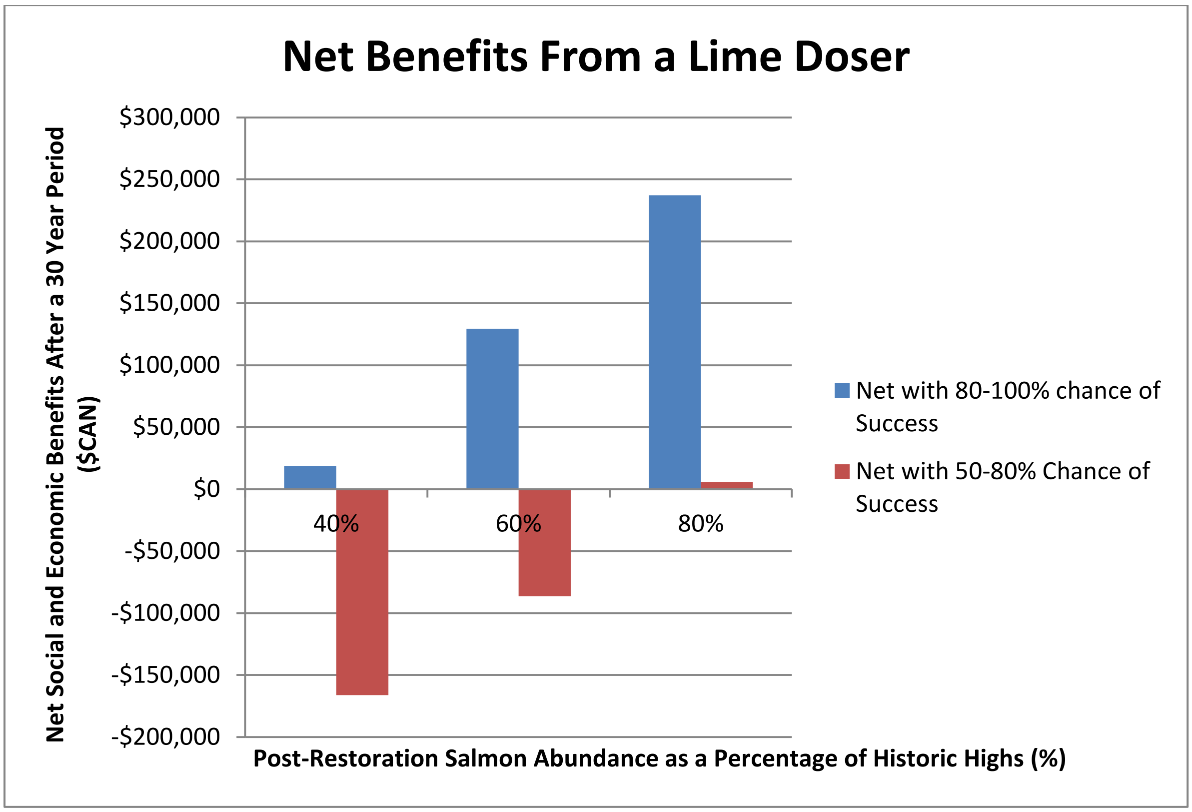


Table 3: Net Benefits from a Lime Doser

Net Benefits From a Lime Doser					
80-100% Chances of Success			50-80% Chances of Success		
40%	60%	80%	40%	60%	80%
$18,678	**$129,304**	**$236,995**	**$-166,266**	**$-86,387**	**$5,854**

The actual chances of success of lime dosing increasing salmon populations in Nova Scotia to levels above 40% of the historic high is not certain. However, based on the initial results from the West River Sheet Harbour and the conclusive evidence of the positive effect of lime dosing on the salmon populations in Norway is it reasonable to say that lime dosing in Nova Scotia would have an 80 to 100% chance of increasing the salmon populations to at least 40% of the historic highs. If this is true it would mean that the net benefit from lime dosing would be positive regardless of the expected increase of salmon populations relative to the historic highs. A positive net benefit indicates that government investment is justified through either reallocation of resources or increased taxation.

Conclusion

Research Constraints

The research in this report is limited by several factors. Firstly, the simplicity of the evaluation methods used in the economic analysis. The values obtained for the economic analysis are very broad and the calculation methods are simplistic. The purpose of this report is to provide a general overview of the potential costs and benefits and the actual values may range greatly from the values presented in this report. However, the report is successful in providing a theory for how lime dosers could be partly economically self-sustained and how the social and economic value of lime dosing is higher than the actual cost of investment.

Another constraint to this research is the controversial nature of contingent evaluations in evaluating the true social value of an environmental asset such as the Atlantic salmon species in Nova Scotia. The Gardner Pinfold report that is extensively used in this report to evaluate both the economic and social value of wild Atlantic salmon in Nova Scotia uses a contingent evaluation method to obtain the social value of Atlantic salmon. This technique is somewhat controversial, and there is debate as to this is a reliable way to obtain the social value of environmental objects. However, for the purposes of this report, the contingent evaluation method was the only practical method with the available resources. Also, given the significant social value this section of the benefits of lime dosing could not be ignored.

The inability for the data from the West River Sheet Harbour to produce significantly conclusive evidence of the scientific effectiveness of lime dosing is a constraint to this research as well. The true effect of lime dosing in Nova Scotia is not totally known or predictable. Much of the economic evaluation relies on scientific evidence that is not statistically significant. Thus, many of the conclusions are based on assumptions of the ability of lime dosing to restore salmon populations to certain levels outlined in the Gardner Pinfold report (2012).

Future Research

More research in two main areas is needed to gain a better understanding of the viability of lime dosing in the Southern Uplands of Nova Scotia. Firstly, scientific research in the actual ability of lime dosing to improve salmon populations and to what levels is required. The West River Sheet Harbour lime doser project should be a better indicator of this in the next several years. Other liming techniques should also be explored in the chance of a more economically viable method of liming for acid rain mitigation may be discovered. Secondly, the economics of lime dosing regarding both the monetary and contingent values of lime dosing should be explored. The important part of analysis for investment from the government is that social and environmental values are considered in the analysis as opposed to solely "market" economics.

Summary

Salmon populations in Nova Scotia are low relative to historical levels, many genetic strains have been lost and many more are at risk. As salmon are a bell-weather species, their plights are an indication of the quality of habitat within many of our watersheds in Nova Scotia and the restoration of rivers for salmon populations is typically benefits the watercourse and watershed as a whole. The recreational salmon fishery has suffered huge setbacks and currently less than one third of our province's coast's rivers are open to the historic sport of salmon angling. This is a loss to Nova Scotians and Atlantic Canadians both socially and economically. Many various programs with great funding are currently in place to try and restore and conserve salmon populations and are successful in helping salmon populations in many places. However, these programs results are not as positive as many Nova Scotians would like. Due to this, many salmon conservationists are resorting to out-of-the box thinking and trying new techniques and new concepts to salmon conservation and management. Lime dosing is an example of one of these out-of-the-box techniques.

Currently, the effectiveness of lime dosing in Nova Scotia does not have enough scientific evidence to conclusively and scientifically say that lime dosing works to restore salmon populations in all rivers in the Southern Uplands in Nova Scotia. However the anecdotal evidence from the West River Sheet Harbour and the conclusive evidence from Norway indicate that lime dosing could be and likely is a useful technique in increasing salmon populations on a river impacted by acid rain. The current trends on the West River Sheet Harbour indicate that this project could increase salmon populations likely ranging in the 40%-80% abundance relative to the historic highs. Also, based on data from Norway, the chances of a well-designed lime dosing project being successful in accomplishing these levels is likely high.

The cost benefit analysis yielded a net positive benefit for a lime dosing program in Nova Scotia for all expected salmon population increases at the 80% chances of success level. The total break-even point for the benefits ranged from 21-29 years at the 80% chances of success level as can be seen in Appendix F. It is important to consider that the model used for these calculations is based on an average representative river in the Southern Uplands region. This means that the actual net benefit and break-even points could be much superior on a river with characteristic's that would lead to more economic and social benefit.

Lime dosing is a river restoration technique that has potential to impact Nova Scotia for good. The technology has the potential to preserve a part of the Southern Uplands genetic strain of salmon while having an economic and social benefit that outweighs the cost of investment. The result of the cost benefit analysis indicates that lime dosing in Nova Scotia is viable and that there is grounds for governmental investment.

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Appendix A: Economic Benefit Calculation Method

$$I = S \times \left(\frac{1}{R}\right) \times \left(\frac{1}{L}\right) \times (D - T)$$

let:

I = Total economic impact per lime doser installed (excluding costs)
S = Total salmon related spending at current level of recreational salmon angling opportunities
R = Number of open salmon angling river outflows visible at the 1:1000000 map scale
L = Number of lime dosers required to fully dose the main stems of an average sized river in the region
T = Total required time required to restore salmon populations to a level where a recreational salmon fishery would be viable on the river (years)
D = Estimated life span of the lime doser

Appendix B: Figure 6: Social Benefits Calculation Method

$$B = W \times (\frac{1}{R}) \times (\frac{1}{L}) \times (\frac{Y}{D})$$

let:

B = Total social willingness to pay value
W = Willingness to pay at determined level of increase in salmon populations relative to historic levels and chances of success.
R = Number of open salmon angling river outflows visible at the 1:1000000 map scale
L = Number of lime dosers required to fully dose the main stems of an average sized river in the region
Y = Desired payment period in years outlined in Garder Pinfold report
D = Estimated life span of the lime doser

Appendix C: Overall Benefit Calculation Method

$$O=\left\{S\times\left(\frac{1}{R}\right)\times\left(\frac{1}{L}\right)\times(D-T)\right\}+\left\{W\times\left(\frac{1}{R}\right)\times\left(\frac{1}{L}\right)\times\left(\frac{Y}{D}\right)\right\}$$

let:

O = Overall social and economic benefit from the installation of a lime doser
W = Willingness to pay at determined level of increase in salmon populations relative to historic levels and chances of success.
Y = Desired payment period in years outlined in Garder Pinfold report
S = Total salmon related spending at current level of recreational salmon angling opportunities
R = Number of open salmon angling river outflows visible at the 1:1000000 map scale
L = Number of lime dosers required to fully dose the main stems of an average sized river in the region
T = Total required time required to restore salmon populations to a level where a recreational salmon fishery would be viable on the river (years)
D = Estimated life span of the lime doser

Appendix D: ANCOVA Multiple Comparisons Analysis

Multiple Comparisons

Bonferroni

(I) Site	(J) Site	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Upper Bound	95% Confidence Interval Lower Bound
West River Main	Little River	1.6955(*)	.34674	.000	.7021	2.6888
	Saint Mary's River	-1.2922(*)	.32691	.003	-2.2288	-.3557
	Lahave River	-1.3056(*)	.26692	.000	-2.0703	-.5409
Little River	West River Main	-1.6955(*)	.34674	.000	-2.6888	-.7021
	Saint Mary's River	-2.9877(*)	.34674	.000	-3.9811	-1.9943
	Lahave River	-3.0011(*)	.29087	.000	-3.8344	-2.1677
Saint Mary's River	West River Main	1.2922(*)	.32691	.003	.3557	2.2288
	Little River	2.9877(*)	.34674	.000	1.9943	3.9811
	Lahave River	-.0134	.26692	1.000	-.7781	.7513
Lahave River	West River Main	1.3056(*)	.26692	.000	.5409	2.0703
	Little River	3.0011(*)	.29087	.000	2.1677	3.8344
	Saint Mary's River	.0134	.26692	1.000	-.7513	.7781

Based on observed means.

The mean difference is significant at the .05 level.

Appendix F: Break Even Analysis