Technical Report No. 37A

Sea Lamprey Control Alternatives in the Lake Champlain Tributaries: Poultney, Hubbardton and Pike Rivers and Morpion Stream

Lake Champlain Basin Program

By
Leigh R. Walrath, Environmental Analyst and
Katherine M. Swiney, Environmental Analyst
New England Interstate Water Pollution Control Commission

for
Lake Champlain Basin Program

August 2001

PUBLICATION SERIES

THIS PROGRAM IS SPONSORED BY U.S.E.P.A. AND THE STATES OF NEW YORK AND VERMONT.

This technical report is the thirty-seventh in a series of reports prepared under the Lake Champlain Basin Program. Those in print are listed below.

Lake Champlain Basin Program Technical Reports

1. *A Research and Monitoring Agenda for Lake Champlain.* Proceedings of a Workshop, December 17-19, 1991, Burlington, VT. Lake Champlain Research Consortium. May, 1992.

2. *Design and Initial Implementation of a Comprehensive Agricultural Monitoring and Evaluation Network for the Lake Champlain Basin.* NY-VT Strategic Core Group. February, 1993.

3. (A) *GIS Management Plan for the Lake Champlain Basin Program.* Vermont Center for Geographic Information, Inc., and Associates in Rural Development. March, 1993.

   (B) *Handbook of GIS Standards and Procedures for the Lake Champlain Basin Program.* Vermont Center for Geographic Information, Inc. March, 1993.

   (C) *GIS Data Inventory for the Lake Champlain Basin Program.* Vermont Center for Geographic Information, Inc. March, 1993.

4. (A) *Lake Champlain Economic Database Project. Executive Summary.* Holmes & Associates. March 1993.

   (B) *Socio-Economic Profile, Database, and Description of the Tourism Economy for the Lake Champlain Basin.* Holmes & Associates. March 1993

   B) *Socio-Economic Profile, Database, and Description of the Tourism Economy for the Lake Champlain Basin. Appendices.* Holmes & Associates. March 1993

   (C) *Potential Applications of Economic Instruments for Environmental Protection in the Lake Champlain Basin.* Anthony Artuso. March 1993.

   (D) *Conceptual Framework for Evaluation of Pollution Control Strategies and Water Quality Standards for Lake Champlain.* Anthony Artuso. March 1993.

5. *Lake Champlain Sediment Toxics Assessment Program. An Assessment of Sediment - Associated Contaminants in Lake Champlain - Phase 1.* Alan McIntosh, Editor, UVM School of Natural Resources. February 1994.

   Lake Champlain Sediment Toxics Assessment Program. An Assessment of Sediment - Associated Contaminants in Lake Champlain - Phase 1. Executive Summary. Alan McIntosh, Editor, UVM School of Natural Resources. February 1994.

6. *(A) Lake Champlain Nonpoint Source Pollution Assessment.* Lenore Budd, Associates in Rural Development Inc. and Donald Meals, UVM School of Natural Resources. February 1994.

   (B) Lake Champlain Nonpoint Source Pollution Assessment. Appendices A-J. Lenore Budd, Associates in Rural Development Inc. and Donald Meals, UVM School of Natural Resources. February 1994.

7. *Internal Phosphorus Loading Studies of St. Albans Bay. Executive Summary.* VT Dept of Environmental Conservation. March 1994.

(A) *Dynamic Mass Balance Model of Internal Phosphorus Loading in St. Albans Bay, Lake Champlain*. Eric Smeltzer, Neil Kamman, Karen Hyde and John C. Drake. March 1994.

(B) *History of Phosphorus Loading to St. Albans Bay, 1850 - 1990*. Karen Hyde, Neil Kamman and Eric Smeltzer. March 1994.

(C) *Assessment of Sediment Phosphorus Distribution and Long-Term Recycling in St. Albans Bay, Lake Champlain*. Scott Martin, Youngstown State University. March 1994.

8. *Lake Champlain Wetlands Acquisition Study*. Jon Binhammer, VT Nature Conservancy. June 1994.

9. *A Study of the Feasibility of Restoring Lake Sturgeon to Lake Champlain*. Deborah A. Moreau and Donna L. Parrish, VT Cooperative Fish & Wildlife Research Unit, University of Vermont. June 1994.

10. *Population Biology and Management of Lake Champlain Walleye*. Kathleen L. Newbrough, Donna L. Parrish, and Matthew G. Mitro, Fish & Wildlife Research Unit, University of Vermont. June 1994.

11. (A) *Report on Institutional Arrangements for Watershed Management of the Lake Champlain Basin. Executive Summary*. Yellow Wood Associates, Inc. January 1995.

    (B) *Report on Institutional Arrangements for Watershed Management of the Lake Champlain Basin*. Yellow Wood Associates, Inc. January 1995.

    (C) *Report on Institutional Arrangements for Watershed Management of the Lake Champlain Basin. Appendices*. Yellow Wood Associates, Inc. January 1995.

12. (A) *Preliminary Economic Analysis of the Draft Plan for the Lake Champlain Basin Program. Executive Summary*. Holmes & Associates and Anthony Artuso. March 1995

    (B) *Preliminary Economic Analysis of the Draft Plan for the Lake Champlain Basin Program*. Holmes & Associates and Anthony Artuso. March 1995

13. *Patterns of Harvest and Consumption of Lake Champlain Fish and Angler Awareness of Health Advisories*. Nancy A. Connelly and Barbara A. Knuth. September 1995.

14. (A) *Preliminary Economic Analysis of the Draft Plan for the Lake Champlain Basin Program. Executive Summary - Part 2*. Holmes & Associates and Anthony Artuso. November 1995

    (B) *Preliminary Economic Analysis of the Draft Plan for the Lake Champlain Basin Program - Part 2*. Holmes & Associates and Anthony Artuso. November 1995

15. *Zebra Mussels and Their Impact on Historic Shipwrecks*. Lake Champlain Maritime Museum. January 1996.

16. *Background Technical Information for Opportunities for Action: An Evolving Plan for the Future of the Lake Champlain Basin*. Lake Champlain Basin Program. June 1996

17. (A) *Executive Summary. Economic Analysis of the Draft Final Plan for the Lake Champlain Management Conference.* Holmes & Associates and Anthony Artuso. July 1996

(B) *Economic Analysis of the Draft Final Plan for the Lake Champlain Basin Management Conference.* Holmes & Associates and Anthony Artuso. July 1996

18. *Catalog of Digital Spatial Data for the Lake Champlain Basin .* Vermont Center for Geographic Information, Inc. September 1996.

19. *Hydrodynamic and Water Quality Modeling of Lake Champlain.* Applied Science Associates, Inc. July 1996.

20. *Understanding Phosphorus Cycling, Transport and Storage in Stream Ecosystems as a Basis for Phosphorus Management. Dr. James P.* Hoffmann, Dr. E. Alan Cassell, Dr. John C. Drake, Dr. Suzanne Levine, Mr. Donald W. Meals, Jr., Dr. Deane Wang. December 1996.

21. *Bioenergetics Modeling for Lake Trout and other Top Predators in Lake Champlain.* Dr. George W. LaBar and Dr. Donna L. Parrish. December 1996

22. *Characterization of On-Farm Phosphorus Budgets and Management in the Lake Champlain Basin.* Robert D. Allshouse, Everett D. Thomas, Charles J. Sniffen, Kristina Grimes, Carl Majewski - Miner Agricultural Research Institute. April 1997

23. (A) *Lake Champlain Sediment Toxics Assessment Program. An Assessment of Sediment - Associated Contaminants in Lake Champlain - Phase 11. Executive Summary.* Alan McIntosh, Mary Watzin and Erik Brown, UVM School of Natural Resources. October 1997

(B) Lake Champlain Sediment Toxics Assessment Program. An Assessment of Sediment - Associated Contaminants in Lake Champlain - Phase 11. Alan McIntosh, Mary Watzin and Erik Brown, UVM School of Natural Resources. October 1997

24. *Development of Land Cover/Land Use Geographic Information System Data Layer for the Lake Champlain Basin and Vermont Northern Forest Lands Project Areas.* Dr. Thomas Millette. October 1997

25. *Urban Nonpoint Pollution Source Assessment of the Greater Burlington Area.* Urban Stormwater Characterization Project. James Pease, VT Dept. of Environmental Conservation. December 1997

26. *Long-Term Water Quality and Biological Monitoring project for Lake Champlain.* Cumulative Report for Project Years 1992- 1996. VT Dept of Environmental Conservation and NYS Dept of Environmental Conservation. March 1998.

27. *Cumberland Bay PCB Study.* Clifford W Callinan, NY State Dept. of Environmental Conservation; Lyn McIlroy, Ph.D., SUNY Plattsburgh; and Robert D. Fuller, PhD., SUNY Plattsburgh. October 1998.

28. *Lake Champlain Underwater Cultural Resources Survey. Volume 1: Lake Survey Background and 1996 Results.* Scott A. McLaughlin and Anne W. Lessman, under the direction of Arthur B. Cohn, Lake Champlain Maritime Museum. December 1998.

29. *Evaluation of Soil Factors Controlling Phosphorus Concentration in Runoff from Agricultural Soils in the Lake Champlain Basin.* Frederick R. Magdoff, William E. Jokela, and Robert P. Durieux, UVM Department of Plant and Soil Sciences. June 1997.

30. *Lower Trophic Level Interactions in the Pelagic Foodweb of Lake Champlain.* Dr. Suzanne N. Levine, Dr. Mark Borchardt, Dr. Moshe Braner, Angela Shambaugh, and Susan Spencer of UVM School of Natural Resources and Marshfield Medical Research Foundation. July 1997.

31. Estimation of Lake Champlain Basinwide Nonpoint Source Phosphorus Export, William Hegman, Associates in Rural Development, Inc., Deane Wang and Catherine Borer, UVM Water Resources & Lake Study Center, September 1999.

32. *The Freshwater Mussels of the Lower Missisquoi Rivers: Current Status and the Potential for a Refugium from Zebra Mussel Impacts.* Paul Marangelo, VT Agency of Natural Resources, Dept of Environmental Conservation. August 1999.

33. *Ecological Effects of Sediment-Associated Contaminants in Inner Burlington Harbor, Lake Champlain.* Tetra Tech, Inc. September 1999.

34. (A) Benthic Phosphorus Cycling in Lake Champlain: Results of an Integrated Field Sampling/Water Quality Modeling Study. Part A: Water Quality Modeling. Jeffrey C. Cornwell and Michael Owens, University of Maryland Center for Environmental Sciences Horn Point Laboratory for HydroQual, Inc. June 1999.

    (B) *Benthic Phosphorus Cycling in Lake Champlain: Results of an Integrated Field Sampling/Water Quality Modeling Study. Part B: Field Studie.* Jeffrey C. Cornwell and Michael Owens, University of Maryland Center for Environmental Sciences, Horn Point Laboratory for HydroQual, Inc. June 1999.

35. *Determination and Quantification of Factors Controlling Pollutant Delivery from Agricultural Land to Streams in the Lake Champlain Basin.* J.W. Hughes, W.E. Jokela, D. Wang, C. Borer, UVM. September 1999.

36. *Cost-Effective Phosphorus Removal from Secondary Wastewater Effluent through Mineral Adsorption.* Larry D. Goehring, Sr., Tammo S. Steenhuis, Andrea S. Brooks, Melissa N. Rosenwald, Jennifer Chen, Cornell University and Victor J. Putnam, Essex County Planning Department. December 1999.

37. *(A)* ***Sea Lamprey Control Alternatives in the Lake Champlain Tributaries: Poultney, Hubbardton and Pike Rivers and Morpion Stream.*** Leigh R. Walrath, Environmental Analyst and Katherine M. Swiney, Environmental Analyst, New England Interstate Water Pollution Control Commission. August 2001.

37 ***(B) Assessment of Sea Lamprey Habitat and the Sea Lamprey Population of the Pike River and Morpion Stream, Quebec, Canada.*** Micah Dean and Adam Zerrenner, Lake Champlain Fish and Wildlife Resources Office, United States Fish and Wildlife Service. September 2001

This report was funded and prepared under the authority of the Lake Champlain Special Designation Act of 1990, P.L. 101-596, through the U.S. Environmental Protection Agency (EPA grant #EPA X LC991923-01). Publication of this report does not signify that the contents necessarily reflect the views of the States of New York and Vermont, the Lake Champlain Basin Program, or the U.S. Environmental Protection Agency.

Sea Lamprey Control Alternatives in the Lake Champlain Tributaries: Poultney, Hubbardton and Pike Rivers and Morpion Stream.

August 2001

Leigh R. Walrath, Environmental Analyst
Katherine M. Swiney, Environmental Analyst
New England Interstate Water Pollution Control Commission

For:
Lake Champlain Basin Program

This report was funded and prepared under the authority of the Lake Champlain Basin Special Designation Act of 1990, PL 100-596, through US Environmental Protection Agency (EPA) grant # LC991923-01 to the New England Interstate Water Pollution Control Commission (NEIWPCC). The views expressed do not necessarily reflect the views of the EPA, NEIWPCC, or the Lake Champlain Basin Program.

Contents

Poultney River Investigations

Hubbardton River Investigations

Pike River Investigations

Morpion Stream Investigations

Bibliography

Tables

Tables (continued)

Figures

Appendices

1.0 Lake Champlain and its Watershed

Lake Champlain is located on the eastern edge of the Adirondack Mountains on the New York-Vermont border. The lake, located within two deep, narrow crytodepressions, is nearly 125 miles (200 km) in length, has a mean depth of 72 ft (22 m) (Myer and Gruendling 1979), and covers a total surface area of 435 mi^2 (1,127 km^2) (Shanley and Denner Unpublished Data).

The Lake Champlain watershed covers 8,166 mi^2 (21,150 km^2) with a distribution of 56.2% within Vermont, 37.4% in New York, and 6.4% in the Canadian province of Quebec (Gersmehl and Barren 1985). Lake Champlain's watershed is a byproduct of ancient mountain building worn by erosion and glacial gouging. The watershed incorporates much of the Adirondack and Green Mountains and a small portion of the Taconic Mountains. In addition, the watershed contains the Lake Champlain Valley and the Vermont Valley (located between the Green and Taconic Mountains); both regions are characterized as being highly productive agricultural lands.

2.0 Background

In the 18th and early 19th centuries large salmon runs were common in Lake Champlain tributaries however, during the mid-19th century the fishery collapsed. Thompson (1853) suggested that the erection of dams across nearly all streams was the primary reason for the collapse of the salmonid fishery. Watson (1876) charged that a combination of clear cutting forests, river pollution, and dam construction resulted in the collapse. Since then better forestry practices have improved spawning habitat and improvements in manufacturing and sewage treatment has greatly improved water quality. Despite the fact that many of the initial anthropogenic activities which destroyed the fisheries have been mitigated there has been limited success in restoring the fishery. To date, the fishery has not attained its full modern day potential (L. Nashett, N.Y.S. Department of Environmental Conservation, Personal Communication, 2000). The invasive exotic sea lamprey was identified as a detrimental factor in recovery of salmonids to Lake Champlain (Anderson *et al.* 1985) and, without control of the sea lamprey, the salmonid populations will remain suppressed.

In response to a variety of fisheries management issues in Lake Champlain, the Lake Champlain Fish and Wildlife Management Cooperative (Cooperative) was formed in 1973. The Cooperative worked to develop and maintain a diverse salmonid fishery. The Cooperative also explored control options for reducing sea lamprey populations. In 1990 an eight-year sea lamprey program was initiated with the objective of applying lampricides to 14 tributaries and 5 lake deltas to quickly and substantially reduce sea lamprey populations (Fisheries Technical Committee 1999). The Poultney River and its tributary, the Hubbardton River, were among those tributaries treated, however the Pike River and its tributary, Morpion Stream, were not included in the lamprey control program. Also, during the 1990s, a dam was renovated to establish a sea lamprey barrier (a permanent trap was incorporated in the structure) on the Great Chazy River (NY) and another dam was rebuilt as a sea lamprey barrier on Lewis Creek (VT).

This report investigates sea lamprey control techniques presently available and assesses the feasibility, ecological and human implications, and costs of each technique as applied to the Poultney, Hubbardton, and Pike Rivers, and Morpion Stream. Alternative, experimental, and future control techniques are also discussed although they will not be presented in the context of any particular river.

3.0 Sea Lamprey (*Pertromyzon marinus*)

The sea lamprey, thought to be a nonnative fish, has negatively impacted the Lake Champlain cold water fishery (Anderson *et al.* 1985, Gersmehl and Baren 1985). Unlike the native northern (*Ichthyomyzon fossor*) and American brook (*Lampetra appendix*) lampreys which are nonparasitic, the sea lamprey aggressively parasitizes fish for 12 to 20 months (Smith 1985). During their parasitic phase, sea lamprey consume no less than 20 pounds (9.1 kg) of host fish (Dees 1980). This degree of parasitism results in considerable host fish mortality. The native silver lamprey (*Ichthyomyzon unicuspis*), a much smaller endemic species, is also parasitic. However, silver lamprey do not have a similar destructive impact on host fish.

Sea lamprey reproduction typically occurs in the spring with spawning runs being triggered in part by tributary water temperatures rising above lake temperatures (Applegate 1950). In Lake Champlain, sea lamprey have been observed migrating upstream to spawn as early as mid-March, although typical spawning runs occur between May and June (Gersmehl and Baren 1985). Spawning runs begin when parasitizing lampreys detach from their host and begin migrating upstream to spawn. Sea lamprey migrate upstream at night and rest under rocks and along river banks during the day (Hardisty and Potter 1971). Immigrants into a stream may spend up to 8 weeks in the watershed before initiating spawning activity (Sea Lamprey Barrier Transition Team 2000). In the St. Marys River, SCUBA divers have observed and killed large numbers of spawning run sea lamprey hidden among the rocks in the Great Lakes Power tailrace up to five weeks before the first lamprey were caught in the proximal traps. Observations have shown that sea lamprey will avoid spawning where large numbers of suckers are present on the grounds (Sea Lamprey Barrier Transition Team 2000).

Sea lamprey are not strong swimmers and, if lamprey cannot find adequate substrate to attach to, a flow of 12 ft/s (3.8 m/s) can be an impenetrable barrier (Hunn and Youngs 1980). Flows in excess of 6.6 ft/s (2 m/s) exhaust a burst-swimming lamprey within 30 seconds under moderate mid-season temperatures (Sea Lamprey Barrier Transition Team 2000). Sea lamprey can pass natural and low man-made barriers by throwing themselves upward and forward, then attaching firmly, resting, and traversing again (Anderson *et al.* 1985, Sea Lamprey Barrier Transition Team 2000).

Male sea lamprey are sexually immature at the start of spawning runs. Evidence suggests that these immature males are attracted to larval pheromones released by lamprey larvae present downstream from appropriate spawning habitat (Li et al. 1995). This attraction to larval pheromones may be the mechanism that allows sea lamprey to select streams which provide adequate spawning and larval environments (Teeter 1980). This sensory cue appears to be very important since sea lamprey do not have homing characteristics and will readily select other streams to spawn (Bergstedt and Seelye 1995). Other laboratory experiments suggest that sexually mature sea lamprey release other pheromones that attract individuals of the opposite sex; a mechanism of importance to successful mating (Teeter 1980).

During upstream migration sea lamprey become sexually mature, the intestine and foregut begin to atrophy, and degeneration of the eyes occurs (Hardisty and Potter 1971). Once the sea lamprey has migrated to the spawning site, the male constructs a crescent shaped nest. If barriers are encountered before reaching a spawning site the sea lamprey may emigrate out of one stream and into another (Swink 1999).

Stream requirements for nest construction include a unidirectional flow with a velocity of 1.6 to 4.9 ft/s (0.5 to 1.5 m/s), and gravel approximately 0.4 to 2 inches (9 to 50 mm) in diameter though other hard debris such as spent clam shells may be utilized (Applegate 1950). Sand or other fine material must also be present for eggs to adhere to and allow for egg settlement on the rim of the nest. Optimum spawning depth is 0.98 to 2.1 ft (30 to 64 cm) and optimum temperature is 18°C while successful spawning can occur between 15.6° and 21.2°C (Applegate 1950, Hardisty and Potter 1971).

The sea lamprey is very fecund with freshwater sea lamprey producing 60,000 (Applegate 1950) to 100,000 (Smith 1985) eggs. Spawning begins with the female anchoring herself to a stone while the male entwines himself around her such that the genital pores are in close contact. Spawning occurs every 5 to 10 minutes and can last from a few hours up to 2 to 3 days (Smith 1985). Immediately after the release of eggs the female drops away and drifts downstream from the nest to die. The male will remain on the nest until he too dies and drifts downstream.

After approximately 14 days the eggs hatch into larvae (ammocoetes) which remain on the nest for up to 5 days before drifting downstream to quiet depositional areas where they burrow into the soft sediments and begin filter feeding on micro-organisms (Hardisty and Potter 1971). Feeding habits do not change during the ammocoete life stage which can last from 2 to 14 years (Hardisty and Potter 1971, Smith 1985). In Lake Champlain the ammocoete stage lasts from 3 to 5+ years with the ammocoete populations in the Poultney and Hubbardton rivers having a 3+ year ammocoete stage (Gersmehl and Baren 1985). In the Pike River and Morpion Stream sea lamprey have a 4 - 6 year ammocoete life stage (Dean and Zerrenner 2001). Sea lamprey metamorphosis or time to transformation (ammocoete to parasitic life stage) may vary due to changes in environmental conditions (water temperature and productivity, and ammocoete density).

The next stage in the sea lamprey's life cycle is the transformer stage which is characterized by four distinct changes in mouth structure (Hardisty and Potter 1971), ending with the elongated mouth structure used for parasitism. Other morphological changes at this time include modifications in the gill structure and the development of eyes. Once this transformation has taken place the sea lamprey, now called a transformer, leaves the burrow and begins its downstream migration in search of prey to parasitize. In Lake Champlain, sea lamprey transformation occurs from July through October and downstream migration from October through April (Gersmehl and Baren 1985). Adult sea lamprey typically parasitize prey by attacking the region between the head and caudal peduncle below the lateral line and particularly in the region behind the pectoral fins (Farmer and Beamish 1973). Sea lamprey may have multiple prey during their predatory phase. The final stage in the sea lamprey life occurs when individuals cease parasitizing fish and begin migrating into streams to spawn.

4.0 Overview of Sea Lamprey Control Methods

A variety of sea lamprey control techniques have been developed in response to social, economic and environmental circumstances. Historic tactics for managing the sea lamprey have included barriers to spawning grounds, trapping of migrating adults, and chemical treatments of larval habitat. Advances in sea lamprey technologies have not only sought to improve control efficiencies but to minimize impacts on nontarget species. While many of the historic sea lamprey control methods are still utilized, technological improvements in design and increased scientific understanding of our environment have greatly increased technique efficiencies while reducing effects on nontarget species. Despite all advances in sea lamprey management two notions are widely held: 1) The eradication of sea lamprey from an ecosystem is an unrealistic goal; and, 2) Control strategies for effective lamprey control will incur non-target impacts.

This paper reviews four available control techniques: physical barriers, electrical barriers, trapping, and use of selectively toxic chemicals. All of these techniques have been utilized in the Great Lakes region and have been instrumental in the recovery of the Great Lakes cold water fisheries (www.glfc.org/sealamp/lmsl.htm 2000). In addition, to provide insight to other types of fish controls and future possibilities of emerging technologies, this paper discusses some experimental and alternative sea lamprey controls including sterile sea lamprey release, pheromone attractants, habitat alteration, and velocity, sonic, and photo barriers.

4.1 Low-head and Adjustable Crest Barrier Dams

A low-head barrier dam is a physical structure which can be installed to block the migration of fish. Barrier dams for sea lamprey may be constructed with an overhanging lip which prevents the sea lamprey from passing over the dam. When encountering a physical barrier, sea lamprey will move back and forth along the surface of the barrier trying to find a means of passing the barrier. Barriers with a head of 12 to 24 inches (~30 to 61 cm) are seldom passed (Hunn and Youngs 1980, Hardisty and Potter 1971). However, when faced with an impenetrable barrier, the sea lamprey may relocate to other tributaries. While this is known to occur (primarily by early run lamprey), the degree to which it occurs is uncertain (Swink 1999). Kelso and Gardner (2000) found that the greater the distance the sea lamprey has to travel before encountering a barrier, the less chance for emigration.

Low-head barrier dams can have profound effects on upstream habitat with the creation of large impoundment areas. Additional adverse impacts include permanent blockage of non-jumping fish from migration, dispersion of sea lamprey to other streams, disruption in recreational activities (users of the river would have to exit the river and reenter on the other side of the barrier), an aesthetically unappealing device, and temporary damage to the ecosystem during the construction of the dam (Hunn and Youngs 1980). Failure to effectively move sport fish above the barrier may impact sport fishing.

Although low-head barrier dams allow for the passage of leaping fish, they have the same impact (although present in lesser degree) on nonleaping fish as do large more conventional barriers with larger vertical drops (Porto *et al.* 1999). Porto *et al.* (1999) found the movements of mottled sculpin, longnose dace, log perch, rockbass, and roseyface shiner to be blocked by low-head barriers. To mitigate some of these adverse effects the Great Lakes Fisheries Commission (GLFC) reduced the head height on more recent barrier dam construction. While the new dams are effective in reducing sea lamprey migration, they are not as effective as the low-head barrier dams constructed during the 1980s which had higher crest heights (E. Koon, U.S. Fish and Wildlife Service, Personal Communication, 2000). Low-head barrier dams can also be designed with removable gates which can allow the passage of all fish and substantially decrease water impoundment after sea lamprey spawning season has ended. Traps which would allow for the manual transfer of non-leaping fish can also be designed into the barrier (section 4.3).

In addition to reducing the crest height of the low-head barrier dam, the GLFC began employing adjustable crest technologies in dam construction. These structures use an air bladder or some other device to adjust the height of the dam such that a desired crest height is properly maintained regardless of river flow. In the Great Lakes a 16 inch (41 cm) drop is maintained during the spawning season (T. McAuley, Canadian Department of Fisheries and Oceans, Personal Communication, 2000). The adjustable crest barriers can be designed to automatically adjust the barrier's crest height to changes in river height. Operation of the barrier can be monitored through a telephone modem connection. The adjustable crest barrier has the added benefit of being lowered below the water's surface thereby allowing all fish to pass and reducing water impoundments once the lamprey spawning season has ended. Since the crest height is adjustable, the degree of flooding and the impounding of water which is typical in a low-head barrier, can be lessened. Presently, difficulties in scheduling the timely raising of the adjustable dams are allowing sea lamprey to pass (E. Koon, Personal Communication, 2000).

Innundation of a barrier during flood events can provide a means of passage for migrating sea lamprey. The degree to which this occurs is uncertain; the Duffins Creek (a Lake Ontario tributary) low-head barrier has been passed only once by migrating sea lamprey despite the fact that flooding had inundated the dam 46 times in April to June over a period of 18 years (T. McAuley, Personal Communication, 2000).

4.1.1 Technical Considerations

In 1985 a preliminary feasibility report for sea lamprey barrier dams was published by the N.Y.S. Department of Environmental Conservation and the Vermont Agency of Natural Resources for the Lake Champlain Fish and Wildlife Management Cooperative (Anderson *et al.* 1985). This report investigated the feasibility of construction of physical barriers to prevent sea lamprey from accessing spawning and larvae habitat. The Poultney, Winooski and Missisquoi Rivers were excluded from this analysis due to large river size and / or at the time, poor lamprey production. The report also did not investigate using barriers in the Pike and Hubbardton Rivers or Morpion Stream. In deciding upon minimum requirements needed for the construction of dams, the report recommended a minimum drop of 18 inches (45 cm) and a 6 to 10 inch (15 to 25 cm) horizontal overhang. The 18 inch vertical drop was to be measured to the higher of two downstream water surface elevations as determined by 1) the appropriate design flow or 2) lake elevation of 101.5 ft (30.9 m) plus an allowance for wave action. This results in a recommendation for the dam lip elevation to be at least 103.0 ft (31.4 m) above mean sea level plus allowance for wave action (Anderson *et al.* 1985). Hunn and Youngs (1980) found that dams constructed with at least 1 ft (~30 cm) of head and 0.5 to 1.0 ft (~15 to 30 cm) of sheet steel overhang would be sufficient in preventing the passage of sea lamprey.

The degree of operation and maintenance of a low-head barrier dam depends on the features of the barrier. A solid barrier that does not include a slide gate, removable components, a fishway or lamprey trap typically does not require additional operation except for monitoring the effectiveness of the barrier. Slide gates, removable components and fishways may require adjustments with changes in water surface elevations and an annual maintenance including greasing and cleaning. The barrier weir itself should be constructed such that very little maintenance would be necessary, and have an expected life span of forty to fifty years. An adjustable crest barrier requires more maintenance than a low-head barrier dam. If the barrier is to be automatically adjusted, power must be present to adjust the crest height. Manual adjustments of the barrier can be made although there is a greater likelihood that the crest will not be positioned properly as water levels can fluctuate rapidly. Manually regulated adjustable crest barriers have not been proven to be effective in the Great Lakes (T. McAuley, Personal Communication, 2000).

There are no proven physical structures which allow for the automatic passage of walleye and other non-leaping fish (i.e. sturgeon, smallmouth bass, minnows) while still blocking sea lamprey. To mitigate the negative impacts of the barrier, manually tended traps can be installed to collect sea lamprey for disposal and collect migrating fish for transport upstream. Refer to section 4.3 for a discussion on the incorporation of a fish trap into a barrier dam and section 4.9 for the current state of velocity barrier technologies that pass non-leaping fish.

4.2 Electrical Fish Barriers

Electric barriers prevent fish passage by administering an electrical shock to fish traveling into an electric current field. The first sea lamprey application of electrical shock technology occurred in the early 1950s when 110 volts of alternating current (AC) was employed to prevent sea lamprey migrations (Hunn and Youngs 1980). Since its inception, the technology has undergone several major improvements increasing the ability to deter fish while avoiding permanent injury or death to sea lamprey and non-target fish.

Today, rapidly pulsating direct current (DC) replaces AC and, in addition to a single current field, a graduated electric field is available. The single current field, which administers a constant DC charge in rapid succession, shocks fish with a single intensity, strong current regardless of where the fish is located in the electrical field. In a graduated electric field, a system of electrodes are wired in series which results in differences in current produced by a particular electrode depending upon its placement in the series. With the electrodes in series, a graduated electrical field is created which results in the electrical shock increasing in intensity as the fish travels further into the grid. For streams and rivers, the electrical current field is placed such that migrating fish are subject to a greater shock as they move further upstream. At some point the fish will find the electrical stimuli unbearable and will turn perpendicular to the water's current thus orienting the body parallel to the electrical current to decrease lateral line exposure. Once the fish moves perpendicular to the current the electrical stimuli ceases and the fish either swims or is swept by the current back downstream. The graduated field is constructed by placing 2 to 6 pulse generators in series with the electrodes evenly spaced apart. The pulse generators are simultaneously triggered which causes an additive effect thereby increasing current along the grid.

Given sufficient current, a single current DC electric field was found to be very effective in preventing the migration of sea lamprey in the Jordan River, Michigan (Swink 1999). A 2-ms pulse width and 10 pulses / second current resulted in no spawning-phase sea lamprey penetrating the electrical barrier. When the current field was set at 1-ms pulse width with 10 pulses / second, only a single spawning-phase sea lamprey out of 900 was successful in penetrating the electric current. Probability analysis of the experiment suggested that, with the lower power setting, 0% to 1.8% of migrating lamprey would be able to pass the barrier and for the higher power setting, 0% to 1.0% may pass (Swink 1999).

Although no specific studies have been conducted, sea lamprey are believed to react to an electrical barrier in a manner identical to that when encountering physical barriers (W. Swink, U.S. Geological Survey, Personal Communication, 2000). Sea lamprey will search along the fringes of the barrier in attempts to find an acceptable route to pass. Some sea lamprey will stray to other tributaries in an attempt to find adequate spawning habitat. In the Great Lakes, the inclusion of traps was made as a recommendation to prevent the straying of lamprey into other tributaries (section 4.3) (GLFC Task Force on Barrier Dams 1988). When incorporating a trap with an electrical barrier application, a bypass channel or weir may be required to generate higher flows which attract fish to the trap (Swink 1999).

Historic surveys conducted to investigate the effects of single current, DC electric barriers documented mortalities of 0% to 8.1% in test species (longnose dace, largemouth bass, rainbow trout, and bluegill (Spencer 1967, Taylor *et al.* 1957). Hilgert *et al.* (1992) report that the intensity of the electrical current and duration of exposure significantly affect the physiological responses of fish (Hilgert *et al.* 1992). Also, the length of fish is directly related to the intensity of electric shock received (Taylor 1957, Kynard and Lonsdale 1975). The most common injury associated with exposure to an electrical shock is fracturing of vertebrae (McCrimmon and Bidgood 1965). Atlantic salmon and brook trout eggs exhibit a decrease in viability with an increase in exposure time and voltage when exposed to a DC electric field Godfrey (1957). No losses were reported for pre-eyed eggs in exposures of 25 seconds, however, mortalities of >80% were reported for exposures >25 seconds. Godfrey's study employed two 150 volt DC generators. More recently, Hilgert *et al.* (1992) report that prespawning coho salmon gametes exposed to electrical fields of 0.9 v/cm for 10 seconds did not affect the viability or the early development of eggs. Jeff Smith (Smith Root Inc., Personal Communication, 2000) has extended an offer to have Smith Root Inc. (a leading manufacturer of electrical barriers) conduct specific experiments in their laboratory if any nontarget impact questions remain.

While activated, electric field barriers prevent the movement of all fish, thus, they have the potential to negatively impact genetic and species diversity. And, as with barrier dams, this impact can be detrimental to fish communities above and below the barrier. To mitigate such problems sea lamprey traps can be designed to also collect non-target fish. Traps designed to collect non-target species require frequent sorting and transporting of nontarget species to prevent non-target mortality. Refer to section 4.3 for a discussion on adult sea lamprey trapping.

Use of an electrical barrier requires a portion of the river to be restricted to human traffic thereby negatively affecting recreational use of the river. This can have considerable implications for recreational boaters as well as anglers who would have to exit the river and reenter on the other side of the barrier. The electrical field barrier will shock anyone entering the field, and special considerations must be made accordingly. Safety lines, floats, and signs should be in place as precautions. The electrical shock produced by an electrical barrier is not sufficient to cause mortality or physical damage to humans or even small pets (D. Smith, Smith Root Inc., Personal Communication, 2000). A minimum flow of 1 to 2 ft/s (0.3 to 0.6 m/s) is recommended in areas where the barrier is to be installed (D. Smith, Personal Communication, 2000). This allows rapid transport out of the electrical field. The electrical barrier may be an aesthetically unappealing device, and temporary damage to the ecosystem during the construction of the barrier may occur.

Smith Root Inc. is in final development stages of a hydro acoustic fish identification system which may eliminate the need to trap and sort nontarget species blocked by an electrical barrier (J. Smith, Personal Communication, 2000). The system works by employing short band sound waves to identify fish within the graduated electrical barrier. If the identified fish is a target species, the electrical barrier becomes active thus preventing passage. If a nontarget species is identified the barrier will remain inactive. The identification system will allow for species specific fish counts as well as an automatic deactivation of the barrier if a large object (i.e. a person or boat) enters the field. Information gathered by the fish identification system can be uploaded and distributed through the Internet. The estimated time to market for this new technology is approximately 1 year. This new system will add approximately $40,000 to $50,000 to the cost of a barrier and will be compatible with older electric barriers. In addition to the fish identification system, Smith Root Inc. is also developing a segmented electrical barrier. This new barrier will incorporate the fish identification system with an x-y coordinate system to allow an accurate determination of the location of a fish in the barrier. This information will be used to activate a portion of the electrical barrier thus allowing nontarget species to pass while blocking target species. Smith Root Inc. is expecting to have this barrier technology available in less than two years (J. Smith, Personal Communication, 2000).

4.2.1 Technical Considerations

Although dependent upon water conductivity, the minimum life expectancy of an electrical barrier is 20 years (D. Smith, Personal Communication, 1999). The electrical barrier is typically installed such that the stainless steel electrodes are mounted on the stream bottom in concrete (Smith Root Inc. 1999). Since the system does not have any moving parts, little physical operation and maintenance is required and with flush mounted electrodes, debris can not become entangled as with a low-head or adjustable crest barrier. A back-up power source can be installed to maintain an effective barrier during power outages. To house the electronic equipment needed to create an electrical barrier, a small shed must be constructed adjacent to the barrier.

4.3 Adult Lamprey Trapping

Adult lamprey trapping is simply the trapping of spawning run adult lamprey using permanent traps, portable assessment traps (PATs) or nets. The removal of blocked sea lamprey is important to prevent their emigration into other rivers. Applegate and Smith (1951) reported that approximately 91% of sea lamprey blocked from the Cheboygan River emigrated out of the river in search of other spawning habitat. While some of the individuals found adequate spawning habitat, some were captured in deep waters and, presumably, would not have spawned successfully. Other individuals wandered in Lakes Huron and Michigan for a considerable length of time and distance before entering another stream; a single sea lamprey was captured in a stream 43 miles (69 km) from the Cheboygan River. Since sea lamprey have a high fecundity rate, avoidance by a relatively small number of lamprey pairs and their successful spawning downstream or in other tributaries may negate trap benefits. The magnitude of lost benefits would be unknown but would depend on stock recruitment, compensation, and associated control strategies within the trapped stream and other tributaries where lamprey may relocate.

Traps can be custom designed for a specific application to take advantage of natural features such as a constriction in river width, a natural barrier, or a section of river with increased flow that attracts migrating lamprey. In addition to custom designed sea lamprey traps, standard and modified fyke nets can be effective in trapping spawning run sea lamprey in small to medium rivers. If a stream is only a few meters across, a trap can block the entire stream and be effective in preventing sea lamprey migration. During a 1990 trapping effort on 17 Lake Superior tributaries, Ebener (1990) estimated 100% trapping efficiency with the employment of a fyke net on the small (1 cfs; 0.03 cms) Red Cliff Creek. In large rivers, fyke net traps become difficult to install due to deep water and high flows (Everhart and Youngs 1981). Gersmehl (U.S. Fish and Wildlife Service (Retired), Personal Communication, 2000) believes larger rivers are too difficult to trap effectively and that, in general, PATs are not an effective method for controlling sea lamprey. The Sea Lamprey Barrier Transition Team (2000) report that Great Lakes fixed-crest barriers had a trapping efficiency ranging from 0.23 to 0.79 (17 barriers); adjustable crest barriers, 0.22 to 0.77 (2 barriers), and velocity barriers, 0.28 (1 barrier).

To assess the 1997 Pike River sea lamprey spawning population, a PAT was employed at the Old Mill Dam in Notre-Dame-de-Stanbridge, Quebec, Canada. This effort resulted in the trapping and removal of 14 spawning run sea lamprey (W. Bouffard, Unpublished Data, 1999). To assess the 1998 Poultney River sea lamprey spawning population, a PAT was placed a few hundred meters below Carvers Falls. This trapping effort was considered unsuccessful because only 3 individuals were trapped. Gersmehl (Personal Communication, 2000) suggests the poor trapping success may have been a result of the trap being placed in the river too late in the season. Since later run mature sea lamprey typically migrate to one of the first available spawning habitats encountered, it may be that late-run individuals did not reach upstream areas in the vicinity of the Carvers Falls trap.

A custom-built permanent trap found at the Old Water Works Dam in Champlain, New York along the Great Chazy River (a tributary to Lake Champlain) has proven to be effective in trapping spawning run sea lamprey. In 1996 over 1,200 individuals were trapped from this location (W. Bouffard, U.S. Fish and Wildlife Service, Unpublished Data, 2000). Though no estimates are available for the Old Water Works Dam, efficiency of trapping spawning run sea lamprey at barrier dams can be as high as 75% to 80% (T. McAuley, Personal Communication, 1999).

Trapping has associated ecological impacts, however. Traps designed for sea lamprey also collect a large number of small teleost species as well as several larger species of fish. Bouffard (Personal Communication, 2000) has observed large white suckers muscling their way into the small 2 to 2.5 inch (5.1 to 6.4 cm) fyke net opening used in some Lake Champlain traps. Ebener (1990) reported 34 species of nontarget fish caught during the 1990 Lake Superior trapping effort. Species with >1,000 individuals caught in the sea lamprey traps included the white sucker, creek chub, and common shiner. Species with <1,000 and >100 individuals caught included rainbow trout [<12 inches (~30 cm) in length], longnose sucker, lake chub, longnose dace, bullhead spp., and rockbass. Other species caught in the traps during the 1990 Ebener study include, walleye, silver lamprey, carp, smallmouth bass, burbot, brown trout, northern pike, a variety of minnow, chub and shiner species, crayfish, frogs, toads, turtles, and ducks. In contrast, 931 sea lamprey were trapped during Ebner's study.

If timely sorting and transfer of fish from the traps is performed, nontarget mortality can largely be reduced to small teleosts. These individuals are unable to continuously swim against the current flowing through the trap and are subsequently swept against the downstream portion of the net and crushed by the water current. In addition, turtles, larger piscivorous fish, and crayfish can prey upon smaller teleosts caught in the trap. If the trap is completely submerged mortalities of turtles and ducks will occur.

If a flow attractant is required to enhance the trapping efficiency, alterations to the river flow may be required. Creation of a refuge which could be utilized by sea lamprey directly below the trap may increase trapping efficiency (J. Gersmehl, Personal Communication, 2000). Traps that block the entire river would require users of the river to exit and reenter on the other side of the trap. Failure to effectively trap and transfer spawning run sport fish that are attempting to access spawning habitat above a trap may impact the region's fishery.

4.3.1 Technical Considerations

A benefit of a trap is that it allows fisheries managers to manually sort and transfer trapped fish. In doing so, sea lamprey are removed from the environment and nontarget species are manually transported above the barrier thus mitigating some of the ecological effects associated with physical or electrical barriers. Trapping and sorting can be made easier by using 2 traps in a series (i.e., two-chamber traps). Walleye and other fish remain in the first trap and lamprey pass through a small funnel to a second trap (T. McAuley, Personal Communication, 1999).

The degree to which a trap must be manually tended depends upon its application. A trap placed against a natural barrier may only need a weekly visit to remove trapped sea lamprey and ensure proper operation. Traps or barriers which block the river below nontarget spawning habitat may require greater effort to allow for manual trapping and transfer of nontarget spawning run fish. More frequent inspection and transfer of fish will reduce stress and mortality of nontarget species. There is circumstantial and anecdotal evidence that the residue from dead lamprey can actually repel live lamprey (Sea Lamprey Barrier Transition Team 2000). Lamprey caught in a trap can be injured or killed if the trap also contains large numbers of suckers (or other fish).

A detriment of trapping is that it requires a commitment of staff time, however, in the Great Lakes subcontractors have been retained to conduct trapping operations at $1,000 to $3,000 per spawning season (E. Koon, Personal Communication, 2000). If subcontractors are used, then staff time could be reduced to training, support, and quality assurance and quality control of the subcontractors. Sea lamprey assessment surveys in Lake Champlain currently involve a bi or tri-weekly inspection of traps. This timing may be used to assess the frequency with which a trap must be inspected to minimize nontarget mortalities. River specific needs will greatly influence the frequency with which traps need to be tended.

4.4 TFM

Selectively toxic chemicals have been instrumental in substantially decreasing sea lamprey populations in the Great Lakes and Lake Champlain (National Research Council of Canada (NRCC) 1985, Fisheries Technical Committee 1999). The most common lampricide used is TFM, a halogenated mononitrophenol (3-trifluormethyl-4-nitrophenol). TFM has been employed in the Great Lakes since 1958 and in Lake Champlain since 1990. This restricted use lampricide is marketed under the brand name Lamprecid® by the Hoechst-AgrEvo Corporation and under the brand name Lampricide® by Kinetics, Inc.. Currently used formulations of TFM contain approximately 34% to 36% active ingredient (Free Cresol) with the remaining 64% to 66% comprised of water and an isopropyl alcohol carrier. TFM is also available as a solid bar for small feeder tributaries. Application of the bars is typically within ~300 ft (100 m) of the junction of the tributary and mainstream, with water velocity of 0.3 to 0.5 ft/s (0.09 to 0.15 m/s) and depth less than 1 ft (0.3 m) (U.S. Fish and Wildlife Service and Canadian Department of Fisheries and Oceans 1999). TFM imparts a yellow tint to the water as the lampricide travels through a river. This alteration is only temporary and ceases once the TFM dissipates.

Unlike organochloride pesticides which remain in our environment for decades, TFM, a nitrophenol class of pesticide, photo-degrades into substances similar to naturally occurring humic acids with little or no toxic hazard. Studies have demonstrated that during sunny weather TFM in streams can degrade into RTFM (3-trifluoromethyl-4-amino-phenol) in 3 to 5 days, and in ponds, 9 days (NRCC 1985). Hussain (1998) suggests TFM persists in the environment for 13 to 15 days depending primarily on pH and rate of degradation. TFM does not undergo volatilization or hydrolysis. Microbial action only affects TFM in anaerobic environments where TFM degrades to the nontoxic RTFM in 5 to 20 days (NRCC 1985). TFM is adsorbed by sediments and, like most chemicals, adheres to fine fractions of sediment with greatest adsorption to silt (NRCC 1985). Adsorption also increases with decreasing pH. Desorption from sediments depends upon the sediment type and water temperature. Gilderhus *et al.* (1980) reported TFM concentrations of 0.8μg/g of sediment during lampricide applications and nondetectable levels after 96 hours.

Though it is not thoroughly understood, TFM's mode of toxic action is through an interference with cellular respiratory metabolism as a result of damage to the lamellar epithelium of the gill (Mallatt *et al.* 1994). In addition to the physical damage, TFM also disrupts the branchial ion regulation (Mallatt *et al.* 1994). TFM uptake is much greater in sea lamprey as compared to teleosts (NRCC 1985). Sea lamprey also have a limited ability to conjugate TFM with glucuronic acid and release the toxicant by biliary excretion through the liver and kidney (Mallatt *et al.* 1994). This is the primary mode of detoxification of teolosts (Mallatt *et al.* 1994, Howell *et al.* 1980). Physical damage to the gill structure does not occur in trout (Mallatt *et al.* 1994).

A major concern with the application of a pesticide is the resistance which may develop over time. In agriculture, nuisance insects have been shown to develop resistance to certain insecticides after repeated use. Species which have historically developed a resistance to a particular insecticide have short generation times and were repeatedly exposed to sub-lethal concentrations or exposed to chronically persistent chemicals (Scholefield and Seelye 1990). After 30 years of application in the Great Lakes, sea lamprey had not developed an increased resistance to TFM (Scholefield and Seelye 1990). In the Great Lakes, typical stream application concentrations range from 1.0 to 1.5 times the stream's minimum lethal concentration (MLC) (U.S. Fish and Wildlife Service and Canadian Department of Fisheries and Oceans 1999). Applying TFM at these concentrations reduces the likelihood of sublethal applications and the chance for sea lamprey to develop a resistance over time.

During TFM treatments, water use advisories are posted and remain in effect until 24 hours after the TFM concentration has fallen below predetermined threshold levels established by permit. The advisories suggest the public refrain from drinking, fishing, swimming, and watering livestock or crops.

4.4.1 Nontarget Impacts of TFM

The selectivity ratio of a lampricide is the ratio of concentration needed to kill an ammocoete to the concentration needed to kill a nontarget species. The selectivity ratio of TFM is considered quite low, ranging from 1:2 to 1:10 (Howell *et al.* 1980). The selectivity ratio of most pesticides ranges from 1:2 to 1:1000 with 1:1000 being the most selective pesticide available. Despite this narrow range of selectivity, the ratio remains constant so that changes in water quality do not appreciably change the selectivity ratio of TFM (Gilderhus *et al.* 1980). This consistency in relative toxicity provides a safety index between nontarget species and sea lamprey.

Methods employed by Applegate and King (1962) showed the differential toxic effects of TFM, expressed as the MLC needed to effect 100% mortality of sea lamprey ammocoetes within 24 hours as compared to the maximum allowable concentration, resulting in 25% mortality of a nontarget fish species within 24 hours, varies greatly. Their early bioassay research suggested walleye, yellow perch, yellow bullhead, and white suckers were all susceptible to TFM while smallmouth bass and trout were more resistant. They also reported walleye as most affected (of all species tested) by TFM, with 25% mortality occurring at concentrations only slightly more than the MLC needed to effect 100% sea lamprey ammocoete mortality. More recent research suggests that walleye are only occasionally affected by TFM treatments (NRCC 1985) and yellow perch are less sensitive to TFM than are trout (Seelye and Scholefield 1990). The NRCC (1985) report suggests that the stonecat (*Noturus flavus*) is a very sensitive species. Native lamprey ammocoetes are in general, more resistant to TFM than are sea lamprey (King and Gabel 1985, NRCC 1985) though mortality is common during TFM applications (Fisheries Technical Committee 1999). NYSDEC *et al.* (1990) report that mortality is common in native lamprey, sucker, bullheads, catfish, pickerel, northern pike, muskellunge, log perch, tesselated darter and sculpin during TFM treatments.

Studies on early life stages of walleye suggest that eggs, sac fry, and swim-up fry are more resistant to TFM than sea lamprey ammocoetes (Seelye *et al.* 1987). Differential toxicity ratios (12 hour LC_{25} : 12 hour LC_{99} for sea lamprey) ranged from 2.5 : 1 for swim-up fry to more than 5.6 : 1 for eyed eggs. Seelye *et al.* (1987) concluded that it is unlikely that TFM treatments during spring walleye spawning season would adversely affect the survival of early life stages.

Twenty-four TFM treatments conducted on fourteen Lake Champlain tributaries (totaling 141 river miles (227 km) support the more recent determinations of fish sensitivities. In the Lake Champlain tributary treatments greatest nontarget mortality occurred in American brook lamprey (40,851), silver lamprey (8,619), stonecats (6,730), and logperch (1,057), bluntnose minnow (755), blacknose dace (517), white sucker (340), tessellated darter (318), brown bullhead (162) and chain pickerel (130); 81% of native lamprey mortalities were observed in the Ausable River and 87% of stonecat mortalities were observed in the Great Chazy River (Fisheries Technical Committee 1999). Very few trout or bass, no walleye, and no New York or Vermont Endangered, Threatened, or Special Concern species were reported killed during any Lake Champlain TFM treatment (Fisheries Technical Committee 1999). In comparison, estimated sea lamprey ammocoete mortality totaled 717,128 individuals for all Lake Champlain TFM applications.

Macroinvertebrates which suffer direct mortality as a result of TFM applications are typically pool fauna which have adapted to less oxygenated stream environments (Dermott and Spence 1984). These organisms typically have thin cuticles or large gill structures. Turbellaria (flat worms), annelids (aquatic worms), black fly larvae, sphaerid clams, and certain species of mayflies are especially sensitive to TFM (Dermott and Spence 1984, NRCC 1985). Langdon and Fiske (1991) reported *Chimarra sp.*, a riffle caddisfly species, declined by as much as 97% while the pool mayfly species, *Hexagenia limbata,* declined by 61% following a TFM treatment of Lewis Creek, VT; however, both species returned to pre-treatment densities one year later (Vermont Department of Environmental Conservation (VTDEC) 1994). During TFM applications freshwater mussels will occasionally "gape" and unbury themselves (Neuderfer 1996a, Neuderfer 1996b, Bills *et al.* 1990, Gilderhus and Johnson 1980). Gaping is a behavior which describes how a mussel will open its valve and expose the foot, mantle, and gill. This behavior is commonly observed in mussels under stress from high water temperature and / or low dissolved oxygen conditions. Although the effects of TFM are temporary, during this time freshwater mussels may be susceptible to predation by crayfish, birds, and raccoons (Neuderfer 1996a, Neuderfer 1996b, Gilderhus and Johnson 1980). No gaping behavior was detected in mussel beds observed during the 1992 and 1996 TFM treatments (applied at 0.8 x MLC in 1992 and 1.0 x MLC in 1996) of the Poultney River, NY and VT (Fichtel 1992, Langdon and Fiske, Agency of Natural Resources (VT) 11/5/96 memo).

Though there are sensitive species which suffer mortality during TFM applications, TFM has the greatest impact on the benthic macroinvertebrate community by increasing drift in annelids, amphipods, blackfly larvae as well as other species. Drift is the behavior of drifting with the water current resulting in passive migration downstream. This impact is responsible for the most change seen in macroinvertebrate communities affected by TFM (Lieffers 1990, Dermott and Spence 1984). During drift, predation on invertebrates or the inability to find adequate substrate can result in substantial mortality.

Despite these impacts macroinvertebrate communities are relatively unaffected by TFM treatments with only the most sensitive species experiencing declines (Langdon and Fiske 1991, Lieffers 1990, NRCC 1985). Measures of benthic macroinvertebrate community structure (i.e. community density, taxa richness, Index of Biotic Similarity) have not elucidated any detectable long-term changes in the macroinvertebrate community structure as a result of TFM applications (VTDEC 1994, Dermott and Spence 1984). Dermott and Spence (1984) report that species substantially impacted by TFM applications typically recovered to pretreatment densities within weeks to months although some longer lived invertebrates (i.e. nymphs of the burrowing mayfly, *Hexagenia limbata*) required a year or more.

Even at high doses, TFM is not toxic, carcinogenic, teratogenic, or mutagenic to mammals (NRCC 1985). Birds exhibit a range of acute oral toxicity with the most sensitive bird species experiencing short duration (<24 hours) lethargy when exposed to TFM concentrations of 50 mg/L (NRCC 1985). TFM applications in Lake Champlain tributaries have been in the 1.5 to 8.5 mg/L range (L. Nashett, Personal Communication, 2000), concentrations which do not affect birds. Mudpuppies and frog tadpoles are amphibians which are sensitive to TFM (Gilderhus and Johnson 1980). Gilderhus and Johnson (1980) report that certain species of amphibians [gill breathing, aquatic forms (NYSDEC *et al.* 1990)] are the only vertebrates other than fish which have been observed to be affected by TFM. Weisser *et al.* (1994) documented 87% survival of caged mudpuppies following a TFM treatment of the Grand River, Ohio, with treatment concentrations of 1.0 to 1.3 x MLC; Matson (1990) reported a 29% decrease in abundance in the natural mudpuppy population one year after the same treatment. Chandler (1975) reported frog larvae to be killed by TFM at 9 hour exposures with concentrations commonly used in sea lamprey ammocoete treatments. The Fisheries Technical Committee (1999) reported the greatest cumulative TFM nontarget amphibian mortality occurred in frog tadpoles (5,461), unidentified salamanders (1,832), and redspotted newts (362). Total verified mudpuppy mortality for Lake Champlain tributaries during the eight-year experimental program was 91 individuals. Greater than 85% of all amphibian mortalities occurred following treatments of the Great Chazy River. Of the unidentified salamanders reported killed, many are believed to be mudpuppies from the Great Chazy River (L. Nashett, Personal Communication, 2000). Reptiles are reported to be unaffected by TFM (NRCC 1985).

TFM temporarily affects aquatic macrophytes, wetland plants and algae by disrupting the photosynthesis process. Short term (96 hour contact) exposures of TFM concentrations of <10 mg/L can reduce algal photosynthesis by as much as 50% and higher plant photosynthesis by 5 to 10% (NRCC 1985). This disruption occurs during contact with TFM, and full photosynthesis activity resumes shortly after the dissipation of TFM.

Cyanobacteria (blue-green algae) are generally the most resistant to TFM followed by green algae with diatoms being most sensitive (Gilderhus and Johnson 1980). At higher concentrations (15 to 25 mg/L for standing water and approximately 100 mg/L for flowing water), TFM can kill aquatic plants (Gilderhus and Johnson 1980). In Lake Champlain, TFM has been applied at concentrations which approximate the initial estimated concentrations of 1.5 to 8.5 mg/L reported in the 1990 Final Environmental Impact Statement (L. Nashett, Personal Communication, 2000). Elimination of TFM occurs readily in aquatic macrophytes and algae. *Cladophora sp.* absorbed TFM more rapidly during a TFM application than did *Elodea sp.*, a higher order plant, though the concentrations in both taxon declined by 89% to 97% in 24 hours and 98% to 99% in 96 hours (Gilderhus and Johnson 1980).

4.4.2 Technical Considerations

Alkalinity, pH, water temperature, dissolved oxygen, nitrate, and ammonia affect the toxicity of TFM (Seelye *et al.* 1988). Howell *et al.* (1980) report that pH, total hardness, and alkalinity have the greatest effect on TFM's toxicity. As pH increases there is a reduction in the amount of the toxic form of TFM available for uptake resulting in a decreasing level of toxicity. This is also true for increases in conductivity and alkalinity (Howell *et al.* 1980, Kanayama 1963). As a result of the TFM / water chemistry characteristic, changes in water chemistry parameters over the course of an application may decrease or increase the toxicity of TFM to sea lamprey and nontarget species.

Low dissolved oxygen concentrations have been shown to increase the toxicity of TFM to rainbow trout (Seelye and Scholefield 1990), but it must be noted that rainbow trout are very sensitive to low dissolved oxygen concentrations which results in a stressed state (Seelye and Scholefield 1990, NRCC 1985). Although changes in water chemistry affect TFM's toxicity, the selectivity ratio of the toxin remains constant (Howell *et al.* 1980).

Before a river treatment of TFM begins, surveys should be conducted to assess sea lamprey ammocoete habitat, locate an appropriate lampricide application point and define points to monitor water quality and TFM concentrations during application (Gersmehl and Baren 1985). TFM MLC may be determined from pretreatment bioassay results, or from regression values in a predictive chart used by the U.S. Fish and Wildlife Service Great Lakes sea lamprey control teams. This predictive chart provides laboratory MLC's based on use of both stream pH and alkalinity values. Two supplemental references that may also be used are the U.S. Fish and Wildlife Service alkalinity chart and the Canadian Department of Fisheries and Oceans alkalinity chart. As water quality characteristics can substantially affect the toxicity of TFM to sea lamprey larvae and nontarget species, flow-through or static bioassays provide a fairly accurate, stream-specific means of determining the MLC needed for 99.9% sea lamprey larvae mortality and the maximum allowable concentration (MAC) above which would result in an unacceptable nontarget species mortality. For sea lamprey lampricide treatments an MLC is defined as 99.9% sea lamprey ammocoete mortality over a 9 hour exposure while an MAC is defined as 25% mortality of nontarget species over a 9 hour exposure (L. Nashett, Personal Communication, 2000). Determination of stream velocity, flow, and water quality (specifically pH, and alkalinity) are also required prior to and throughout the TFM application. Finally, additional TFM application points may be required to compensate for the attenuation or changes in toxicity related to shifts in pH or alkalinity of the TFM as it travels downstream. At these locations a boost can be applied to maintain the desired TFM concentration. In the Great Lakes, typical application time for a TFM treatment is 12 hours but may be adjusted to achieve 9 hours of MLC exposure, while the typical treatment concentration ranges from 1.0 to 1.5 x MLC (U.S. Fish and Wildlife Service and Canadian Department of Fisheries and Oceans 1999).

4.5 Bayer 73

Bayer 73 (5,2'-dichloro-4'-nitrosalicylanilide), a lampricide used for sea lamprey control, is also used worldwide to treat human tape worms outside the United States. In tropical regions it is used to control snail populations which are the vector carriers of schistosomiasis (Gilderhus and Johnson 1980).

Bayer 73 is also used for conducting sea lamprey ammocoete surveys and for control of sea lamprey ammocoetes in estuarine or lentic habitats. Bayer 73 is formulated as a wettable powder, a granular formulation, or a solid brick while an emulsifiable concentrate formulation currently under development (U.S. Fish and Wildlife Service and Canadian Department of Fisheries and Oceans 1999). The wettable powder form is sometimes mixed with TFM in stream treatments to reduce the amount of TFM needed (section 4.6). The granular formulation is typically applied to deltas and very slow moving water where TFM is largely ineffective (NRCC 1985). When applied, Bayer 73 (granular) quickly settles to the lake or river bottom where it becomes a bottom releasing toxicant (Howell *et al.* 1980).

As with TFM, Bayer 73 is toxic to sea lamprey ammocoete populations. The mode of toxicity for Bayer 73 is largely unknown but like TFM, it is thought to be an uncoupler of oxidative phosphorylation (NRCC 1985). Despite the similarities in the mode of toxicity, Bayer 73 is much more toxic and not as selective a lampricide as TFM (Gilderhust and Johnson 1980). The NRCC (1985) reports Bayer 73 to be more than 43 times as toxic as TFM to lamprey ammocoetes with essentially no selectivity between sea lamprey ammocoetes and rainbow trout. In addition to rainbow trout, brown bullhead, flathead catfish, small and largemouth bass are also very sensitive with 50% mortality occurring with a single brief exposure to concentrations as low as 0.062 mg/L (Marking and Hogan 1967) [0.052 mg/L for rainbow trout (NRCC 1985)]. Bayer 73 does not become proportionally more toxic with an increase in contact time. Although Bayer 73 is extremely toxic and nonselective to nontarget fish, at sublethal concentrations teleosts are able to conjugate the toxicant with glucuronic acid and release it through biliary excretion. In addition, given the bottom releasing nature of Bayer 73 granular formulation, mortality of nontarget teleosts is greatly reduced over early formulations (NRCC 1985).

As with TFM, even at high doses Bayer 73 is not toxic, carcinogenic, teratogenic, or mutagenic to mammals (NRCC 1985). Though sensitivities to Bayer 73 are different among birds, Bayer 73 is less toxic than TFM. Like TFM, the Bayer 73 concentrations used in sea lamprey control do not affect birds (NRCC 1985). The effects of Bayer 73 on aquatic plants has not been as well studied as TFM effects. Aquatic plants have been shown to have a considerable range of sensitivity to Bayer 73; diatoms, for example, suffered 50% growth inhibition at concentrations less than 130 ppb while green algae growth sensitivity ranged from 0.41 to 1,450 ppm (EPA 1999).

Macroinvertebrates exhibit a wide range of sensitivity to Bayer 73. The most sensitive species are freshwater mussels, snails, flatworms, worms, leeches, and blackfly larvae (NRCC 1985). Bayer 73 is toxic to all of these taxon at concentrations of <1.0 mg/L with molluscs being one of the most sensitive species with LC_{50} of <0.4 mg/L (NRCC 1985). When used in a TFM : Bayer 73 treatment, Bayer 73 (wettable powder) concentrations are well below 0.4 mg/L. Taxon shown to be generally resistant to Bayer 73 include crustaceans, dobsonflies, and dragonflies while mayflies are considered moderately resistant to Bayer 73 (NRCC 1985).

4.5.1 Reason for Inapplicability at Present

Given the lack of selectivity to nontarget fish and freshwater mussels, widespread use of granular Bayer 73, alone, is not appropriate for treating the Poultney, Hubbardton, or Pike Rivers or Morpion Stream. If this formulation were used as a primary control methodology, unacceptably high mortalities of freshwater mussels as well as resident bottom dwelling fish populations may occur. While the nonspecificity of Bayer 73 granular precludes its application in the Poultney, Hubbardton, and Pike Rivers and Morpion Stream, the combination of TFM and Bayer 73 (wettable powder) may be feasible in high discharge situations. This combination offers a degree of enhanced selectivity as well as a considerable reduction in the amount of lampricide needed for any given application. This lampricide combination is discussed below.

4.6 TFM : Bayer 73 Combination

Combining the lampricide TFM (section 4.4) and Bayer 73 (section 4.5) can substantially reduce the amount of lampricide required to treat a river. Though the lampricide combination is not synergistic, adding as little as 1% Bayer 73 (wettable powder) to a TFM treatment can boost the toxicity thereby reducing the total amount of TFM required to effect the same MLC by as much as 50% (Gilderhus and Johnson 1980). In laboratory studies, the TFM : Bayer 73 combination resulted in greater increases in toxicity to sea lamprey ammocoetes than to most of the invertebrates studied (Gilderhus and Johnson 1980).

The mode of toxicity of the TFM : Bayer 73 combination is similar to that of TFM alone (Mallatt *et al.* 1994). As with TFM, the disruption of the ion-uptake cells of the respiratory lamellae is believed to be the primary mode of toxicity. In addition to the ion-uptake disruption, physical damage in the sea lamprey gill structure occurs as a result of exposures to the TFM : Bayer 73 combination (Mallatt *et al.* 1994). Even at lethal concentrations, physical damage has not been observed in trout (Mallatt *et al.* 1994).

The TFM : Bayer 73 treatment will have similar human and habitat impacts as a TFM application except in-lake advisories should be of shorter duration and over a smaller area than TFM alone due to lesser amounts of chemicals used (section 4.4).

4.6.1 Nontarget Impacts of TFM : Bayer 73

The TFM : Bayer 73 combination is believed to have approximately the same toxicity characteristics as TFM alone (Gilderhus and Johnson, 1980). Most sensitive fish species include channel catfish, white sucker, and longnose sucker (NRCC 1985). Fish with an intermediate sensitivity include northern pike, walleye, brown and rainbow trout, and coho salmon. During treatments, minor kills have been reported for stonecat, common and spottail shiner, johnny darter, longnose and blacknose dace, brook stickleback, sculpin, logperch, troutperch, and mudminnow (NRCC 1985).

In laboratory studies, the TFM : Bayer 73 combination resulted in greater increases in toxicity to sea lamprey ammocoetes than to most of the invertebrates studied (Gilderhus and Johnson 1980). Since this increase in toxicity to sea lamprey does not occur for most invertebrates, the safety index (24 hour LC_{50} for nontarget organisms / 24 hour LC_{50} for larval sea lamprey) for many invertebrates actually increases (Gilderhus and Johnson 1980). This occurs for aquatic and flat worms, freshwater mussels (Pelecypoda), leeches, stoneflies, blackfly larvae, and mayfly nymphs, however a decrease in the safety index occurs in snails. While there is a general increase in the safety index for TFM : Bayer 73 applications, there is great variability in sensitivity among taxa as well as within a particular taxon. For instance, dragonflies, megaloptera, and stoneflies are all very resistant to the mixture while the gastropod *Physa sp.* is very sensitive (NRCC 1985). Within a particular taxon sensitivities can vary widely as exhibited in Diptera; blackfly larvae are approximately 25 times more sensitive to the combination as are snipeflies (NRCC 1985).

An increase in drift in aquatic worms, flatworms, leeches, amphipods, caddisflies, and diptera occurs as a result of a TFM : Bayer 73 treatment compared to application of TFM alone (NRCC 1985). Dermott and Spence (1984) suggest that the use of lampricides has a greater impact on invertebrate community structure by increasing drift rather than direct mortality.

No data are available on the toxicity of TFM : Bayer 73 on amphibians or reptiles (NRCC 1985). However, some data exists on the effects of the individual constituents and are presented in section 4.4 for TFM and 4.5 for Bayer 73. Field observations suggest that mudpuppy mortalities occur during treatment (Gilderhus and Johnson 1980). TFM : Bayer 73 is not toxic, teratogenic, mutagenic, nor does it have an adverse effect on the reproductive performance of rats or hamsters (NRCC, 1985).

Oral acute toxicity of the TFM : Bayer 73 combination on birds is slightly greater than that of TFM alone (for mallards; LD_{50} values of 458 mg/kg for TFM : Bayer 73 combination and 472 mg/kg for TFM) (NRCC 1985). Exposure of mallards to concentrations of approximately 16 mg/L for 7 hours resulted in a decrease in coordination which improved substantially 22 hours later (NRCC 1985). Birds exposed to 50 mg/L of TFM : Bayer 73 experienced lethargy and moderate to extreme loss of coordination. All birds recovered within 48 hours of termination of the exposure. These concentrations are approximately 5 to 10 times treatment levels and, when mallards were exposed to actual treatment concentration of TFM : Bayer 73, little or no effect was observed.

4.6.2 Technical Considerations

The application of TFM : Bayer 73 is more complicated than a TFM treatment. Historically, Bayer 73 has been applied a short distance downstream from the TFM application point (NRCC 1985). Applying Bayer 73 to a river can be difficult for a number of reasons. It has low solubility and pumps have a tendency to clog (Gilderhus and Johnson 1980). Measuring the concentrations of Bayer 73 in water can only be done by High Performance Liquid Chromatography (HPLC). HPLC's are very expensive and are typically not used in field analysis. Requiring the use of an HPLC for the determination of Bayer 73 concentration and a Spectrophotometer for the determination of TFM concentration complicates analyses. Additional personnel are also needed to perform the application of the Bayer 73. For additional application considerations refer to the technical considerations for TFM (section 4.4.2).

Bayer 73 should not be applied in streams with high suspended solids since it readily binds with the solids (especially collodial clay) and can attenuate quickly (D. Johnson, U.S. Fish and Wildlife Service, Personal Communication, 2000). Also, Bayer 73 should not be applied to streams with pH <7.0 or water temperature <10°C (U.S. Fish and Wildlife Service and Canadian Department of Fisheries and Oceans 1999). Lower temperatures reduce the efficacy of Bayer 73 while lower pH values causes Bayer 73 to become insoluble (NRCC 1985).

The increase in effort to apply the TFM : Bayer 73 combination can offset any cost savings realized in the approximate 50% reduction in TFM needed to treat a river. Johnson (Personal Communication, 2000) suggests that in the Great Lakes the general "rule of thumb" is that a TFM : Bayer 73 treatment becomes cost effective when the river has >100 cfs (2.80 cms) flow. With greater flows, the cost savings in the amount of lampricide required is greater than the additional application costs associated with labor requirements. If a lampricide application is to be conducted on a river, a benefit / cost analysis will be required in addition to other considerations to elucidate the most appropriate treatment.

4.7 Sea Lamprey Sterilization

One of the more recent experimental control techniques under development for fisheries managers is the release of sterilized male lamprey to reduce sea lamprey reproductive success. Male sterilization technology applied to insects has been shown to be effective in the elimination of the *Callitroga hominivorax*, a livestock pest in the southeastern United States (Knipling 1960). Sterilization and release of male sea lamprey has been implemented experimentally since

1991 in the Great Lakes and presently is used to augment trapping and Bayer 73 treatments on the St. Marys River (M. Twohey, U.S. Fish and Wildlife Service, Personal Communication, 1999). Sterile males are sexually competitive and will readily spawn with fertile females resulting in the reduction in the number of viable larvae produced in that stream. The reduction in reproductive success is related to the ratio of sterile males to normal males in the population. Hanson and Manion (1980) reported that when 90% of all breeding males were sterile, 86% of males on nests with females were sterile, and 73% of nests contained only dead eggs or embryos.

Sterilization by irradiation has not been shown to be an effective method in sea lamprey (Twohey *et al.* 1997, Hanson 1990). Sterilization, however, is accomplished by administering Bisazir (P,P-bis (1-ariridinyl) -N-methyphosphinothioic amide), an alkylating agent which is a derivative of aziridine. Bisazir can be an effective sterilant when administered through direct injection and also by immersion in an aqueous solution (Hanson and Manion 1978).

Bisazir is considered highly toxic to humans via inhalation, ingestion, and dermal contact exposures, and toxic by nose-only exposure (Twohey *et al.* 1997). Bisazir is also suspected to have mutagenic properties in humans. There is no evidence of environmental bioaccumulation of Bisazir although research is still underway to determine the environmental fate of Bisazir. Food and Drug Administration approval may be necessary to extend Bisazir use to Lake Champlain (M. Twohey, Personal Communication, 2000). A sterilization facility at the Lake Huron Field Station was specially designed to prevent environmental release and human exposure of the chemosterilant. The Lake Huron Field Station sea lamprey sterilization facility cost was approximately $1 million dollars (M. Twohey, Personal Communication, 2000). No cost estimates are available for a sterilization facility in the Lake Champlain Basin although it is suggested that the facility could be constructed for considerably less (M. Twohey, Personal Communication, 2000). An alternative to a within-basin sterilization facility for Lake Champlain might be to utilize the Lake Huron Biological Field Station and have sea lamprey transported to the facility and then returned to the Lake Champlain basin.

In 1998 approximately 10,000 additional males were needed for an effective sterile male release program in the St. Marys River (Schleen *et al.* 1998). To increase the number of sea lamprey available for the Great Lakes control program, Atlantic origin lamprey migrating into the Connecticut River are presently being evaluated as a source of additional males (M. Twohey, Personal Communication, 2000). Issues regarding Connecticut River sea lamprey population dynamics, disease and genetics must be evaluated before individuals can be harvested.

In the Great Lakes sterilization program the majority of lamprey collected come at a cost of approximately $6 per lamprey (M. Twohey, Personal Communication, 2000). As the need increases and the collecting becomes more intense the cost per lamprey can quickly rise to over $30 per individual. These costs are for the collection and transport of lamprey only, they do not include the cost of sterilization and release of the lamprey.

4.7.1 Reason for Inapplicability at Present

There are several aspects of the sterile male release technique that make it technically difficult to implement and thus reduces its applicability for sea lamprey control in Lake Champlain. In order for sterile male release to be effective, a large number of adult males must be obtained in a timely manner for sterilization. Given their parasitic phase, there is currently no technology available which would allow sea lamprey to be farm raised so sea lamprey must be captured from natural environments. Trapping operations targeting sea lamprey in tributaries where they congregate early in the spawning season is crucial to obtain the large number of males needed for sterilization. These males must be trapped and transported to a sterilization facility, sterilized, and returned to a target tributary for the start of the spawning season. In Lake Champlain, the Great Chazy River is presently the only tributary which has both a large sea lamprey run and an effective trap in place to capture the lamprey. This sea lamprey spawning run, however, is one of the latest in the lake and occurs too late in the season to be of use in a sterile male release program (D. Nettles, Personal Communication, 2000). Sea lamprey would need to be effectively trapped within the Lake Champlain Basin or imported from another river to be available at the start of the spawning runs. In Lake Champlain this would require effective trapping efforts on tributaries having early spawning runs and sizable sea lamprey populations. Since this presently does not occur, collection of sea lamprey outside the basin may be necessary to provide sea lamprey to support a sterile male program. Finally, changes in spawning run populations found elsewhere could interfere with the number of males available. The lack of available sea lamprey on a timely basis has great potential to reduce the success of a sterile male program. Although these considerations are formidable, they may be surmountable with the implementation of an aggressive trapping program. An effective trapping program could be used to: 1) remove female reproductive potential, 2) reduce male competitors, and 3) provide a supply of males for sterilization and re-release.

An alternate or complimentary sea lamprey sterilization technique to Bisazir proposes using a protein-based gonadotropin analog as a sterilant (Sower et al. in review). This methodology is currently being researched and, if sufficiently developed, may offer a nontoxic method of sterilization employable locally or streamside. Until a locally available sterilant is available, a sterile male program cannot be considered a viable Lake Champlain sea lamprey control technique. Additionally, the sterile male sea lamprey control technique is still under evaluation in the Great Lakes. Uncertainty in our understanding of stock/recruitment relationships and compensatory mechanisms are sufficient to caution the immediate implementation of a sterile male program; if this technology is considered for experimentation on Lake Champlain tributaries, these and other relationships should be evaluated to determine whether a sterile male program is effective and whether it's efficacious with proposed actions for long-term sea lamprey control in the Basin.

4.8 Pheromone Attractants

Use of pheromones to control sea lamprey populations is still in the research and development stage and not yet available as a control option. Despite this, three possible methods for using migratory or sex pheromones to augment sea lamprey control have been identified. The first is as an attractant to enhance the removal of spawning run adults by mass trapping (Li *et al.* 1995) or to enhance the trapping capture of sea lamprey to provide more sea lamprey for sterilization. The second utilizes a pheromone attractant to lure sea lamprey into a river which does not have adequate spawning or ammocoete (including the river delta) habitat or to a river scheduled for control activities where removal or mortality of concentrated sea lamprey may result. The third is the disruption of pheromone communications between sea lamprey, thus interfering with sea lamprey spawning or mating (Li *et al.* 1995). In addition, Sorenson (Personal Communication, 2000) has indicated the existence of a pheromone which may repel the sea lamprey. Aside from the identification of this pheromone, no other research has been conducted on its repellant capabilities.

Since sea lamprey do not have strong homing characteristics, they must rely on other sensory cues to find adequate spawning tributaries (Bergstedt and Seelye 1995). Evidence is accumulating that migratory pheromones released by larval sea lamprey attract adults to spawning rivers. Sea lamprey are also known to produce a sex pheromone which appears to guide adults to each other, after having entered the spawning stream. Two important points should be understood concerning the natural behavior of sea lamprey with regard to pheromones which may lessen any impacts of a pheromone control program. First, sea lamprey migrate above ammocoete habitats and spawning grounds and thus travel above areas which are releasing larval and adult pheromone attractants. Second, if sea lamprey do not spawn they may emigrate out of a river. This emigration occurs despite the presence of attractant pheromones.

Two bile acids, allocholic acid (ACA) and petromyzonol sulfate (PS) and key substituents of these acids (5α-hydrogen, three axial hydroxyls, and a C-24 sulfate ester or carboxyl), are specifically recognized by the sea lamprey and are present in the migratory pheromone (Li *et al.* 1995). A sexual male sea lamprey hormone has also been identified and is similar to petromyzonol sulfate but differs in chemical structure by a functional group at the C3 position (Li, in review). While these compounds have been identified in sea lamprey, they are not species specific and sea lamprey are known to be attracted to other lamprey pheromones (P. Sorenson, University of Minnesota, Personal Communication, 2000).

Insight into the effectiveness of using natural and synthetic pheromones to attract or disrupt the behavior of a nuisance species can be realized by studying integrated pest management strategies for insects in the agriculture and forestry industry. The Douglas-fir bark beetle (*Dendroctonus pseudotsugae*), a serious nuisance pest, has been effectively controlled using pheromone attractants (Speight *et al.* 1999). Traps using an attractant pheromone resulted in an 80% reduction in the number of attacks to Douglas-fir trees within a particular plot. Bark beetles were killed after being lured into traps located away from the selected plot. On the other hand, use of attractant pheromones in the population control of insects where males are polygamous has, in some instances, not resulted in an effective control. For instance, after 5 years of aggressively trapping the spruce bark beetle in Europe it was determined that the use of pheromone attractants did not substantially change population densities (Speight *et al.* 1999). In addition to polygamous mating, immigration was identified as an aggregate reason for failure. Immigration of sea lamprey from regions outside Lake Champlain is not a factor to be considered within the Lake Champlain ecosystem.

4.8.1 Reason for Inapplicability at Present

Identification of an attractant or repellant pheromone does not provide sufficient basis for application in nuisance population management (Speight *et al.* 1999). Field research must be initiated to determine just how effective a pheromone attractant will be in increasing trapping efficiencies. In nuisance insect pheromone research, preliminary studies are conducted to ascertain trapping efficiencies before studying the effectiveness of a pheromone attractant (Ananthakrishnan and Sen 1998). Like insect trapping, sea lamprey trapping efficiencies can vary considerably and a trapping efficiency baseline must be established to ascertain the overall contribution a pheromone attractant has on trapping efficiency.

Aside from a lack of field studies, several hurdles must be overcome before a pheromone attractant could be used in controlling sea lamprey populations. Large quantities of bile acids must be readily available. Synthesizing the bile acids is very expensive and not identical to the natural acid. It is uncertain what effect the differences in the natural vs. synthetic acid will have in attracting sea lamprey in a natural environment (P. Sorenson, Personal Communication, 1999). Lamprey pheromones are non-species specific and care must be taken not to negatively impact the native lamprey species. This is especially true where application of a pheromone may affect the northern brook (Endangered in Vermont) and American brook lamprey (Threatened in Vermont). Obtaining natural bile acids from spawning run sea lamprey or ammocoetes may be difficult. Holding lamprey in cages or establishing native lamprey in upstream habitat from which pheromones could be secreted are also possibilities. Field experiments which will test the effectiveness of sea lamprey pheromone attractants are presently being designed and implemented.

Much work has to be done before pheromones can be utilized in controlling sea lamprey, however, successes in management of insect nuisance species provide reasons to be cautiously optimistic. Unfortunately, given the current status of sea lamprey pheromone knowledge and its utility for controlling the sea lamprey population, pheromone attractants and repellants cannot be considered as a control option for Lake Champlain at this time. Sorenson (Personal Communication, 2000) has expressed interest in Lake Champlain as a site for experimental field investigations.

4.9 Velocity Barriers

Velocity barriers are structures that increase water velocity beyond that which sea lamprey are able to navigate. Preliminary studies conducted by Bergstedt (1981) suggested velocities greater than 5.6 ft/s (1.7 m/s) would be needed to stop sea lamprey migration while

Hunn and Youngs (1980) determined velocities would have to be approximately 12.3 ft/s (3.75 m/s). Water temperature affects the maximum swim speed of sea lamprey with colder temperatures negatively affecting maximum swim speed (E. Koon, Personal Communication, 2000). No studies have been conducted to determine the relationship between water temperature and maximum sea lamprey swim speed.

The Great Lakes is presently experimenting with a velocity barrier on the McIntyre River [mean annual discharge of 51.6 cfs (1.46 cms)]. This barrier is comprised of a dam with a flume chute approximately 33 ft (10 m) long and a slope of 1% to 1½% (A. Hallett, Canadian Department of Fisheries and Oceans, Personal Communication, 2000). At the base of the chute there is an entrance drop of 0.3 ft (10 cm) which is intended to prevent sea lamprey passage during low flows (McAuley and Young 1995). The barrier is designed to pass larger fish [i.e. suckers >12 inches (30 cm) in length] while preventing sea lamprey from passing. To date, the velocity barrier has not been effective in stopping sea lamprey from migrating above the barrier. Innundation of the barrier during high flows may allow sea lamprey to pass abutments, the crest of the dam, or the velocity chute itself (A. Hallett, Personal Communication, 2000).

4.9.1 Reason for Inapplicability at Present

The McIntyre River experimental barrier is still in development and, to date, has not effectively prevented sea lamprey from reaching upstream spawning sites. While still not proven, the technology does show promise in passing larger nontarget species while blocking sea lamprey.

Until found effective, velocity barriers cannot be considered an option for sea lamprey control in Lake Champlain.

4.10 Sonic Barriers

Sonic fish barriers incorporate different combinations of sound frequencies and pulses to selectively repel different fish species. For instance, white perch and striped bass avoid low frequency sounds between 10 and 500 Hz while members of the herring family avoid high frequencies of 125,000 Hz (Smith Root Inc. 1999). Sounds are generated by a shore mounted, computer generated power amplifier with the sound being transmitted to the water via hydro phones.

Both low and high sound frequencies were studied for their effectiveness in controlling sea lamprey. The feasibility study reported that low frequency sounds, 12 to 16,000 Hz, did not damage sea lamprey tissue nor did it alter sea lamprey behavior (Cormack 1959). High frequencies (>16,000 Hz) have been used to kill fish and will damage tissue. High frequencies are damaging to tissue due to cavitation bubbles which are created as the sound wave travels through a liquid medium (Cormack 1959). One problem with the use of high frequency sound waves to repel or kill fish is that sound attenuates quickly and fish must be very close to the hydro phone in order to be affected by it. Fish Guidance Corporation of England is currently assessing the effects of encapsulating the sound wave within an air bubble to provide an impenetrable air curtain (J. Smith, Personal Communication, 2000). Ecological implications are likely to be similar to those associated with electrical barriers.

4.10.1 Reason for Inapplicability at Present

This technology is still in development, however, given the fact that sea lamprey lack a swim bladder (organ impacted by sound waves) a sound barrier is unlikely to be effective in the control of sea lamprey while preventing fish with swim bladders from passing the barrier.

4.11 Photo Barriers

Photo barriers, known as strobe-light fish guidance systems, are typically used as a way to guide fish. The flash rate and light output of a strobe-light fish guidance system is controlled by a shore mounted computer that can be accessed and controlled remotely via modem. This type of barrier is most effective when used with other control techniques such as fish traps and barriers (Smith Root Inc. 1999). Since sea lamprey migrate at night and avoid sunlight during the day by resting under rocks or along river banks, the use of light may assist in prevention of migration upstream.

4.11.1 Reason for Inapplicability at Present

The strobe-light guidance system's effectiveness is related to water clarity and flow, as well as taxa, physiological and metabolic states, and life stages. Due to episodic rain events, a strobe-light guidance system would not be effective during times of high flow and high turbidity. During spawning runs, sea lamprey slowly lose their ability to see, and this decrease in visual sensitivity would make a photo barrier impractical. A photo barrier will impact nontarget species by preventing passage, but the degree of impact is unknown.

4.12 Disruption of Spawning Habitat

During Lake Champlain sea lamprey assessment surveys, crews will, on occasion, destroy a sea lamprey nest by kicking it apart (D. Nettles, Personal Communication, 2000). However, no studies have been conducted to evaluate the effectiveness of physical disruption as a sea lamprey control method. In addition, the ecological impacts associated with physical disruption of the river bottom have not been investigated. Since sea lamprey eggs remain attached to the nest for approximately 14, days all spawning habitat must be inspected and all nests disrupted at an interval of less than 14 days.

In 1990 the United States Patent Office granted a patent (#4,934,318) to Mr. William A. Davis for a method of altering sea lamprey spawning habitat to create unsuitable spawning sites (U.S. Patent and Trademark Office Webpage 2000). The patented method also describes how to determine what is suitable sea lamprey spawning habitat. To create unsuitable habitat for sea lamprey the river bottom is altered through the introduction of stones ≥1.54 pounds (0.7 kg) in weight and ≥0.3 ft (10 cm) in diameter. These stones are larger than those used by sea lamprey for nest construction and would prevent sea lamprey from initiating spawning activities.

4.12.1 Reason for Inapplicability at Present

Using nest disruption as method for controlling sea lamprey populations has not been investigated for its effectiveness or ecological impacts. During the spring, streams and rivers have extended periods of high flows and low visibility. Poor visibility during these spring rain events will greatly reduce the ability to visually identify sea lamprey nests and high flows will make walking sea lamprey nesting habitats difficult. To be considered a viable control option, research must be conducted to elucidate the effectiveness and impacts of such a control technique. Likely impacts include increase in daytime drift of macroinvertebrates, increase in siltation as a result of increased human activity in and along the river, and disruption of nontarget spawning activities.

The alteration of a river bottom to create unsuitable spawning habitat would impact nontarget fish with similar spawning habitat requirements. In addition, river bottoms are formed through a variety of hydrologic actions. The introduction of a homogenous stream bottom would likely substantially and permanently alter the river community structure and species diversity. As with physical disruption of sea lamprey nests, this control technique has not been evaluated for nontarget impacts or effectiveness.

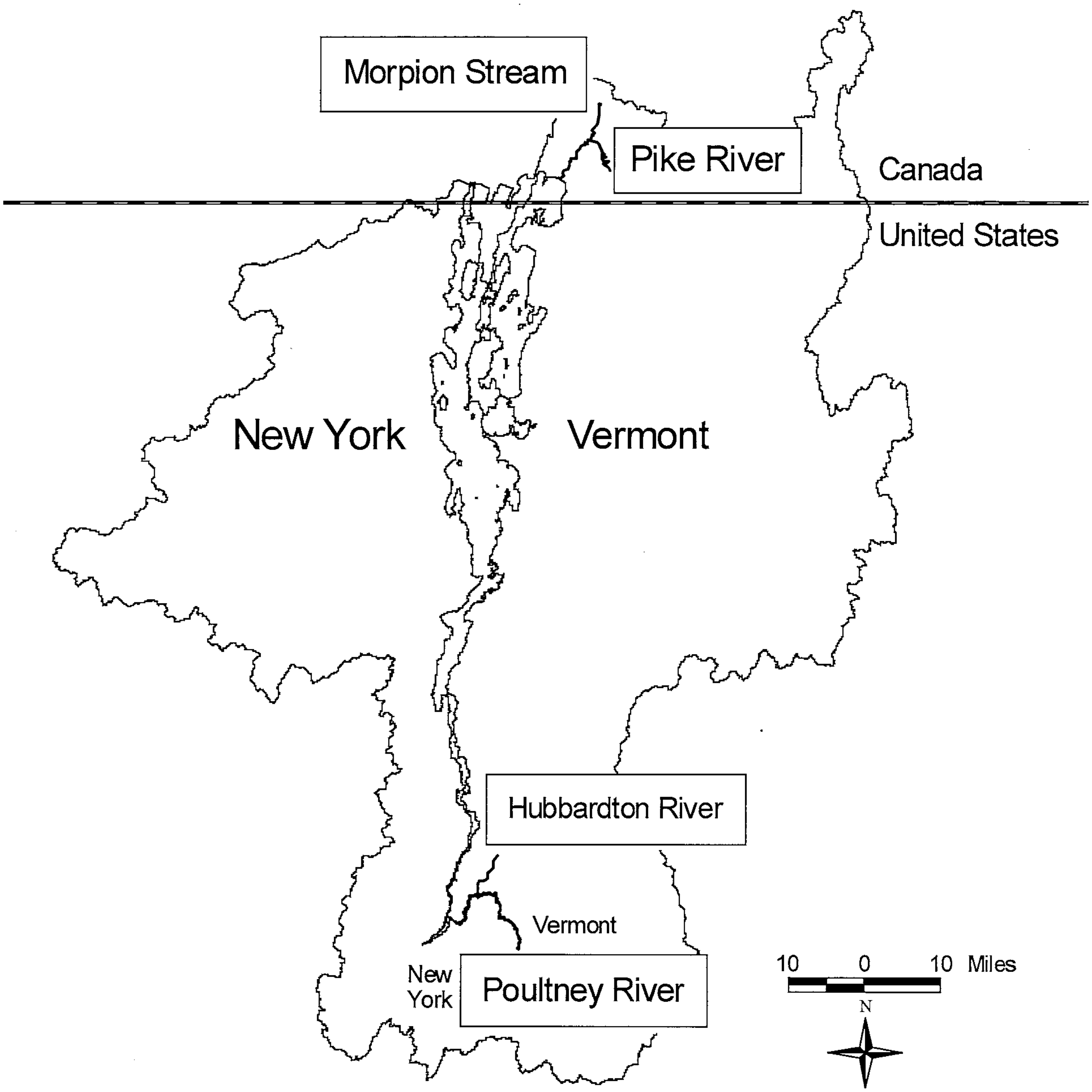
5.0 River Specific Investigations

River specific applications for all feasible sea lamprey control techniques are discussed in the following sections. Included in this discussion are site specific technical considerations, nontarget, habitat, and human impacts, and costs. These discussions are for impacts associated with a control option as described within a particular application and are in addition to the previous general discussion. If no additional impacts are expected, the section will simply state "No unique impacts". All cost estimates must be considered as preliminary since few accurate estimates were available. As a result, it is recommended that cost should not be used to accept or exclude a particular control option. See Tables 15 through 18 for detailed information of the amortized costs for all control options for the Poultney, Hubbardton, Pike Rivers and Morpion Stream respectively. Permits and approvals for each governmental jurisdiction are presented in Appendicies I (New York), II (Vermont), and III (Quebec).

5.1.0 Poultney River Physical Description

The Poultney River originates between Tinmouth and Spoon Mountains, Vermont (Figure 1). For part of its 39 mile (63 km) length the river defines the New York-Vermont border. Since 1991 the Lower Poultney River has been designated an Outstanding Resource

Figure 1. Lake Champlain, its watershed, Poultney, Hubbardton and Pike Rivers and Morpion Stream.



Water by the Vermont Water Resources Board (Vermont Department of Environmental Conservation and The Lower Poultney River Citizens Committee 1992). This designation was given to the lowermost 22 miles (35 km) of the Poultney River because of its natural, cultural, and scenic values. Much of the Lower Poultney River is undeveloped and serves as a resource for the study of archeology, geology, and natural history by colleges and universities as well as private organizations and museums.

The soil found along the Poultney River is primarily a dark grayish-brown clay that is moderately well drained. In the fall and spring the river occasionally floods its banks leaving behind a deposit of loam and silt along the flood plain. The soil below Carvers Falls (a natural sea lamprey barrier and site of a hydroelectric generating facility) is deep [typically >60 inches (1.5 m) to bedrock] and prone to erosion (Ferguson 1998). Below Coggman Bridge the Poultney River becomes drowned by Lake Champlain, and along its lowermost stretches, numerous marshes bracket the river.

5.1.1 Biological Resources of the Poultney and Hubbardton Rivers

Reflective of their diverse habitat, the Poultney and Hubbardton Rivers have considerable species richness. Of the 88 fish species known to occur in Vermont, 45 have been documented in the Poultney and Hubbardton Rivers (Table 1). Thirty-five of the 44 species reported in the Poultney River were documented below Carvers Falls (Facey and LaBar 1989, Fisheries Technical Committee 1999, NYSDEC *et al.* 1990). One fish species, the channel darter (*Percinia copelandi*), is listed as Endangered in Vermont while the eastern sand darter (*Ammocrypta pellucida*) is listed as Threatened. The eastern sand darter is also listed as Threatened in New York.

Twenty-one fish species have been documented in the Hubbardton River, 15 species were found below the natural sea lamprey barrier located approximately 1.5 miles (2.4 km) above the confluence of the Poultney and Hubbardton Rivers (Facey and LaBar 1989, Fisheries Technical Committee 1999, NYSDEC *et al.* 1990). None of the fish present below the barrier are listed as Threatened or Endangered in Vermont.

The Poultney River is also known for its diverse freshwater mussel communities. Seventy percent of freshwater mussel species known to be present in Vermont are found in the Poultney River. Of the 13 species, 5 are listed as Endangered and 3 listed as Threatened in Vermont (Table 2). One Threatened species, the eastern pearlshell (*Margaritifera margaritifera*) has only been documented above Carvers Falls. No mussel surveys have been conducted in the Hubbardton River.

Table 1. Fish species documented in the Poultney and Hubbardton Rivers.

Species	Poultney River Above Sea Lamprey Barrier	Poultney River Below Lamprey Barrier	Hubbardton River Above Sea Lamprey Barrier	Hubbardton River Below Sea Lamprey Barrier
banded killifish	X[a]		X[a]	
black crappie		X[a]		
blackchin shiner		X[a,b]		X[a]
blacknose dace	X[a]	X[b]	X[a]	X[a]
bluegill	X[a]	X[a,b]	X[a]	X[a]
blueback herring		X[b]		
bluntnose minnow	X[a]	X[a,b]	X[a]	X[a]
brassy minnow		X[b]		
bridle shiner		X[a]		
brown trout	X[a]			X[a]
brown bullhead	X[a]			
carp		X[a]		
channel darter *		X[a,b]		
common shiner	X[a]		X[a]	
creek chub	X[a]	X[a,b]	X[a]	X[a]
cutlips minnow	X[a]		X[a]	X[a]
eastern silvery minnow		X[a]		
eastern sand darter []		X[a,b]		
emerald shiner		X[a,b]		
fallfish	X[a]	X[a]	X[a]	X[a]
fathead minnow	X[a]		X[a]	X[a]
golden shiner		X[a]	X[a]	
largemouth bass		X[a,b]	X[a]	
logperch		X[a,b]	X[a]	X[a]
longnose gar		X[a]		

Table 1 continued. Fish species documented in the Poultney and Hubbardton Rivers.

Species	Poultney River Above Sea Lamprey Barrier	Poultney River Below Lamprey Barrier	Hubbardton River Above Sea Lamprey Barrier	Hubbardton River Below Sea Lamprey Barrier
longnose dace	X[a]	X[a,b]		X[a]
mimic shiner	X[a]	X[a,b]		
northern pike		X[b]		
pearldace	X[a]			
pumpkinseed	X[a]	X[a]	X[a]	X[a]
rock bass			X[a]	
rosyface shiner		X[a]		
sand shiner		X[b]		
sea lamprey		X[b]		
silver lamprey		X[b]		X[b]
silver redhorse		X[a,b]		
silvery minnow		X[b]		X[b]
slimy sculpin	X[a]			
smallmouth bass		X[b]	X[a]	X[a]
spotfin shiner		X[a,b]		
tessellated darter	X[a]	X[a,b]	X[a]	X[a]
troutperch	X[a]			
walleye		X[a]		
white perch		X[a]		
white sucker	X[a]	X[a,b]	X[a]	X[a]
yellow perch		X[a,b]	X[a]	

* denotes of Endangered in Vermont.
[] denotes Threatened in Vermont and New York
Source: a. Facey and LaBar (1989) Surveys conducted during June and July.
b. Fisheries Technical Committee 1999, NYSDEC, USFWS, and VTDFW, 1990.
Species Status Source: VT - May 1999 Vermont Deptartment of Fish and Wildlife Factsheet
NY - www.dec.state.ny.us/website/dfwmr/wildlife/endspec/etsclist.html

Table 2. Unionid species and likely host fish documented in the Poultney River.

Common Name	Scientific Name	Status	Fish Hosts Needed for Mussel Larvae
black sandshell	*Ligumia recta*	E (VT)	banded killifish largemouth bass bluegill walleye
cylindrical papershell	*Anodontoides ferussacianus*	E (VT)	molted sculpin sea lamprey
creek heelsplitter	*Lasmigona compressa*		slimy sculpin spotfin shiner black crappie yellow perch
eastern lampmussel	*Lampsilis radiata*		No definitive studies have been conducted to determine fish hosts of this species. Closely related species use many warm water species
eastern pearlshell*	*Margaritifera margaritifera*	T (VT)	Various trout and salmon species
eastern eliptio	*Elliptio complanata*		yellow perch banded killifish (Suspected Host) sunfish - several species (Suspected Hosts)
eastern floater	*Pyganodon cataracta*		carp Closely related species use many warm water species.
fluted shell	*Lasmigona costata*	E (VT)	carp northern Pike bluegill largemouth Bass yellow Perch walleye
fragile papershell	*Leptodea fragilis*	E (VT)	freshwater drum (Possible Host)

Table 2 continued. Unionid species and likely host fish documented in the Poultney River.

Common Name	Scientific Name	Status	Fish Hosts Needed for Mussel Larvae
giant floater	*Pyganodon grandis*	T (VT)	longnose gar golden shiner blacknose dace creek chub common shiner blacknose shiner blackchin shiner bluntnose minnow banded killifish black crappie rock bass largemouth bass bluegill pumpkinseed yellow perch
pink heelsplitter	*Potamilus alatus*	E (VT)	freshwater drum may be a host
pocketbook	*Lampsilis ovata*	E (VT)	largemouth bass bluegill walleye yellow perch
squawfoot	*Strophitus undulatus*		Glochidia may be able to develop without host spotfin shiner fathead minnow creek chub yellow bullhead largemouth bass bluegill walleye
triangle floater	*Alasmidonta undulata*		common shiner blacknose dace longnose dace

* Only documented above the Carvers Falls Dam.
E = Endangered, T=Threatened
Source: Ferguson, M. (2000). Vermont Agency of Natural Resources, unpublished data. Watters (1994)
Species Status Source: VT - May 1999 Vermont Department of Fish and Wildlife Factsheet; VTDEC, unpublished data, 2000.
NY - www.dec.state.ny.us/website/dfwmr/wildlife/endspec/etsclist.html

To facilitate reproduction, freshwater mussels may require close interactions with species-specific fish hosts. Hosts carry the mussel larvae (glochidia) attached to their fins, gills, and body surface for 10 to 190 days (Pennak 1989). While some fish are infected as a direct result of close interactions with the mussel, others become infected with glochidia that have been deposited in the sediments. Glochidia not attached to an appropriate host will die within a few days. There can be a species-specific mussel / fish host relationship, and Table 2 provides a list of known fish hosts for each mussel species.

No specific surveys have been conducted to comprehensively document the flora and fauna present along the Poultney and Hubbardton Rivers. Amphibians and reptiles likely to be found along the Poultney and Hubbardton Rivers are listed in Table 3; mammals are listed in Table 4. Flora and bird species lists could not be compiled. For a complete list of flora and bird species found in Vermont refer to the 1990 Environmental Impact Statement (NYSDEC *et al.* 1990).

5.1.2 Poultney River Water Quality

The Poultney River's water quality reflects the landscape and land use within the watershed. High phosphorus concentrations are primarily the result of non-point agricultural runoff and sewage treatment plant discharges. Calcium and Total Suspended Solids are among the highest found within the Lake Champlain watershed and reflect the limestone and clay soils found within the region. Selected parameters of the Poultney River's water quality are summarized in Table 5.

5.1.3 Poultney River Flows

The United States Geological Survey (USGS) has flow data from two locations along the Poultney. A USGS gage below Fair Haven is located 0.3 miles (0.48 km) downstream from Carvers Falls. Historic stream flow and stage records date back to October 1928 from this gage. The second site, no longer operated, was located above Carvers Falls in East Poultney, Vermont. Information from both staff gages can be accessed via the Internet at http//www.bowdnhbow.er.usgs.gov/. Dye studies conducted before the 1996 lampricide treatment elucidated an error in the flow calibration curve of the Below Fair Haven gage station (G. Neuderfer June 23, 1997 Memorandum). It is uncertain how long the gage has read in error but it is believed that the gage has seen a gradual shift in the flow curve over the years (G. Hilgendorf, U.S. Geological Survey, Personal Communication, 2000). Mean monthly flow for the period of 1973 to 1998 is provided in Table 6.

Table 3. Amphibians and reptiles documented within and near the Poultney and Hubbardton watersheds.

common mudpuppy	gray treefrog	eastern ribbon snake
Jefferson salamander -	northern spring peeper	northern ringsnake
blue spotted salamander -	bull frog	smooth green snake
spotted salamander	green frog	black rat snake
redspotted newt	wood frog	eastern milk snake
northern dusky salamander	northern leopard frog	timber rattlesnake * []
Allegany dusky salamander	pickerel frog	common snapping turtle
northern redback salamander	five-lined skink *	common musk turtle
four-toed salamander	northern water snake	wood turtle
northern spring salamander	northern brown snake	eastern box turtle
northern 2-lined salamander	northern redbelly snake	common map turtle
eastern American toad	common garter snake	painted turtle

* denotes Endangered in Vermont
[] denotes Threatened in New York
- denotes of Special Concern in New York
Source: Amphibian and Reptile Maps Source: http://www.dec.state.ny.us/website/dfwmr/wildlife/herp/index.html
Species Status Source: VT - May 1999 Vermont Department of Fish and Wildlife Factsheet
NY - www.dec.state.ny.us/website/dfwmr/wildlife/endspec/etsclist.html

Table 4. Mammals likely to be found within the Poultney and Hubbardton watersheds.

beaver	long-tailed weasel	water shrew
deer mouse	meadow jumping mouse	white-footed mouse
eastern chipmunk	river otter	woodchuck
eastern cottontail	short-tailed weasel	woodland vole
gray squirrel	white-tailed deer	porcupine
hairy-tailed mole	racoon	red bat
house mouse	red fox	bobcat
long-tailed shrew *	woodland jumping mouse	little brown bat
masked shrew	silver-haired bat	smokey shrew
meadow vole	Indiana bat ~	snowshoe hair
muskrat	mink	southern red-backed vole
New England cottontail *+	black bear	southern bog lemming
northern short-tailed shrew	moose	star-nosed mole
northern flying squirrel	eastern pipestrelle	Virginia opossum
norway rat	gray fox	coyote
pygmy shrew	hoary bat	striped skunk
red squirrel	big brown bat	eastern mole (Possible)
rock vole	small-footed bat	pine martin (Possible) *
fisher		

* denotes Endangered in Vermont
\+ denotes of Special Concern in New York
~ denotes listed as Endangered in New York, Vermont, and United States

Sources: Kathleen Nelson, United States Dept. of Agriculture, Personal Communication, 2000
Richard Chipman, United States Dept. of Agriculture, Personal Communication, 2000

Species Status Source: VT - May 1999 Vermont Department of Fish and Wildlife Factsheet
NY - www.dec.state.ny.us/website/dfwmr/wildlife/endspec/etsclist.html

Table 5. Summary of selected water quality surveys for the Poultney River.

Date	Location	Temperature (°C)	pH	Alkalinity ($CaCO_3$)	Flow (cfs)
9/23/92	Below Carvers Falls	N/A	8.2 - 8.6	70 - 78	N/A
9/24/92	Below Carvers Falls	14	7.9 - 8.5	70 - 80	170
9/25/92	Below Carvers Falls	13 - 15	8.0 - 8.5	74 - 80	170
9/24/92	Coggman Bridge	N/A	7.9 - 8.6	84 - 90	210
9/24/92	Schoolhouse Marsh	N/A	7.6 - 8.4	86 - 94	>210
10/30/96	Below Carvers Falls	N/A	7.9 - 8.2	87 - 100	150

Source: Fisheries Management Subcommittee 1994
G. Neuderfer, Memorandum, June 23, 1997

Note: Flows recorded during regulated periods. Refer to Table 6 for summary of the Poultney River's mean monthly flow. Additional water quality information is available through the Lake Champlain Long-Term Monitoring Program.

Table 6. Mean monthly flows for the Poultney (1974 - 1998) and Pike (1979 - 1995) Rivers.

Month	Poultney River Flow (cfs)	Pike River Flow (cfs)
January	305	175
February	311	189
March	608	472
April	678	591
May	351	210
June	174	131
July	113	62
August	117	71
September	106	82
October	213	184
November	296	300
December	316	243

Source: Poultney River: United States Geological Survey. Dam located Below Fair Haven Gage.
Pike River: A. Bouchard, Personal Communication, 1999. Dam located Above Notre-Dam-de-Stanbridge.

5.1.4 Poultney River Sea Lamprey Habitat

Carvers Falls, a natural barrier located 7.8 miles (12.6 km) above the river's mouth, prevents sea lamprey migration beyond that point (Lake Champlain Salmonid / Sea Lamprey Subcommittee 1985). However, directly below the falls is 0.5 (Fisheries Technical Committee 1999) to 1.0 (Gersmehl 1996) miles (0.8 to 1.6 km) of riffle habitat. This habitat provides adequate spawning grounds for sea lamprey and 0.5 miles of it is considered optimum for spawning (Figure 2). The remaining 6.8 miles (10.9 km) of river has a sand, silt, or mud bottom. Small riffle areas can be found as far downstream as Coggman Bridge but the substrate is generally not considered adequate for sea lamprey spawning.

Ammocoete habitat occurs from just below Carvers Falls to Schoolhouse Marsh. Prime habitat begins approximately 0.25 miles (0.4 km) below Carvers Falls and continues to just below Sciota Road (Figure 2). Within this region a 0.25 mile section (located directly above the Hubbardton River confluence) survey crews collected the highest number of dead sea lamprey ammocoetes (2,137) during the 1996 Poultney River TFM treatment (Fisheries Technical Committee 1999).

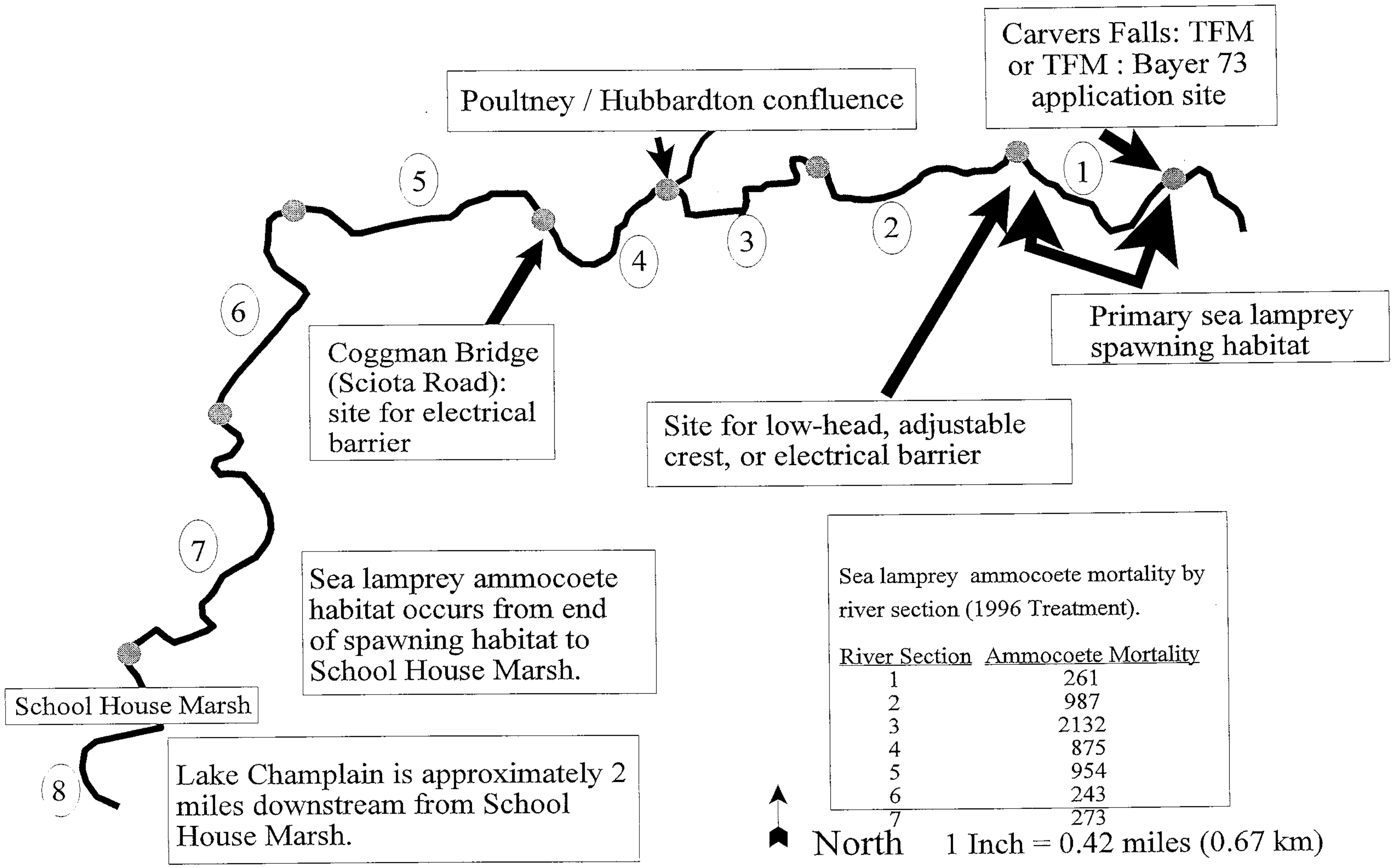
5.1.5 Poultney River Treatment History

The Poultney River from Carvers Falls to Lake Champlain was treated with the lampricide TFM in the fall of 1992 and 1996. The 1992 treatment was considered largely ineffective due to permit restrictions requiring TFM concentrations not to exceed 0.8 x MLC as determined by the lower of either predictive chart or bioassay procedures (Fisheries Technical Committee 1999). During the 1992 treatment, 195 sea lamprey ammocoetes and no transformers were observed killed. Under modified permit conditions, the 1996 TFM treatment was considered effective despite the fact that a TFM concentration of 1.0 x MLC, as determined by bioassay procedure, was not maintained for 9 consecutive hours (G. Neuderfer, June 23, 1997 Memorandum). The estimated mortality of the 1996 treatment, obtained through direct counts, was approximately 5,770 sea lamprey ammocoetes and 989 transformers. Refer to Figure 2 for a breakdown of ammocoete mortality by river section. Pre- and post-treatment sea lamprey ammocoete surveys indicated no reduction in sea lamprey abundance after the 1992 TFM treatment and a 95.6 percent reduction during the 1996 treatment (Fisheries Technical Committee 1999).

5.1.6 Poultney River Estimate of Sea Lamprey Transformer Production

To date, no specific studies to ascertain the sea lamprey transformer production for the Poultney River have been completed. A transformer production of 989 individuals was estimated for the Poultney River from the 1996 TFM treatment mortality estimates (Fisheries Technical Committee 1999). The unsuccessful 1992 TFM treatment produced no sea lamprey transformer estimate (Fisheries Technical Committee 1999). The U.S. Fish and Wildlife Service is presently planning to conduct a sea lamprey ammocoete and transformer production survey of

Figure 2. Poultney River sea lamprey habitat and summary of control options.



the Poultney River during the summer of 2000.

5.1.7.a TFM

A TFM treatment in 1996 demonstrated that a considerable number of sea lamprey ammocoetes can be removed from the Poultney River with a minimal amount of nontarget mortality. The Poultney River has stable water quality and the 1992 TFM treatment demonstrated that water flows may be made constant by regulating the release of water from Lake Bomoseen and altering turbine settings at the Carvers Falls Hydroelectric Plant (FMSC 1994). Lake Bomoseen can only be regulated within the limits of the existing permit issued by the Vermont Water Resources Board indicating water level fluctuation restrictions [± 3 inches (7.6 cm)] (C. MacKenzie, Vermont Agency of Natural Resources, Personal Communication, 2000). In 1996 the TFM treatment was conducted shortly after a high flow event and the Carvers Falls turbine was again employed to reduce and stabilize flow during treatment but also to flush the lampricide out of the Poultney River once the treatment was complete (B. Chipman, Vermont Agency of Natural Resources, Personal Communication, 2000). Applying TFM through the Carvers Falls Hydroelectric Plant penstock allows for rapid and thorough mixing of TFM with the Poultney River water (Figure 2).

An application of TFM at 1.0 to 1.5 x MLC (typical Great Lakes treatment concentration) may result in higher ammocoete mortalities and a more effective treatment. Failure to maintain an effective lethal block of TFM may result in lamprey populations being exposed to sublethal doses, posing the possibility that sea lamprey resistance to TFM could be developed over time (section 4.4).

Adequate treatment would require simultaneous treatment of a portion of the Hubbardton River timed to converge with TFM as it progresses through the Poultney River to account for the additional water it contributes to the Poultney River. A determination must be made as to the feasibility of treating the entire stretch of the Hubbardton River accessible to the sea lamprey as in 1992, or the lowermost 0.5 miles (0.8 km) as in 1996. The advantage of treating only the lowermost 0.5 mile of river is that the timing of the convergence of the TFM blocks from the Poultney and Hubbardton Rivers is more predictable. During the 1992 TFM treatment, approximately 50% (85 individuals) of all sea lamprey ammocoetes reported killed in the Hubbardton River were in this lowermost 0.5 mile stretch of river. Also, by allowing the Poultney and Hubbardton River TFM blocks to converge, a more effective treatment of the Poultney River below the convergence will likely occur through maintenance of TFM target concentrations. In 1996 nearly 2,500 ammocoetes and 860 transformers were estimated killed on the Poultney River below the Poultney / Hubbardton River confluence.

5.1.7.b Nontarget Impacts

During the 1996 TFM treatment over 2,500 silver lamprey ammocoetes were reported killed in the Poultney River. Nine tessellated darters, 4 log perch, 3 white suckers, 1 largemouth bass, 1 bluntnose minnow, 1 fathead minnow, 1 brassy minnow, and 1 fallfish mortalities were recorded. Two salamanders were also reported killed during the treatment. It is unclear what the impacts of a long-term TFM program would have on the resident silver lamprey population. Smith (1985) and Scott and Crossman (1973) state that silver lamprey ammocoete life stage lasts 4 to 7 years while and Hardisty and Potter (1971) describe field observations which suggest silver lamprey can transform after 3 years. Though no statolith analysis has been performed, Bouffard (Personal Communication, 2000) believes silver lamprey ammocoete life stage in the Poultney River is approximately 3 years. As with sea lamprey, the silver lamprey ammocoete life stage is, in part, dependent upon the water temperature and productivity and ammocoete abundance. Depending upon the frequency of treatment, silver lamprey populations may or may not be as severely impacted as that of sea lamprey populations. Determination of the rate to transformation for silver lamprey may help determine the overall impacts though it is presently believed that a generation of silver lamprey will survive and spawn between scheduled treatments (D. Nettles, Personal Communication, 2000).

Frog tadpoles and mudpuppies may suffer considerable mortalities resulting from TFM applications. Seven frog species, the eastern American toad, and the common mudpuppy have been documented in the Poultney River region. No amphibian species are listed as Threatened or Endangered in Vermont. The Jefferson and blue spotted salamander are listed as of Special Concern in New York but are not likely to be affected by TFM application. During the 1992 and 1996 TFM treatments a total of two individual salamander mortalities were reported. A 1.5 x MLC (Great Lakes maximum "typical" treatment concentration) treatment may result in higher amphibian mortalities than was documented for the 1996 treatment.

No negative impacts to the lower Poultney River wetlands were reported for either TFM treatment. Gruendling and Bogucki (1986) reported the Poultney River is well channelized and wetland areas adjacent to the tributary are high on the flood plain, behind levees, or otherwise isolated from the river and thus isolated from TFM exposure. Two small wetlands (total area <0.2 acres (890 m^2) located at the mouth of the Poultney River and within New York State could receive low levels of TFM associated with a TFM treatment (Gruendling and Bogucki 1986). Gruendling and Bogucki (1986) suggested that a TFM application during low lake levels would minimize any impact.

5.1.7.c Habitat Impacts

No unique impacts.

5.1.7.d Human Impacts

A TFM treatment of the Poultney River will create noticeable but manageable human impacts. The 1992 and 1996 treatments resulted in water use advisories which began at the TFM application point and extended north to Ticonderoga, NY in Lake Champlain [a distance of approximately 20 miles (32 km)] (J. Sausville, NYSDEC, Personal Communication, 2000). The remoteness of this region precluded the need for extensive water supply efforts. Only two homes required a supply of water on the New York side while in Vermont the small demand for water was met by establishing water tanks at strategic locations. During the 1992 treatments six Vermont farms were impacted by the treatment. Four of the farmers moved their herds, one farm was supplied with fresh water and food, and one required the installation of a water filtration system (N. Staats, U.S. Fish and Wildlife Service, Personal Communication, 2000). The 1992 (0.8 x MLC treatment) and 1996 (1.0 x MLC treatment) treatments resulted in water use advisories which lasted approximately 2 weeks and 24 days respectively. Treating the Poultney River with a 1.5 x MLC may extend the range and duration of human impacts.

5.1.7.e Cost

The fall 1996 treatment required approximately 1,200 pounds (544 kg) of TFM (active ingredient) formulation to be applied to the Poultney River at the Carvers Falls Hydroelectric plant and an additional 164 pounds (74 kg) (active ingredient) to the Hubbardton River (G. Neuderfer, Memorandum, June 23, 1997). The Hubbardton River was treated in part to maintain the desired TFM concentration in the Poultney River once the two rivers converged. Total cost for the TFM was $37,586 (1996 cost), or $32.45 per pound of active ingredient. This cost reflects a target concentration of 1.0 x MLC, a Poultney River pH range of 7.90 to 8.20, and Total Alkalinity (as $CaCO_3$) of 94. If a treatment were to occur under the same water quality conditions and flow, but with a target concentration of 1.5 x MLC, then the cost of TFM would be approximately $66,000. This cost reflects a 4% annual rate of inflation adjustment.

A short-term intensive need for staff is required during a TFM treatment. Approximately 820 staff hours are required to conduct a 12 hour TFM treatment (as estimated from a 1996 NYSDEC Personnel Assignment Schedule). Additional costs include public notification, travel, and a number of miscellaneous expenses. It is important to note that this cost incorporates concurrent treatment of the Hubbardton River and costs could be incurred every three to four years, given the current rate of transformation, as long as sea lamprey continued to spawn in the river system. Amortizing these estimates, the annual cost for a TFM treatment of the Poultney and Hubbardton Rivers would be $21,625 to $28,850. This reflects a labor cost estimate of $25.00/hour. See Table 7 for a comparison of amortized costs for sea lamprey control of the Poultney River. See Appendix IV for a generalized comparison of control techniques considered for the Poultney River.

5.1.8.a TFM : Bayer 73 (wettable powder)

Prior to approval of a Poultney or Poultney / Hubbardton River TFM : Bayer 73 treatment, an analysis must be conducted to determine the rate of attenuation of Bayer 73 due to suspended solids (especially colloidal clay) in the river. If the Poultney River is treated at a flow of greater than 100 cfs (2.80 cms) it may be economically advantageous to treat the Poultney River with a TFM : Bayer 73 combination as compared to TFM. Treatment would be similar to that of a TFM application but with an increase in effort associated with the addition of Bayer 73

Table 7. Amortization of Poultney River sea lamprey control options.

	Cost Estimates for Chemicals, Construction of Physical or Electrical Barriers and Traps			Hours Required to Accomplish Control				
Control Option	Cost Estimate or Range	Benefit Duration	Cost / Year	Labor (Hours For Control)	Frequency	Costs / year *	Total Estimated Cost / Year **	Notes
TFM	$66,000	3 to 4 years	$16,500 to $22,000	820 hours	3 to 4 years	$5,125 to 6,850	$21,625 to $28,850	Includes treatment of the Hubbardton River
TFM : Bayer 73	$33,750	3 to 4 years	$8,430 to $11,250	>820 Hours	3 to 4 years	$5,125 to 6,850	$13,563 to $18,100	Includes treatment of the Hubbardton River
Low Head Barrier	$590,000 to $740,000	40 to 50 years	$11,800 to $18,500	See Trapping Below	Annual	$1,900 to $7,200	$13,700 to $25,700	Trapping required.
Adjustable Crest Barrier	$683,000 to $883,000	40 to 50 years	$13,660 to $22,075	See Trapping Below	Annual	$1,900 to $7,200	$15,560 to $29,275	Trapping required. Does not include annual electrical and telecommunications costs
Electrical Barrier (Coggman Bridge)	$202,700 to $302,700	>20 years	$10,135 to $15,135	See Trapping Below	Annual	$1,900 to $7,200	$12,235 to $23,135	Trapping required. Also controls the Hubbardton River. Total estimated costs include $200 (min) to $800 (max) annual electrical costs. Does not include backup generator ($4,000 to $11,000) or telecommunications.
Electrical Barrier (below Carvers Falls)	$253,000 to $353,000	>20 years	$12,650 to $17,650	See Trapping Below	Annual	$1,900 to $7,200	$14,750 to $25,650	Trapping required. Does not control the Hubbardton River. Total estimated costs includes $200 (min) to $800 (max) annual electrical costs. Does not include backup generator ($4,000 to $11,000) or telecommunications.
Trapping	$18,000 (max)	20 years	$900	$1,000 to $6,300	Annual	$1,000 to $6,300	$1,900 to $7,200	

* Labor Costs for TFM and TFM : Bayer 73 are estimated at $25.00 / hour.

** Total Estimated Cost Range is Total Minimum to Total Maximum.

to the treatment. Application and analysis efforts would require additional personnel and equipment to accommodate such a treatment.

Applying TFM : Bayer 73 at the Carvers Falls Hydroelectric Plant would allow for rapid and thorough mixing of these combined lampricides with the Poultney River water (Figure 2). Space requirements and other logistics for application of a second lampricide (Bayer 73 wettable powder) into the same penstock opening need to be verified.

As with a TFM treatment, treating the Poultney River with TFM : Bayer 73 at 1.5 x MLC (Great Lakes maximum typical treatment concentration) may result in higher ammocoete mortalities and a more effective treatment. Again, failure to maintain an effective lethal block of TFM : Bayer 73 may result in lamprey populations being exposed to sublethal doses, posing the possibility that sea lamprey resistance to TFM : Bayer 73 could be developed over time (section 4.4).

Simultaneous treatment of a portion of the Hubbardton River with TFM timed to converge with the chemical block progressing through the Poultney River would be required for effective control. Consideration regarding location of application point is the same as for TFM (section 5.1.7.a).

5.1.8.b Nontarget Impacts

The nontarget impacts of a TFM : Bayer 73 treatment will be similar to those noted for TFM treatments. See sections 5.1.7.b (Poultney River), 4.4.1 (TFM general overview) and 4.6.1 (TFM : Bayer 73 general overview) for additional information on nontarget impacts.

5.1.8.c Habitat Impacts

No unique impacts.

5.1.8.d Human Impacts

The human impacts of a TFM : Bayer 73 treatment will be similar to a TFM treatment, though shorter in duration (section 5.1.7.d).

5.1.8.e Cost

A TFM : Bayer 73 treatment of the Poultney River at a concentration of 1.5 x MLC would result in a considerable cost savings in the purchase of lampricides compared to costs associated with a TFM treatment. The addition of approximately 21 pounds (9.5 kg) of Bayer 73 to TFM would result in about a 50% reduction in the amount of TFM needed. Thus only 1,018 pounds (462 kg) of TFM (active ingredient) would be required to treat the Poultney and Hubbardton Rivers during similar environmental conditions as during the 1996 TFM treatment.

This would result in a cost of $33,000 for TFM (1996 treatment costs adjusted for inflation at an annual rate of 4%). Bayer 73 lampricide costs would be an estimated $750 [$35.56/pound ($16.14/kg)] based on 1998 cost adjusted for inflation at an annual rate of 4%. This estimate assumes the use of a 1% Bayer 73 active ingredient formulation and is adjusted for inflation to reflect 2000 prices. The total cost savings for lampricides would amount to approximately $22,000 though actual treatment costs may or may not result in monetary savings. Additional personnel costs may offset or even increase costs associated with TFM treatment alone. Amortizing these estimates, the annual cost for a TFM : Bayer 73 treatment of the Poultney and Hubbardton River would be $13,563 to $18,100. This reflects a labor cost estimate of $25.00/hour. See Table 7 for a comparison of amortized costs for sea lamprey control of the Poultney River. See Appendix IV for a generalized comparison of control techniques considered for the Poultney River.

5.1.9.a Low-head and Adjustable Crest Barriers

A prior assessment of the Poultney River for sea lamprey control alternatives resulted in the identification of a potential low-head barrier site (NYSDEC *et al.* 1990). The site, located approximately 1 mile (1.6 km) below Carvers Falls (Figure 2), is in a remote stretch of the Poultney and within The Nature Conservancy holdings. A low-head or adjustable crest barrier placed at this location would eliminate approximately 99% of sea lamprey spawning habitat (NYSDEC *et al.* 1990).

Due to the highly erosional soils and large fluctuations in water level, design and construction at this location would be difficult (NYSDEC *et al.* 1990, J. Guilmette, VT Agency of Natural Resources, Personal Communication, 2000). Construction of a barrier at this site would allow sea lamprey to fall back and relocate and spawn in other tributaries including the Hubbardton River. This could be mitigated by establishing an effective sea lamprey trap to be incorporated into the barrier and / or a separate sea lamprey control measure in the Hubbardton River.

Establishing an adjustable crest barrier is also possible at the proposed low-head barrier site. Construction of an adjustable crest barrier would mitigate some of the flooding and erosion problems likely to be realized with a low-head barrier (T. McAuley, Personal Communication, 2000). An adjustable crest barrier would allow fish passage and reduce the amount of impounded water when the barrier is down and sea lamprey are not spawning. However, the sea lamprey spawning period may coincide with spring runoff and walleye spawning periods (J. Gersmehl, Personal Communication, 2000). Thus the barrier may exacerbate spring flooding and prevent walleye spawning activity. Also, electricity is not readily available and power lines would have to be run to this location. Unless cellular telephone technologies are utilized, land lines would also be needed to support telecommunications. Incorporation of removable slide gates into a low-head barrier may provide similar results as an adjustable crest barrier but a lift system would be required to install and remove heavy gates.

5.1.9.b Nontarget Impacts:

Unless an effective trap is incorporated into its design, placing a low-head barrier on the Poultney River would impact the spawning of walleye and sauger by preventing these nonleaping fish from passing over the barrier (NYSDEC *et al.* 1990). Preventing host fish / mussel interactions could also lead to localized impacts to certain freshwater mussel species including the Vermont Threatened or Endangered black sandshell, eastern floater, fluted shell, fragile papershell, giant floater, pocketbook, and pink heelsplitter. Walleye spawning may overlap with the sea lamprey spawning season so trapping will still be required to facilitate walleye spawning.

The construction and operation of a barrier may result in an increase in siltation above and below the proposed site. The area downstream of the dam likely to be affected by this siltation has been identified as nursery habitat for the New York and Vermont Threatened eastern sand darter (NYSDEC *et al.* 1990). Siltation below the dam would result when high flows mobilize sediments initially deposited in the impoundment area, to downstream areas (J. Guilmete, Personal Communication, 2000). Nursery habitat of the eastern sand darter requires habitat of sand but no silt (Smith 1985). Cyprinids, smallmouth bass, and redhorse suckers also spawn below the proposed barrier site (J. Gersmehl, Personal Communication, 2000). The degree to which any of these species will be impacted by an increase in siltation is uncertain.

5.1.9.c Habitat Impacts

Considerable habitat impacts would occur during construction of a low-head or adjustable crest barrier. The remoteness of this stretch of river would require the construction of a temporary road to facilitate access for construction vehicles. Due to erosional soils, downstream habitat may be affected by siltation during construction. Once the barrier is in place, an impoundment of water will occur within which siltation is likely (NYSDEC *et al.* 1990). Directly below the barrier the river may become scoured while further downstream additional siltation may occur. Guilmette (Personal Communication, 2000) suggests that this downstream siltation would be the result of the settling of silt "sucked" from behind the barrier during episodic high flow events. If an adjustable crest barrier is installed, power lines would have to be run. This may result in the establishment of a corridor for the installation of utility poles to carry electrical and telecommunication wires. Corridors and access roads may result in habitat fragmentation of the surrounding forest.

5.1.9.d Human Impacts

No unique impacts.

5.1.9.e Cost

The 1990 cost estimate for a low-head barrier on the Poultney was between $400,000 and

$500,000 (NYSDEC *et al.* 1990). Assuming an annual rate of inflation of 4%, the present cost would be approximately $590,000 to $740,000. This estimate must be considered preliminary since no engineering studies have been conducted.

Construction of an adjustable crest barrier would add approximately $40,000 to $90,000 to the cost of a low-head barrier (T. McAuley, Personal Communication, 2000). In addition, power and possibly telephone lines would have to be run a distance of 1 mile. Preliminary cost estimates for running electricity in this area is $10 per foot (total cost is approximately $53,000) (G. Barbagallo, Central Vermont Power Authority, Personal Communication, 2000). No cost estimate was made for the running of phone lines nor was an estimate made for the incorporation of a cellular communication system. Additional costs will be incurred for the maintenance and operation of traps (section 5.1.11.e). Amortizing these estimates, the annual cost for a low-head or adjustable crest barrier on the Poultney River would be $13,563 to $29,275. This includes annual trapping effort of $1,900 to $7,200 (section 5.1.11.e). See Table 7 for a comparison of amortized costs for sea lamprey control of the Poultney River. See Appendix IV for a generalized comparison of control techniques considered for the Poultney River.

5.1.10.a Electrical Barrier

Coggman Bridge may provide an acceptable site for the installation of an electrical barrier (Figure 2). Telephone poles are present at the site and power is only 0.25 miles (0.4 km) away. There appears to be an increased flow on the New York State side of the river which may be employed as a flow attractant for trapping spawning run fish. Since this site is below the Poultney / Hubbardton River confluence, an electrical barrier here would preclude the need for any sea lamprey control in the Hubbardton River. The proposed site is on an uninhabited stretch of Sciota Road with surrounding lands a combination of The Nature Conservancy refuge and private agriculture properties. Parking areas adjacent to Coggman Bridge show signs of vandalism.

An electrical barrier may also be placed approximately 1 mile (1.6 km) below Carvers Falls (Figure 2). This is the same location described in NYSDEC *et al.* (1990) as a potential site for a low-head barrier (section 5.1.9.a). Placing an electrical barrier at this location would not prevent sea lamprey from spawning in the Hubbardton River.

5.1.10.b Nontarget Impacts

An electrical barrier located under Coggman Bridge will likely have considerable impacts to spawning run fish. As a result, an effective trap would need to be incorporated into the electrical barrier. Walleye, smelt, pike, suckers, longnose gar, a host of Cyprinid species, and the Vermont - New York Threatened eastern sand darter are species which are known to utilize the Poultney and / or the Hubbardton Rivers above Coggman Bridge (J. Gersmehl, Personal Communication, 2000, C. MacKenzie, Personal Communication, 2000). In addition, certain freshwater mussel species (i.e. *Lampsilis* sp.) require close interactions with species specific host fish in the spring before glochidia can be released. Preventing host fish / mussel interactions could lead to localized impacts to certain freshwater mussel species.

Nontarget impacts associated with an electrical barrier placed below Carvers Falls would be similar to those expected for a low-head or adjustable crest barrier (section 5.1.9.c). Since electrical barriers do not impound water, siltation will not threaten the eastern sand darter's nursery habitat which is located below the barrier site.

Incorporation of an effective trap into the design of the electrical barrier will help to mitigate the impacts of an electrical barrier. In order to preserve the fish and freshwater mussel communities within the Hubbardton and lower Poultney Rivers, the trap must be highly effective in the capture of nontarget fish species for manual transfer above the barrier.

5.1.10.c Habitat Impacts

No unique impacts.

5.1.10.d Human Impacts

Since the proposed sites are in unpopulated areas, human impacts of an electrical barrier would center around those using the lower Poultney River as a recreational resource. If spawning run walleye and other sport fish are impacted by the barrier, the associated fishery may be adversely impacted.

5.1.10.e Cost

Dave Smith (Personal Communication, 2000) has given a preliminary cost estimate of \$200,000 to \$300,000 for the construction of an electrical barrier at Coggman Bridge. In addition to this cost, electrical lines would have to be run to the site from a distance of approximately 0.25 mile (0.4 km). If existing utility poles can be used to run the power lines, the cost is estimated to be approximately \$2/ft (\$6.56/m) resulting in an approximate cost of \$2,700 (Niagara Mohawk Customer Service, Personal Communication, 2000). Niagara Mohawk would not provide a cost estimate for the installation of new power poles without a site inspection. Additional costs associated with an electrical barrier include fish trapping and transfer and potential sea lamprey trapping (section 5.1.11.e), and barrier maintenance.

The estimated average monthly energy demand for a barrier on the Poultney River would be approximately 1,600 KWH. Given the current rate for electricity (12.383 cents/KW), the monthly charge would be approximately \$200 (Customer Service, Niagara Mohawk Power Corporation, Personal Communication, 2000). During months when the barrier is not active the power can be disconnected for a small fee (approximately \$25). At maximum capacity, the draw of a Smith Root Inc. electrical barrier is 6,480 KWH/month (J. Smith, Personal Communication, 2000). The maximum cost, given current electrical rates, would be approximately \$800 per month. A backup power source can add $4,000 to $11,000 to the cost of an electrical barrier (http://www.nooutage.com/automati.htm#Automatic Standby Generators). Amortizing these estimates, the annual cost for an electrical barrier at Coggman Bridge would be $12,235 to $23,135. This includes annual trapping effort of $1,900 to $7,200 (section 5.1.11.e).

The costs for installing an electrical barrier below Carvers Falls would be identical to those for Coggman Bridge with the exception of the costs associated with establishing electrical power in this remote stretch of river. Establishing power at the proposed site would be approximately $53,000, identical to those associated with an adjustable crest barrier (section 5.1.9.e). Amortizing these estimates, the annual cost for an electrical barrier (including trapping) would be $14,750 to $25,650. See Table 7 for a comparison of amortized costs for sea lamprey control of the Poultney River. See Appendix IV for a generalized comparison of control techniques considered for the Poultney River.

5.1.11.a Adult Trapping

Adult trapping using fyke nets or PATs could be employed at a number of locations along the Poultney River. The 1996 sea lamprey assessment trapping effort near Coggman Bridge was regarded as ineffective (J. Gersmehl, Personal Communication, 2000). Gersmehl further suggests that the Poultney River is too large to trap effectively and that, in general, PATs are not an effective method for controlling sea lamprey.

A trap incorporated into the design of an electrical, low-head, or adjustable crest barrier will be required to mitigate impacts of a barrier. Traps must be designed to be very effective in the collection of both sea lamprey and nontarget species. These traps must be manually tended at frequent intervals to remove sea lamprey and transport nontarget species above the barrier.

5.1.11.b Nontarget Impacts

No unique impacts.

5.1.11.c Habitat Impacts

No unique impacts.

5.1.11.d Human Impacts

No unique impacts.

5.1.11.e Cost

The cost of a PAT or fyke net is quite low; PATs can be constructed for as little as a few hundred dollars. Fyke nets can be purchased from a fishery supply store and also cost only a few hundred dollars. The primary expense in trapping comes from the labor required to tend the trap on a regular basis. With more frequent inspections there is a reduction in nontarget mortality, however, an increase in the number of inspections also increases labor requirements. Presently, traps installed on Lake Champlain tributaries are tended approximately every other day (W. Bouffard, Personal Communication, 2000).

To facilitate frequent trapping requirements for some remote sites in the Great Lakes, contract employees are hired for $1,000 to $3,000 per spawning season (E. Koon, Personal Communication, 2000). A similar program may provide an economically feasible way to tend traps along the Poultney. In addition, the U.S. Fish and Wildlife Service National Fish Hatchery in Pittsford, Vermont is a short distance away and staff from this facility may be able to assist in the tending of traps (D. Tilton, U.S. Fish and Wildlife Service, Personal Communication, 2000). If tended by U.S. Fish and Wildlife staff from the Essex Junction, Vermont office, the cost for trapping is likely to be similar to those reported by Gersmehl (Interoffice Memo, 1997) for the Pike River in 1997. Adjusted for inflation (4% annual adjustment), the annual trapping cost for this effort is estimated to be $6,300. A trap on the Poultney River could be tended concurrently with the servicing of a Hubbardton River trap without incurring much additional cost.

The costs to incorporate a permanent trap into a barrier varies greatly. Using the Preliminary Feasibility Study for Sea Lamprey Barrier Dams on Lake Champlain Tributaries as a guide, the incorporation of a trap into a barrier can cost (1985 estimates) between $2,500 and $10,000 (Anderson *et al.* 1985). Assuming an average annual rate of inflation of 4%, present cost would be $4,500 to $18,000. Additional costs will be required if a flow attractant or some other physical modification of the surrounding habitat must be constructed to create an effective trapping situation. Amortizing these estimates, the annual cost for sea lamprey trapping would be $1,900 to $7,200. See Table 7 for a comparison of amortized costs for sea lamprey control of the Poultney River. See Appendix IV for a generalized comparison of control techniques considered for the Poultney River.

5.2.0 Hubbardton River Physical Description

Entering 2.2 miles (3.5 km) below Carvers Falls, the Hubbardton River is the largest stream flowing into the lower Poultney River. The soil along the Hubbardton River is similar to that found along the Poultney River with the exception of very steep clay hills which bracket the lower stretches and north side of the river. Along its banks, loam and silt are prevalent.

5.2.1 Biological Resources of the Hubbardton River

Since very few Hubbardton River specific biological inventories have been conducted, a more thorough understanding of the natural biota is obtained by using the Poultney River biological resources as a surrogate. Refer to section 5.1.1 for a discussion of the biological resources of the Poultney and Hubbardton Rivers.

5.2.2 Hubbardton River Water Quality

Little water quality information is available for the Hubbardton River. Two sources of information are the 1992 and 1996 lampricide treatments and the 1989 fish survey conducted by Facey and Labar. See Table 8 for a summary of water quality as recorded during the 1989 fish survey and the 1992 and 1996 lampricide treatments.

5.2.3 Hubbardton River Flows

The United States Geological Survey does not maintain a gage station on the Hubbardton River and, as a result, the only flows available are those collected as part of the 1992 and 1996 lampricide treatments. A rain event two days before the 1992 treatment increased flow to 121 cfs (3.4 cms) but 2 days later the flow had receded to 19 cfs (0.62 cms). The 1996 lampricide treatment reported pretreatment and treatment flows of 19 and 22 cfs (0.53 cms) respectively (G. Neuderfer, Memorandum, June 23, 1997, Fisheries Technical Committee 1999).

5.2.4 Hubbardton River Sea Lamprey Habitat

Approximately 2 miles (3.2 km) above its confluence with the Poultney River is a region of stepped bedrock which acts as a natural sea lamprey barrier. Sea lamprey utilize nearly all of the riffle habitats below the bedrock region and the uppermost 1.0 mile of this area (1.6 km) offers prime spawning habitat (Fisheries Technical Committee 1999). Prime larval habitat is in the lowermost 0.5 miles (0.8 km) of river, however, ammocoetes utilize the entire stretch of available habitat. Refer to Figure 3 for a review of sections monitored during the TFM treatments and a summary table of the sea lamprey mortality for each section.

5.2.5 Hubbardton River Treatment History

In the fall of 1992, following completion of the Poultney River treatment, the Hubbardton River was treated with the lampricide TFM. During this treatment all habitat accessible to sea lamprey was treated at a concentration of 1.0 x MLC (FMSC 1994). A second TFM treatment, conducted simultaneously with a Poultney River treatment, took place in the lowermost 0.5 miles of the Hubbardton in the fall of 1996. The primary application point for this second treatment was moved primarily to achieve the precise timing of chemical convergence between the Hubbardton and Poultney Rivers (D. Nettles, Personal Communication, 2000). In doing so, treatment crews avoided chemical dilution and maintained the appropriate MLC for effective treatment of the Poultney River.

5.2.6 Hubbardton River Estimate of Sea Lamprey Transformer Production

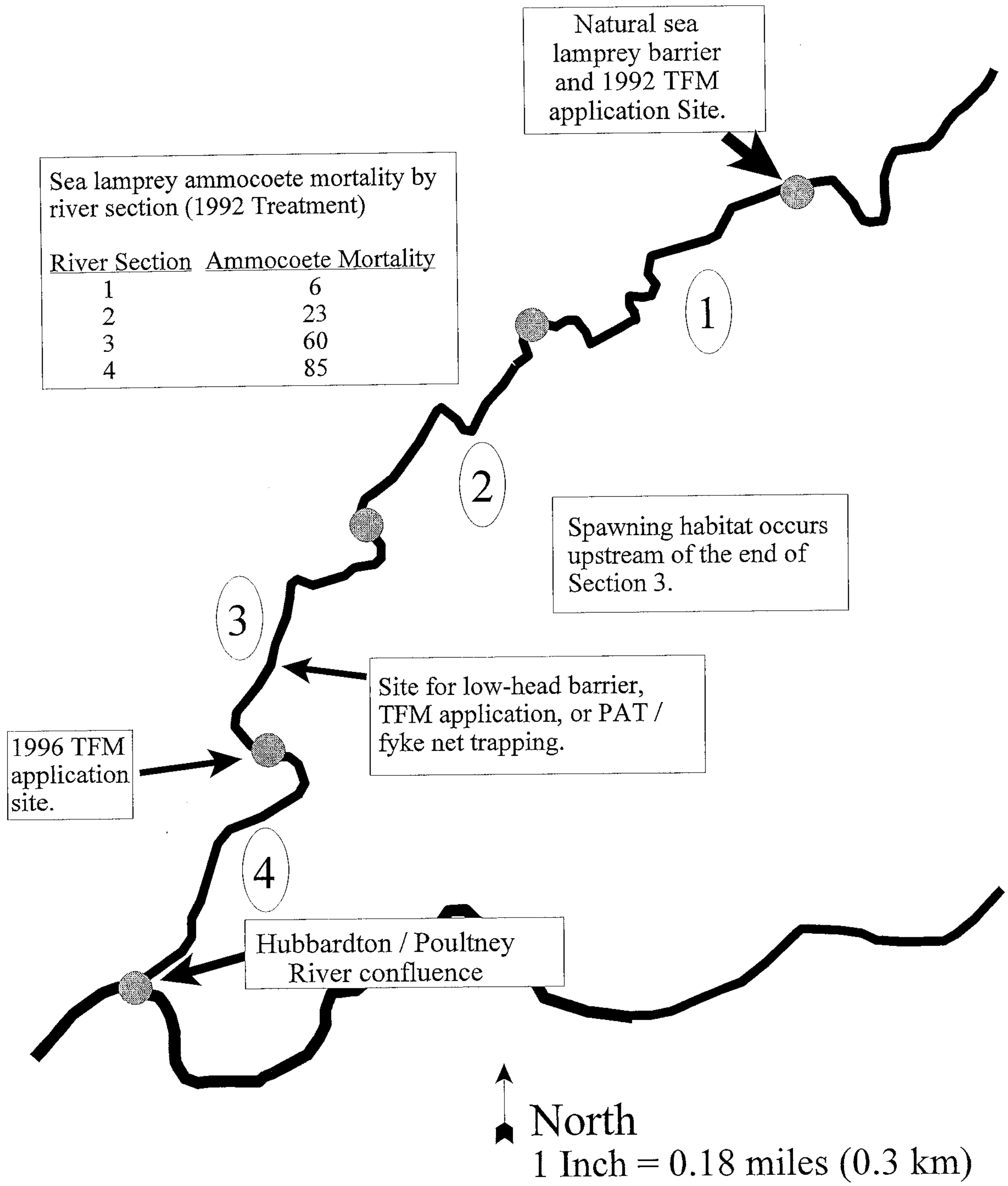
No specific sea lamprey transformer assessment has been conducted for the Hubbardton River. Little insight into transformer production can be obtained from the 1992 and 1996 TFM treatments. During the 1992 treatment 174 ammocoetes and 8 transformers were reported killed

Table 8. Summary of the Hubbardton River water quality surveys.

Date	Location	Temperature (°C)	pH	Alkalinity ($CaCO_3$)	Flow (cfs)
6/29/89	Lower Hubbardton	23	8.2	N/A	N/A
9/24/92	TFM AP Site (1992)	14 - 16	8.3 - 8.5	118 - 126	40
9/25/92	TFM AP Site (1992)	N/A	8.0 - 8.2	124 - 126	19
10/30/96	TFM AP Site (1996)	N/A	7.82 - 7.98	120 - 124	22

Source: Fisheries Management Subcommittee 1994
G. Neuderfer, Memorandum, June 23, 1997

Figure 3. Hubbardton river sea lamprey habitat and summary of control options.



and 20 ammocoetes and no transformer mortalities were reported during the 1996 treatment (Fisheries Technical Committee 1999). While the 1996 TFM treatment was only for the lowermost 0.5 miles of habitat it covered the best ammocoete habitat available in the Hubbardton (Figure 3). The Hubbardton River's high turbidity reduced visibility and hampered counting and collection efficiencies (Fisheries Technical Committee 1999).

5.2.7.a TFM

As demonstrated with the 1992 and 1996 lampricide treatments, the Hubbardton River can be treated with TFM in a number of ways (section 5.2.5). While different treatment options are available, the Hubbardton River would probably not be treated without a concurrent treatment of the Poultney River unless other control strategies are employed to change the current setting (i.e. barrier on the Poultney River) (D. Nettles, Personal Communication, 2000). Refer to section 5.1.7.a for an overview of a Poultney River TFM treatment.

5.2.7.b Nontarget Impacts:

The 1992 TFM treatment of the Hubbardton River resulted in a single mortality observed for each of the following species: tessellated darter, silvery minnow, unidentified minnow, pumpkinseed (Fisheries Technical Committee 1999). The 1996 TFM treatment resulted in the observed mortality of a single tessellated darter. The nontarget mortality assessment crew reported poor visibility, making collections difficult (G. Neuderfer, Memorandum, June 23, 1997). As a result, actual mortality of nontarget species may have been greater than that reported. If the Hubbardton River were to be treated at dosage of 1.5 x MLC (Great Lakes maximum typical treatment concentration) nontarget mortality may rise. Potentially sensitive fish species documented in the Hubbardton River which have had noted mortality in other Lake Champlain TFM treatments include logperch, bluntnose minnow, and to a lesser degree blacknose dace, tessellated darter and white sucker.

Although no amphibians have been reported killed during the 1992 or 1996 TFM treatments, mudpuppies and frog tadpoles may suffer mortality resulting from TFM applications. No amphibian species are listed as Threatened or Endangered in Vermont. For all Poultney and Hubbardton River TFM treatments, only 2 amphibian mortalities (both salamanders) were reported (Fisheries Technical Committee 1999). See Table 3 for list of amphibians documented in the vicinity of the Poultney and Hubbardton Rivers.

A TFM treatment of the Hubbardton is not likely to impact associated wetlands. Two small wetlands [total area <0.2 acres (890 m^2)] located at the mouth of the Poultney River and within New York State could receive low levels of TFM associated with a TFM treatment of the Hubbardton.

5.2.7.c Habitat Impacts

No unique impacts.

5.2.7.d Human Impacts

Human impacts associated with a segmented TFM treatment of the Hubbardton River alone would be shorter in duration and over a smaller area than that experienced during the 1992 and 1996 Poultney / Hubbardton River treatments. The reduction in impacts would be a result of the decrease in lampricide used to treat the Hubbardton River alone as well as the dilution of the lampricide by the Poultney River. Human impacts of a Poultney / Hubbardton River treatment are discussed in section 5.1.7.d.

5.2.7.e Cost

The fall 1996 simultaneous treatment (1.0 x MLC) of the Poultney and Hubbardton Rivers required approximately $5,300 [~164 pounds (74 kg) active ingredient] of TFM to be applied to the Hubbardton River (G. Neuderfer, Memorandum, June 23, 1997). If treated at dosage of 1.5 x MLC, approximately 248 pounds (112 kg) active ingredient of TFM would be required at a cost of $8,000.

A short-term intensive need for personnel is required during a TFM treatment. During the 1996 TFM treatment of the Poultney and Hubbardton Rivers approximately 820 staff hours were required to conduct a 12 hour treatment (as estimated from a 1996 NYSDEC Personnel Assignment Schedule). Additional costs include public notification, travel, and a number of miscellaneous expenses. Treating the Hubbardton River alone is likely to require fewer staff hours. Actual reduction in labor required to treat the Hubbardton River alone is uncertain. Costs would be incurred every 3 to 4 years, given the current rate of sea lamprey transformation to parasitic phase, as long as sea lamprey continued to spawn in the river system. Amortizing these estimates, the annual cost for a TFM treatment of the Hubbardton River is estimated at $7,125 to $9,517. This reflects a labor cost estimate of $25.00/hour. See Table 7 for a comparison of amortized costs for sea lamprey control of the Hubbardton River. Cost associated with treating the Hubbardton River concurrently with the Poultney River is discussed in section 5.1.7.e. See Appendix IV for a generalized comparison of control techniques considered for the Hubbardton River

5.2.8.a TFM : Bayer 73 (wettable powder)

Since the Hubbardton River has a flow of <100 cfs (2.80 cms), benefits associated with a segmented application of TFM : Bayer 73 combination cannot be realized for the Hubbardton River and such an application is unlikely (D. Nettles, Personal Communication, 2000). Refer to section 5.1.8.a for a discussion of a TFM : Bayer 73 treatment on the Poultney River.

5.2.9.a Low-head and Adjustable Crest Barriers

A low-head barrier dam could be constructed on the Hubbardton River approximately 0.5 miles (0.8 km) above the Poultney River confluence (Figure 3). Establishing a barrier in the lowermost stretches is necessary to prevent sea lamprey from taking advantage of the spawning habitat which is found sporadically upstream from that location (J. Gersmehl, Personal Communication, 2000). The location appears to have substrate which wouldn't be prone to erosion and the river slope is such that a large impoundment area would not be created.

Since there are no roads, access to the site would be difficult and a road would be required to facilitate the construction and servicing of a dam. To prevent sea lamprey from emigrating out of the Hubbardton and into the Poultney, a trap should be incorporated into the barrier design. Installation of removable slide gates would provide a way to lessen impacts to nontarget species during times when sea lamprey are not spawning.

Though not likely to be a concern, an adjustable crest barrier will also reduce the size of the impoundment created and allow all fish to pass once the lamprey spawning season has ended. During sea lamprey spawning, a trap may be desired to pass nontarget species. An adjustable crest barrier would require the installation of utility poles to carry electrical and telecommunication wires.

5.2.9.b Nontarget Impacts

Specific nontarget impacts associated with a low-head barrier or adjustable crest barrier on the Hubbardton River are unknown. Though no specific surveys have been conducted, walleye have not been observed utilizing the river for spawning and suckers and various Cyprinid species have only been observed in the lower stretches of the river (C. MacKenzie, Personal Communication, 2000). Since sea lamprey utilize the spawning habitat above the proposed barrier site it is likely that silver lamprey do as well, though no silver lamprey mortalities were observed above the lowermost 0.5 mile (0.8 km) during the 1992 TFM treatment (Fisheries Technical Committee 1999). Impacts associated with a low-head or adjustable crest barrier may be mitigated if an effective trap is incorporated into the barrier's design (section 5.2.11.a-e).

5.2.9.c Habitat Impacts

Since the proposed location is in a remote area, an access road for the construction and servicing of the dam may be required. Given the slope at the proposed site, a low-head barrier dam is not likely to require much habitat alteration nor will it create a large impoundment area. If an adjustable crest barrier is installed, power lines would need to be run. This may result in the establishment of a corridor for the installation of utility poles to carry electrical and telecommunication wires. Corridors and access roads may result in habitat fragmentation of The Nature Conservancy property.

5.2.9.d Human Impacts

Though not specifically studied, it is believed that walleye and smallmouth bass do not use the Hubbardton River for spawning (C. MacKenzie, Personal Communication, 2000, J. Gersmehl, Personal Communication, 2000). If sport fish utilize the Hubbardton River for spawning, the local fishery may be impacted with the creation of a low head or adjustable crest barrier. An effective trap may lessen human impacts associated with a low-head or adjustable crest barrier (section 5.2.11.a-e).

5.2.9.e Cost

Guilmette (Personal Communication, 2000) suggests the costs for constructing a low-head barrier on the Hubbardton are similar to those for Morpion Stream. Costs which are likely to differ include the amount of sheet steel needed, and the degree to which levees would have to be constructed. The construction costs are estimated at $116,000; $101,000 for the actual construction and $15,000 for contingencies. All cost estimates are rounded to the nearest $1,000 and are based on Guilmette (1997) estimates for a low-head barrier on Morpion Stream with a 4% annual inflation adjustment to reflect year 2000 costs.

An adjustable crest barrier would increase the cost of a low-head barrier by approximately $40,000 to $90,000. Since the Hubbardton River is so small, the costs are likely to be on the low end of this scale. In addition, power would have to be run approximately 0.7 miles (1.1 km) at an estimated cost of $10/ft ($32.81/m) (~$37,000 dollars). Amortizing these estimates, the annual cost for a low-head or adjustable crest barrier on the Hubbardton River would be $12,100 to $23,000. This includes annual trapping effort of $1,900 to $7,200 (section 5.1.11.e). See Table 9 for a comparison of amortized costs for sea lamprey control of the Hubbardton River. See Appendix IV for a generalized comparison of control techniques considered for the Hubbardton River

5.2.10.a Electrical Barrier

An electrical barrier could be constructed on the Hubbardton River in the same location suitable for other forms of barriers, approximately 0.5 miles (0.8 km) above the Poultney River confluence (Figure 3). Unfortunately, this area is remote, and electrical lines would need to be run approximately 0.7 miles (1.1 km).

Again, an access road would be needed to facilitate the construction and servicing of an electrical barrier. To prevent sea lamprey from emigrating out of the Hubbardton River and into the Poultney River a trap should be incorporated into the design.

5.2.10.b Nontarget Impacts

Nontarget impacts associated with an electrical barrier on the lower Hubbardton River are

Table 9. Amortization of Hubbardton River sea lamprey control options.

	Cost Estimates for Chemicals, Construction of Physical or Electrical Barriers and Traps			Hours Required to Accomplish Control				
Control Option	Cost Estimate Or Range	Benefit Duration	Cost / Year	Labor (Hours For Control)	Frequency	Costs / year *	Total Estimated Cost / Year **	Notes
TFM	$8,000	3 to 4 years	$2,000 to $2667	<820	3 to 4 years	$5,125 to $6,850	n/a	Included in a Poultney River treatment.
TFM : Bayer 73	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Inappropriate for use in low flow streams
Low Head Barrier	$116,000	40 to 50 years	$2,320 to $2,900	See Trapping Below	Annual	$1,900 to $7,200	$4,220 to $10,100	Trapping required.
Adjustable Crest Barrier	$193,000 to $243,000	40 to 50 years	$3,860 to $6,075	See Trapping Below	Annual	$1,900 to $7,200	$5,760 to $13,275	Trapping required. Does not include electrical and telecommunications costs.
Electrical Barrier	$237,000	>20 years	$11,850	See Trapping Below	Annual	$1,900 to $7,200	$13,850 to $19,850	Trapping required. Total estimated costs includes $100 (min) to $800 (max) annual electrical costs. Does not include backup generator costs ($4,000 to $11,000) or telecommunications costs.
Trapping	$18,000 (max)	20 years	$900	$1,00 to $6,300	Annual	$1,000 to $6,300	$1,900 to $7,200	

* Labor Costs for TFM and TFM : Bayer 73 are estimated at $25.00 / hour.

** Total Estimated Cost Range is Total Minimum to Total Maximum.

likely to be similar to those for a low-head or adjustable crest barrier (section 5.2.9.b).

5.2.10.c Habitat Impacts

The electrical barrier itself would have a negligible impact on the surrounding habitat except during the construction phase when some alterations to the surrounding area would occur. The access road for its construction and servicing and a corridor for the installation of utility poles to carry electrical and telecommunication wires may result in habitat fragmentation.

5.2.10.d Human Impacts

Since the lower Hubbardton River is an unpopulated area, human impacts of an electrical barrier would center around those using the river as a recreational resource, and would be similar to those identified for an electrical barrier on the Poultney River (section 5.1.10.d).

5.2.10.e Cost

The estimated cost for an electrical barrier on the Hubbardton River is $200,000 (J. Smith, Personal Communication, 2000). Utility poles and power lines would need to be run approximately 0.7 miles (1.1 km) at an estimated cost of $10/ft ($32.81/m) (~$37,000 dollars). The estimated mean monthly energy demand for a Smith Root Inc. barrier on the Hubbardton River is $100. At maximum load, the electrical costs associated with a Smith Root Inc. electrical barrier would be no more than $800 a month. Since the Hubbardton River is so small, the maximum load possible for the Hubbardton River is much less than the barrier's capacity thus a lower maximum demand will occur (J. Smith, Personal Communication, 2000). During months when the barrier is not active the power can be disconnected for a small fee (approximately $25) thus eliminating a monthly service fee. A back up power source can add $4,000 to $11,000 to the cost of an electrical barrier (http://www.nooutage.com/automati.htm#Automatic Standby Generators). Amortizing these estimates, the annual cost for an electrical barrier on the Hubbardton River would be $13,850 to $19,850. This includes annual trapping effort of $1,900 to $7,200 (section 5.2.11.e). See Table 9 for a comparison of amortized costs for sea lamprey control of the Hubbardton River. See Appendix IV for a generalized comparison of control techniques considered for the Hubbardton River

5.2.11.a Adult Trapping

Adult trapping using a fyke net, a PAT, or a permanent trap incorporated into a barrier could be employed on the Hubbardton River. As with the proposed site for a low-head, adjustable crest, or electrical barrier, the constriction located approximately 0.5 miles (0.8 km) above the Poultney River confluence is likely to be the best location for a PAT or fyke net. At this location the river is approximately 40 ft (12 m) wide and shallow. Since the river is so narrow, incorporating a permanent trap into a barrier on the Hubbardton River should be feasible.

5.2.11.b Nontarget Impacts

Specific nontarget trapping impacts are unclear but considering known uses of the river by various fish species, they would likely be minimal.

5.2.11.c Habitat Impacts

No unique impacts.

5.2.11.d Human Impacts

No unique impacts.

5.2.11.e Cost

Trapping costs for the Hubbardton River are likely to be similar to those for the Poultney River (section 5.1.11.e). Due to the small size of the Hubbardton River, the cost of incorporating a permanent trap into a low-head barrier is likely to be on the low end of the $4,500 to $18,000 range outlined in the Poultney River section. Amortizing these estimates, the annual cost for sea lamprey trapping would be $1,900 to $7,200. See Table 9 for a comparison of amortized costs for sea lamprey control of the Hubbardton River. See Appendix IV for a generalized comparison of control techniques considered for the Hubbardton River

5.3.0 Pike River Physical Description

The Pike River is located in Quebec, Canada and flows into Missisquoi Bay in northern Lake Champlain (Figure 1). The drainage area of the Pike River is 200 mi^2 (517 km^2) (Shanley and Denner, Unpublished Data, 1999). Below a natural sea lamprey barrier there are 5.3 miles (8.6 km) of wadeable waters (Dean and Zerrenner 2001). This portion of the Pike River has a mean width of 130 ft (40 m). The 2.8 miles (4.6 km) of non-wadeable waters below the Route 133 bridge have a mean width of 207 ft (63 m) (Dean and Zerrenner 2001). The average slope of the Pike River is 0.67 ft/mi (1.55 m/km) (Simoneau 1993).

The Pike River has a watershed primarily comprised of agricultural dairy farming with 76% of the watershed used for livestock grazing and farming (Environment Quebec 1993). Roads and agricultural fields border the Pike River and restrict the riparian habitat to a very narrow strip which is oftentimes only one tree deep and with very little understory growth. This lack of riparian habitat allows rapid nonpoint runoff of the agricultural lands during rain events.

5.3.1 Biological Resources of the Pike River and Morpion Stream

Forty-eight fish species have been documented in the Pike River below the dam at Notre-

Dame-de-Stanbridge (Gratton 1995[1]) (Table 10). Of species present, the redfin pickerel (*Esox americanus*) and cisco (*coregonus artedi*) are soon to be listed as Susceptible[2] by the province of Quebec (P. Aquin, Societe de la faune et des parcs Quebec, Personal Communication 2000; Beaulieu 1992). Cisco are also designated as Vulnerable[2] in Canada (Shank 1999). Sea lamprey, American brook lamprey and silver lamprey, have been documented in the Pike River.

Numerous fish species use the Pike River as spawning, feeding and nursery grounds (M. Léveillé, Ministére de l'Environment et de la Faune, Personal Communication, 1999) (Table 10). The area between Notre-Dame-de-Stanbridge and Saint Pierre de Véronne à Pike River has been designated as a fish sanctuary to preserve spawning activities, and fishing in the area is more limited than other sections of the Pike River (Figure 4) (M. Léveillé, Personal Communication, 1999).

The Pike River provides essential habitat for migratory birds while nearby, upland wetlands are used extensively during the nesting season (M. Léveillé, Personal Communication, 1999). Seventy-five species of birds have been associated with the Pike River (Gratton 1995) (Table 11). In the near future, the Cooper's hawk (*Acipiter cooperi*) and the least bittern (*Ixobrychus exilis*) will be designated Susceptible by the province of Quebec (P. Aquin, Personal Communication, 2000, Beaulieu 1992). Least bittern are also designated as Vulnerable in Canada (Shank 1999).

Six large mammal species utilize the resources of the Pike River (Gratton 1995) and none of these species are listed (Susceptible, Vulnerable, Threatened) in Canada or the province of Quebec (P. Aquin, Personal Communication, 2000, Beaulieu 1992, Shank 1999) (Table 12). No information is available for small, nongame species.

The Pike River has one of the most diverse herpetologic assemblages in the southern part of Quebec (M. Léveillé, Personal Communication, 1999). Ten amphibian and reptile species have been documented along the Pike River (Gratton 1995) (Table 13). The eastern spiny soft-shelled turtle (*Trionyx spinifera*) will soon be listed Susceptible while the map turtle (*Graptemys geographica*) is listed as Threatened[2] in the province of Quebec (P. Aquin, Personal Communication, 2000, Beaulieu 1992). The eastern spiny soft-shelled turtle is also considered Vulnerable in Canada (Shank 1999).

---

[1]We have noticed several inconsistencies in the Gratton (1995) report, specifically omissions of common mammals and the reporting of alewife, a nonnative species presently not found in Lake Champlain.

[2]Susceptible: Species with depressed populations.
Vulnerable: Species with precarious populations.
Threatened: Species endangered of becoming extinct.

Table 10. Fish species documented in the Pike River and / or Morpion Stream.

alewife+	emerald shiner []	redfin pickerel *
American eel	fallfish	rock bass []
American brook lamprey <>	fantail darter	sand shiner
banded killifish	freshwater drum []	sea lamprey []
black crappie	golden shiner []	shorthead redhorse []
blacknose dace <>	greater redhorse []	silver lamprey <>
bluegill <>	johnny darter	silver redhorse []
bluntnose minnow <>	lake whitefish	smallmouth bass []
brook trout	largemouth bass []	spotfin shiner
brown trout	longnose dace	spottail shiner []
brown bullhead []	mimic shiner []	stonecat
burbot	mudminnow <>	tesselated darter <>
carp []	muskellunge []	threespine stickleback
central mudminnow	northern pike []	walleye []
cisco * ~	pumpkinseed []	white sucker []
common shiner	quillback []	white perch
creek chub []	rainbow trout	yellow perch []
eastern silvery minnow	rainbow smelt	yellow bullhead <>

Sources: Gratton 1995; Fichier informatisé des releve's des relevés fauniqus en miliru aquatique et riparien, 1999.
* denotes soon to be listed as Susceptible in the province of Quebec.
~ denotes a Vulnerable species in Canada (Shank, 1999).
<> denotes Morpion Stream only.
[] denotes documented use of river for spawning habitat.
+ Species is highly improbable. No verification could be made for this species. Gratton (1995) is the only reported survey listing alewife in Lake Champlain.
Note: We have noticed several inconsistencies in the Gratton (1995) report, specifically omissions of common mammals and the reporting of the alewife, a nonnative species presently not found in Lake Champlain.

Table 11. Bird species associated with the Pike River and / or Morpion Stream.

osprey	common tern	common egret
least sandpiper	white-breasted nuthatch	brown creeper
common snipe	blue-winged teal	evening grosbeak
black-crowned night heron	purple finch	black tern
song sparrow	semipalmated plover	green-backed heron
chipping sparrow	eastern kingbird	purple martin
northern harrier	turkey vulture	bank swallow
American bittern	mourning dove	northern rough-winged swallow
mallard	lesser yellowlegs	barn swallow
wood duck	northern flicker	cliff swallow
northern shoveler	downy woodpecker	tree swallow
American black duck	rock dove	glossy ibis
northern pintail	eastern wood-pewee	cedar waxwing
red-winged blackbird	great crested flycatcher	belted king-fisher
American goldfinch	warbling vireo	chimney swift
spotted sandpiper	killdeer	American robin
solitary sandpiper	American coot	blacked-capped chickadee
ruby-throated hummingbird	common moorhen	house sparrow
American crow	common golden-eye	gray catbird
American kestrel	ring-billed gull	eastern pheobe
Cooper's hawk *	bobolink	least flycatcher
European starling	Wilson's warbler	willow flycatcher
yellow-rumped warbler	palm warbler	northern oriole
common yellow-throat	greater yellowlegs	least bittern * ~
yellow warbler	great blue heron	

Source: Gratton 1995.
* denotes soon to be listed as Susceptible in the province of Quebec.
~ denotes a Vulnerable species in Canada.
Note: We have noticed several inconsistencies in the Gratton (1995) report.

Table 12. Large mammal species documented in the vicinity of Pike River and / or Morpion Stream .

beaver
white-tailed deer
snowshoe hare
muskrat
raccoon
mink

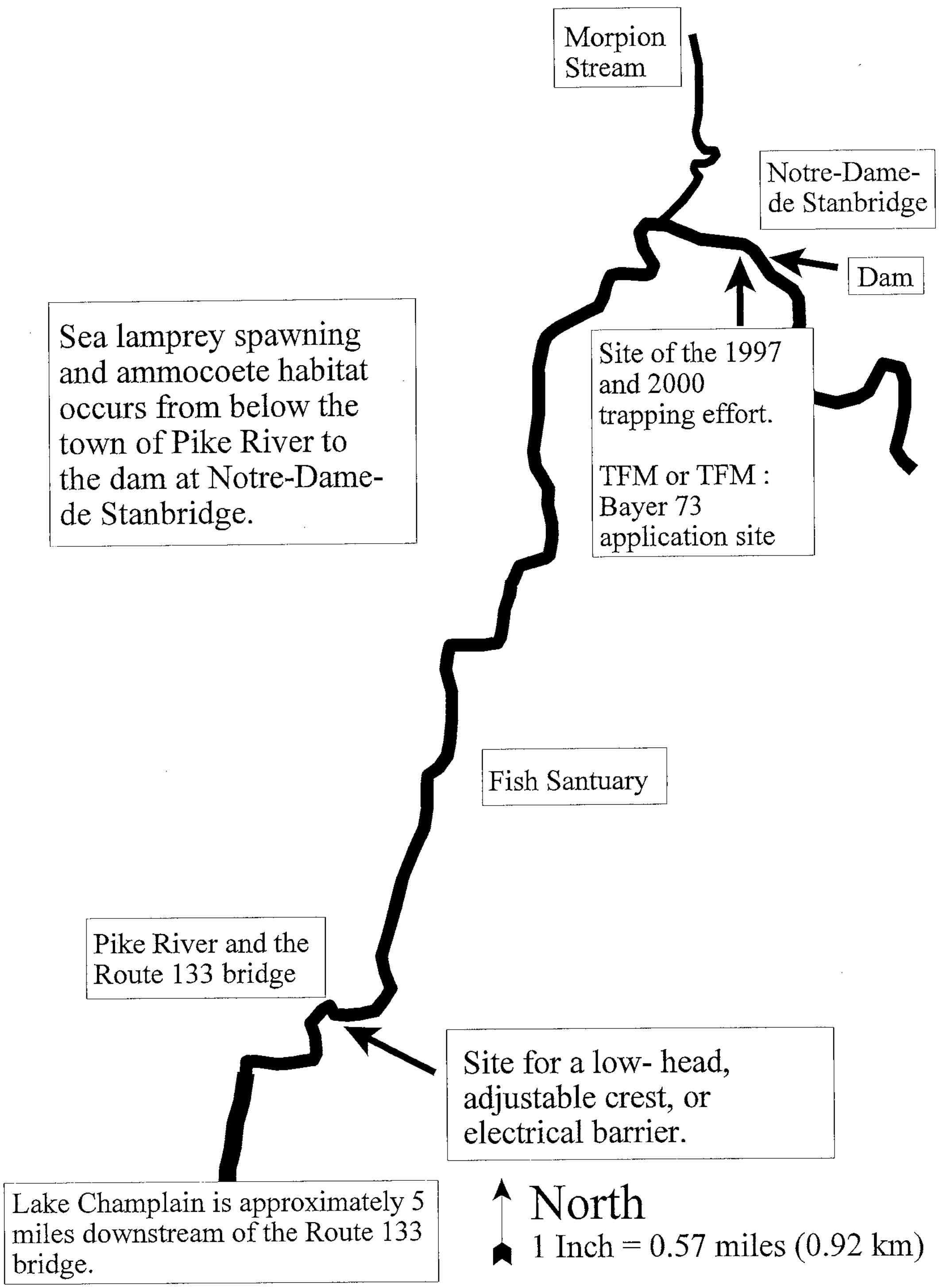
Source: Gratton 1995.
Note: We have noticed several inconsistencies in the Gratton (1995) report, specifically omissions of common mammals and the reporting of alewife, a nonnative species presently not found in Lake Champlain.

Table 13. Amphibians and reptiles documented in the vicinity of Pike River and / or Morpion Stream.

common snapping turtle	northern spring peeper
eastern American toad	gray tree frog
northern leopard frog	common map turtle *
green frog	eastern spiny soft-shelled turtle + ~
bullfrog	midland painted turtle

Source: Gratton 1995
* denotes soon to be listed as Susceptible in the province of Quebec.
+ denotes Threatened in the province of Quebec.
~ denotes Vulnerable in Canada (Shank 1999).
Note: We have noticed several inconsistencies in the Gratton (1995) report.

Figure 4. Pike River sea lamprey habitat and summary of control options.



Forty-six plants and three mosses have been documented along the Pike River (Gratton 1995) (Table 14). Of these, 15 plants will soon be listed as Susceptible in Quebec while no moss species are listed as Susceptible, Vulnerable or Threatened in Quebec or Canada.

Nineteen fish species have been documented in Morpion Stream as a result of two late summer / early fall surveys (Gratton 1995, Fichier informatisé des releve's des relevés fauniqus en miliru aquatique et riparien 1999). The August 1995 survey documented fish just upstream from Morpion Stream / Pike River confluence. The September 1999 survey documented fish at approximately 6.2 miles (10 km) above the confluence. None of the fish documented during these two surveys are listed at Susceptible, Vulnerable, or Threatened in Quebec or Canada (Table 10) (P. Aquin, Personal Communication, 2000, Shank 1999, Beaulieu 1992).

5.3.2 Pike River Water Quality

The Pike River is typical of rivers which drain highly fertilized agriculture lands and receive untreated urban discharges. Although the river is considered to have poor water quality (defined by low dissolved oxygen and pH fluctuations), improvements occurred from 1979 to 1991 (Simoneau 1993). Other surveys conducted in fall of 1989, spring of 1991, fall of 1994, fall of 1995 and summer 1994, 1995 and 1996 suggest that diurnal pH fluctuations may still occur along the Pike River (G. Neuderfer, Personal Communication, 1999, Anderson 1991, Anderson 1994, Anderson and Staats 1995). A summary of water quality surveys is provided in Table 15.

5.3.3 Pike River Flows

Monthly discharge records for 149 mi^2 (387 km^2) of the Pike River drainage area are available from 1979 through 1995. During this 16-year period mean annual flow was 218 cfs (6.10 cms) (Simoneau 1993). Highest mean monthly flow (591 cfs; 16.55 cms) occurred in April while lowest mean flow monthly flows occurred from July (62 cfs) through September (82 cfs) (1.74 to 2.30 cms) (A. Bouchard, Environment Canada, Personal Communication, 1999). A summary of mean monthly flow for the Pike River above the dam at Notre-Dame-de-Stanbridge is provided in Table 6.

5.3.4 Pike River Sea Lamprey Habitat

Sea lamprey have access to 8.2 miles (13.2 km) of the Pike River and upstream lamprey movement is blocked by a dam at Notre-Dame-de-Stanbridge[1], Quebec (Figure 4). The river is rated as a high producer of ammocoetes and is considered the largest producer of parasitic sea lamprey to the Inland Sea portion of Lake Champlain (Gersmehl 1994). Dean and Zerrenner

---

[1] Bouffard (Personal Communication, 2000) believes cracks in the dam at Notre-Dame-de-Stanbridge may provide a means for some sea lamprey to pass the dam.

Table 14. Plants and mosses documented in the vicinity of the Pike River and / or Morpion Stream.

Plants	
flagroot	highbush blueberry
frost flower *	speckled alder
beggar's ticks	false nettle
water shield	brome-grass *
flowering rush	swamp white oak *
buttonbush	dogwood
white oak *	silver maple
water willow	black ash
swamp maple	golden pert *
love grass *	*Lipocarpha micrantha* *
green ash	loosestrife *(L. hybrida)* *
black alder	water lily
water meal	sensitive fern
yellow loosestrife	interrupted fern
pond lily	*Platanthera flava* *
white elm	bur reed
flowering fern	bulrush *(S. pendulus)* *
clammy weed	sedge (*Scirpus sp.)*
pondweed	meadow sweet
smith's club rush *	mint (*Trichostema dichotomum)* *
bur-reed *	cat tail
meadow fern	wild rice
Mosses	
Ephemerum spinulosum	*Riccia fluitans*
Ricciocarpos natans	

Source: Gratton 1995
* denotes soon to be listed as Susceptible in the province of Quebec.
Note: We have noticed several inconsistencies in the Gratton (1995) report.

Table 15. Summary of Pike River water quality surveys.

Date	Location	Temperature (°C)	pH	Alkalinity ($CaCO_3$)	Flow (cfs)
5/6 - 6/6/91*	Barrier Dam	10 - 18	7.11 - 7.69	45 - 190	N/A
9/13/89	Barrier Dam	21 - 22	7.45 - 7.63	133 - 140	N/A
Aug. 1994	Barrier Dam	17 - 23	7.79 - 8.63	124 - 135	N/A
Aug. 1995	Barrier Dam	22 - 23	8.08 - 8.42	93 - 99	N/A
Aug. 1996	Barrier Dam	23 - 24	8.51 - 8.74	131 - 131	N/A
9/13/89	Point Couvert	20 - 22	7.65 - 8.67	130 - 137	N/A
Aug. 1994	Point Couvert	17 - 21	7.80 - 8.38	139 - 144	N/A
Aug. 1995	Point Couvert	19 - 23	7.87 - 8.43	101 - 102	N/A
Aug. 1996	Point Couvert	23 - 26	7.77 - 8.87	133 - 133	N/A
9/13/89	Pike River Town	20 - 22	7.80 - 9.03	29 - 32	N/A
Aug. 1994	Pike River Town	17 - 23	7.73 - 9.00	131 - 144	N/A
Aug. 1995	Pike River Town	18 - 23	7.85 - 8.97	91 - 92	N/A
Aug. 1996	Pike River Town	23 - 27	7.66 - 8.95	123 - 124	N/A

*Maximum 24 hour difference reported.
Refer to Table 6 for additional flow information.
Source: G. Neuderfer, Personal Communication, 1999
Anderson 1991, 1994
Anderson and Staats 1995
Anderson and Chipman 1996

(2001) estimated the 1999 ammocoete production of Pike River at 55,671 lamprey. Of the total area available for sea lamprey ammocoetes, 21.3% (~69,500 m^2) is "optimal" or "good but not optimal" habitat. While ammocoete habitat occurs throughout the entire wadeable portion of Pike River habitat, most spawning habitat was found directly below the dam at Notre-Dame-de-Stanbridge.

5.3.5 Pike River Treatment History

To date no efforts have been made to prevent sea lamprey from spawning or to eliminate ammocoete populations in the Pike River.

5.3.6 Pike River Estimate of Sea Lamprey Transformer Production

The 1999 estimate of transformer production for the wadeable waters of the Pike River was 2,264 individuals (Dean and Zerrenner 2001).

5.3.7.a TFM

A TFM treatment of the Pike River is possible despite historically large (>1 pH unit in 24 hours) diurnal shifts in pH documented between Notre-Dam-de-Stanbridge and Pike River Town (Table 15, Figure 4). Large fluctuations in pH or alkalinity can result in large shifts in toxicity of TFM if not carefully compensated through adjustments to the lampricide application rate. Neuderfer (Personal Communication, 1999) suggests that these pH swings are a result of extensive aquatic vegetation beds which grow throughout this stretch of river during the summer and early fall. These large fluctuations in pH were not observed during a May, 1991 water quality survey (Table 15). This survey of 10 diurnal sampling events from May 9 to June 6, documented 24 hour pH fluctuations to be no more than 0.59 units. Treating the Pike River in the early spring could be performed before the growth of aquatic vegetation and the subsequent diurnal pH fluctuations (G. Neuderfer, Personal Communication, 1999).

Applying TFM at the dam at Notre-Dam-de-Stanbridge would result in the treatment of all sea lamprey ammocoete habitat and would also allow rapid assimilation of TFM with the river. Since the Pike River / Morpion Stream confluence is approximately 325 ft (100 m) below the dam, a concurrent treatment of Morpion Stream or a boost would be required to maintain the desired MLC. A concurrent treatment of the entire Morpion Stream is possible though a treatment of both rivers would require considerably longer treatment time. Sea lamprey ammocoetes are found throughout Morpion Stream's 17.1 mile (27.5 km) length. In addition, Morpion Stream does not have high velocity and the time of travel would be considerable. The timing of the convergence of the Morpion Stream and Pike River TFM blocks would be relatively easy since the Pike River / Morpion Stream confluence is very near the dam.

Neuderfer (Personal Communication, 1999) has estimated the amount of TFM needed to treat the Pike River in May to be 4,080 pounds (1,851 kg) (active ingredient). This estimate is for a 1.5 x MLC (maximum typical concentration used in the Great Lakes) treatment with water pH of 7.9, alkalinity of 90 (expressed as $CaCO_3$), and flow of 210 cfs (5.88 cms). This does not include the estimated 13+ cfs (0.36 cms) flow of Morpion Stream. Neuderfer (Personal Communication, 1999) estimates a 1.5 x MLC TFM treatment of Morpion Stream would require 287 pounds (130 kg). The Morpion Stream estimate is based on fall water quality and flow information. No Morpion Stream flow data is available for the spring. Neuderfer (Personal Communication, 1999) suggests that one TFM boost would be required for the Pike River during a spring treatment. See section 5.4.7.a for an overview of a Morpion Stream TFM treatment.

Transformer aging analyses on the Pike River and Morpion Stream indicated that all animals transformed by age 6: 12.5% by age 4, 87.5% by age 5, and 100% by age 6 (Zerrenner 2001). This transformation rate suggests that lampricide treatments could occur on a four year cycle as long as sea lamprey populations persist.

5.3.7.b Nontarget Impacts

A TFM treatment on the Pike River would likely result in the mortality of stonecats and logperch and to a lesser degree, bluntnose minnow and white suckers. These species are sensitive to TFM and have been killed during previous Lake Champlain TFM treatments (Fisheries Technical Committee 1999). Early life stages of walleye (eggs, sac fry, and swim-up fry) are more resistant to TFM than are sea lamprey ammocoetes and are not likely to be impacted by a TFM treatment of the Pike River. The redfin pickerel (listed as Vulnerable in Quebec) belongs to the esocid family, which are generally sensitive to TFM (NYSDEC *et al.* 1990). To date, no toxicity tests have been conducted to elucidate redfin pickerel sensitivity to TFM (D. Johnson, Personal Communication, 2000).

Frog tadpoles which come in contact with a TFM block are likely to suffer considerable mortalities. Since water quality concerns suggest that a spring treatment is most appropriate for the Pike River, amphibian abundance may also be affected by a treatment. Spring peepers, bullfrog, Northern leapord frog, gray tree frog, and American toad are the only amphibians documented in the Pike River and Morpion Stream systems (Gratton 1995). The degree to which juvenile forms of these amphibians utilize the Pike River and Morpion Stream is unknown. Frogs and toads will utilize quiet, shallow portions of streams to breed. See section 4.4.1 for an overview of TFM impacts to amphibians. During the 1992 and 1996 TFM treatments of the Great Chazy River, considerable mortalities of tadpoles and salamanders (mostly suspected to be mudpuppies) were reported (Fisheries Technical Committee 1999). In other Lake Champlain river systems (i.e. Boquet, Saranac, and Little Ausable Rivers and Lewis Creek) few or no amphibians were reported killed. See section 5.4.7.b for a discussion of Morpion Stream nontarget impacts.

5.3.7.c Habitat Impacts

No unique impacts.

5.3.7.d Human Impacts

A TFM application on the Pike River could impact the Philipsburg municipal water intake. A Pike River dye study conducted on September 12, 1989 elucidated the potential for Pike River water to be drawn into the Philipsburg municipal water treatment facility. Additional dye studies may be warranted prior to a Pike River and / or Morpion Stream TFM treatment. Since TFM has a high affinity to carbon, the addition of powdered or granular carbon to the water treatment plant's sand filters would remove TFM from drinking water (G. Neuderfer, Personal Communication, 2000).

No information could be obtained concerning water use advisories, restrictions, or pesticide notifications in Quebec.

5.3.7.e Cost

The cost of TFM required to conduct a spring treatment on the Pike River is approximately $142,000. This cost is for 4,367 pounds (1,981 kg) of TFM (active ingredient) at a cost of $32.45/pound [based on 1998 cost of $30.00/pound ($66.08/kg) with a 4% annual adjustment for inflation]. The lampricide cost includes the treatment of the Pike River and Morpion Stream but does not include labor. Personnel requirements are likely to be similar to that of the 1996 Poultney / Hubbardton River treatment where an estimated 820 staff hours were required to facilitate a treatment. It is important to note that this cost incorporates concurrent treatment of the Morpion Stream and costs could be incurred every 4 to 5 years, given current rate of transformation, as long as sea lamprey continued to spawn in the river system. Amortizing these estimates, the annual cost for a TFM treatment of the Pike River and Morpion Stream would be $32,500 to $40,125. This reflects a labor cost estimate of $25.00/hour. See Table 16 for a comparison of amortized costs for sea lamprey control of the Pike River. See Appendix IV for a generalized comparison of control techniques considered for the Pike River.

5.3.8.a TFM : Bayer 73 (wettable powder)

As with TFM, a TFM : Bayer 73 treatment of the Pike River may be desirable during the spring to avoid substantial diurnal pH fluctuations. Since mean monthly flow of the Pike River is 210 cfs (5.88 cms) (Table 6) it is above the 100 cfs (2.80 cms) minimum flow required to realize an economic advantage provided by this lampricide application (section 4.5). Analysis of the river's suspended solids concentrations should be conducted prior to a TFM : Bayer 73 treatment to determine the rate of Bayer 73 attenuation. Morpion Stream would likely require concurrent lampricide application during a Pike River treatment, but that application would use TFM alone due to the problematic logistics of a TFM : Bayer 73 treatment at low flows. Frequency of application would be identical to TFM alone.

Addition of approximately 45 pounds (20.4 kg) (active ingredient) of Bayer 73 would reduce the TFM requirements to approximately 2,200 pounds (998 kg)(active ingredient). Refer

Table 16. Amortization of Pike River sea lamprey control options.

	Cost Estimates for Chemicals, Construction of Physical or Electrical Barriers and Traps			Hours Required to Accomplish Control				
Control Option	Cost Estimate Or Range	Benefit Duration	Cost / Year	Labor (Hours For Control)	Frequency	Costs / year *	Total Estimated Cost / Year **	Notes
TFM	$142,000	4 to 5 years	$28,400 to $35,500	820 hours	4 to 5 years	$4,100 to $5,125	$32,500 to $40,125	Includes treatment of the Morpion Stream.
TFM : Bayer 73	$73,100	4 to 5 years	$24,040 to $29,800	>820 hours	4 to 5 years	$4,100 to $5,125	$28,140 to $34,925	Includes treatment of the Morpion Stream.
Low Head Barrier	$1,112,000	40 to 50 years	$22,240 to $27,800	See Trapping Below	Annual	$1,900 to $7,200	$24,140 to $35,000	Trapping required.
Adjustable Crest Barrier	$1,152,000 to $1,202,000	40 to 50 years	$23,040 to $30,050	See Trapping Below	Annual	$1,900 to $7,200	$24,940 to $38,040	Trapping required. Does not include electrical and telecommunications costs.
Electrical Barrier	$500,000	>20 years	$25,000	See Trapping Below	Annual	$1,900 to $7,200	$27,000 to $33,000	Trapping required. Total estimated costs includes $100 (min) to $800 (max) annual electrical costs. Does not include backup generator costs ($4,000 to $11,000) or telecommunications costs.
Trapping	$18,000 (max)	20 years	$900	$1,000 to $6,300	Annual	$1,000 to $6,300	$1,900 to $7,200	

* Labor Costs for TFM and TFM : Bayer 73 are estimated at $25.00 / hour.
** Total Estimated Cost Range is Total Minimum to Total Maximum.

to section 5.3.7.a for a review of TFM application of the Pike River and section 4.5 for a review of TFM : Bayer 73 applications.

5.3.8.b Nontarget Impacts

Nontarget species impacts would be similar to those of a TFM treatment (section 5.3.7.b).

5.3.8.c Habitat Impacts

No unique impacts.

5.3.8.d Human Impacts

A TFM : Bayer 73 treatment will have the same human impacts occurring over a shorter duration and over a smaller area, by comparison to a TFM application (section 5.3.7.d). Like TFM, Bayer 73 has a high affinity to carbon, and the addition of a carbon filter to the Philipsburg water treatment plant should remove Bayer 73 from drinking water (D. Johnson, Personal Communication, 2000).

5.3.8.e Cost

Considerable costs savings can be realized with a TFM : Bayer 73 treatment by reducing the overall amount of chemical necessary for treatments. Using a treatment scenario identical to that for TFM presented in section 5.3.7.e (1.5 x MLC, the Great Lakes maximum typical treatment concentration), pH of 7.9, alkalinity of 90 ($CaCO_3$), a lampricide cost savings of approximately $71,000 may be realized. The cost of 45 pounds (20.4 kg) (active ingredient) of Bayer 73 is approximately $1,600 while the cost of 2,200 pounds (998 kg) (active ingredient) of TFM is approximately $71,500. The lampricide cost savings would be somewhat offset by increases in labor required to conduct a TFM : Bayer 73 treatment.

The lampricide cost includes the treatment of the Pike River and Morpion Stream but does not include personnel costs. Labor requirements are likely to be similar or greater than that of the 1996 Poultney / Hubbardton River treatment where an estimated 820 staff hours were required to facilitate a treatment. This cost would also cover the expenses of a concurrent treatment with the Morpion Stream. Costs would be incurred every 4 to 5 years, given current rate of transformation, as long as sea lamprey continued to spawn in the river system. Amortizing these estimates, the annual cost for a TFM : Bayer 73 treatment of the Pike River and Morpion Stream would be $28,140 to $34,925. This reflects a staffing cost estimate of $25.00/hour. See Table 16 for a comparison of amortized costs for sea lamprey control of the Pike River. See Appendix IV for a generalized comparison of control techniques considered for the Pike River

5.3.9.a Low-head or Adjustable Crest Barriers

A low-head or adjustable crest barrier may be feasible directly below the Route 133 bridge (Figure 4). At this location the river has an approximate drop of 1 ft over 250 ft (0.6 m over 150 m), and thus may prevent the creation of a large impoundment. One concern with this location is the possibility that the decrease in flow above the barrier may result in the formation of ice jams upstream from the Route 133 bridge (J. Guilmette, Personal Communication, 2000). Hydrologic studies must be completed to address this concern.

The placement of a barrier at the Route 133 bridge would restrict sea lamprey to all but 0.5 miles (0.8 km) of wadeable river. Though not extensive, sea lamprey will still have a small amount of spawning habitat available directly below the Route 133 Bridge (Dean and Zerrenner, 2001). Though small, this spawning habitat may allow for the production of a substantial number of ammocoetes. However, a low-head or adjustable crest barrier in the vicinity of the Route 133 bridge would eliminate any need for control on Morpion Stream.

The installation of an adjustable crest barrier at the Route 133 bridge would reduce the volume of impounded water and allow for fish passage when sea lamprey are not spawning. An adjustable crest barrier may also reduce the possibility of ice jams forming since the barrier would be down during the ice-out season. Power and telephone lines cross the bridge and would be readily accessible. A low-head barrier with removable slide gates could be installed and would allow fish to pass unimpeded once the sea lamprey spawning season has ended.

5.3.9.b Nontarget Impacts

Passing nontarget species over the low-head or adjustable crest barrier will be essential to mitigate impacts to migratory fish species. Walleye and smallmouth bass are species of particular concern to local anglers and a physical barrier will impact the walleye's ability to access and spawn above the barrier without a provision for fish passage. Other lake species which utilize the Pike River for spawning and are likely to be impacted by a barrier include greater, silver, and shorthead redhorse, and quillback.

The region directly above the Route 133 Bridge is designated a fish spawning sanctuary and has fishing restrictions imposed. See sections 5.3.11.a-e for a discussion of adult lamprey trapping.

5.3.9.c Habitat Impacts

No unique impacts.

5.3.9.d Human Impacts

A low-head barrier at the Route 133 bridge would be visible from the road. Since there is a fair amount of slope in this region of river, only a small water impoundment is likely. Without a hydrologic survey the impacts to upstream land owners is not known. A physical barrier at the Route 133 bridge will prevent migrating sport fish from accessing the fish sanctuary above the barrier. Failure to effectively move sport fish above the barrier may impact the fisheries. Refer to sections 5.3.11.a-e for a discussion of Pike River trapping.

5.3.9.e Cost

A preliminary cost estimate for a low-head barrier dam on the Pike River is $1,112,000 with the following breakdown; $29,000 for preliminary studies and permit procedures includes, but is not limited to, the differential level survey, topographic survey, soil investigation and a hydrologic / hydraulic study; $66,000 for land and easement acquisition; $17,000 for final design, contract drawings, specifications, cost estimates and construction service; $870,000 for the actual construction; and $130,000 for contingencies (J. Guilmette, Personal Communication, 2000).

Including an adjustable crest design into the barrier will add approximately $40,000 to $90,000 to the cost of the barrier (T. McAuley, Personal Communication, 2000). Since the Pike River is so wide, the cost is likely to be on the high end of this range. Amortizing these estimates, the annual cost for a low-head or adjustable crest barrier on the Pike River would be $24,140 to $38,050. This includes annual trapping effort of $1,900 to $7,200 (section 5.1.11.e). See Table 16 for a comparison of amortized costs for sea lamprey control of the Pike River. See Appendix IV for a generalized comparison of control techniques considered for the Pike River

5.3.10.a Electrical Barrier

As with the low-head or adjustable crest barrier, the Route 133 Bridge appears to be the most appropriate location for an electrical barrier on the Pike River (Figure 4). Approximately 0.5 miles (0.8 km) below this site the river becomes wide and unwadeable, and it would be difficult to incorporate a trap into the barrier.

Abutments of the Route 133 bridge divide the Pike River into 4 separate flows. During low flow the river flows through only two of these channels while all four channels are utilized during high flow events. The channels result in areas of increased flow which could aid in the trapping of sea lamprey and nontarget species.

5.3.10.b Nontarget Impacts

Nontarget impacts would be similar to that of a low-head or adjustable crest barrier (section 5.3.9.b).

5.3.10.c Habitat Impacts

Since the Pike River is approximately 180 ft (55 m) wide at the Route 133 bridge, it may be economically advantageous to channelize flow to reduce the width of barrier required (J. Smith, Personal Communication, 2000). The increased velocity in this restriction would result in a change in downstream substrate. Also, some habitat modifications may have to be made to create flow attractants for the incorporation of a sea lamprey and nontarget species trap. The electrical barrier itself is not expected to alter the surrounding habitat.

5.3.10.d Human Impacts

An electrical barrier at the Route 133 bridge will prevent migrating sport fish from accessing the fish sanctuary above the barrier. Failure to effectively move sport fish above the barrier may impact the fisheries. Refer to sections 5.3.11.a-e for a discussion of Pike River trapping.

5.3.10.e Cost

Jeff Smith (Personal Communication, 2000) has given a preliminary cost estimate of $500,000 for the construction of an electrical barrier under the Route 133 Bridge. Costs would be reduced if water could be restricted to only 2 of the possible 4 channels under the bridge. Actual cost estimate could be obtained through a site inspection visit by representatives of Smith Root Inc. (J. Smith, Personal Communication, 2000). A back up power source can add $4,000 to $11,000 to the cost of an electrical barrier (http://www.nooutage.com/automati.htm#Automatic Standby Generators). Amortizing this estimate, the annual cost for an electrical barrier on the Pike River would be $27,200 to $33,000. This includes annual trapping effort of $1,900 to $7,200 (section 5.3.11.e). See Table 16 for a comparison of amortized costs for sea lamprey control of the Pike River. See Appendix IV for a generalized comparison of control techniques considered for the Pike River

5.3.11.a Adult Trapping

Much of the Pike River is wide and has relatively even flow thus adult trapping as the sole method for sea lamprey control is not feasible. The U.S. Fish and Wildlife Service installed a PAT at the Old Mill Works dam and two fyke nets at the Route 133 bridge (Figure 4) as an assessment tool during the 2000 spawning run. The results of this trapping effort suggest that while the trapping was effective (39 individuals caught at the Old Mill Works dam and 18 individuals at the Route 133 bridge) it does not collect enough sea lamprey to affect ammocoete populations (W. Bouffard, Personal Communication, 2000). One problem with trapping spawning run sea lamprey as a control technique at the Old Mill Works dam would be the fact that this site is upstream of all available spawning habitat. Gersmehl (Personal Communication, 2000) suggests that only early run sea lamprey migrate until encountering a barrier and later run lamprey will initiate spawning at the first available habitat. Installation of a trap at the Old Mill

Works Dam may be successful in removing early run lamprey from the Pike River, but will not be effective in removing any late run spawners.

Traps, however, should be incorporated into any barrier design for the Pike River. These traps could be used to remove sea lamprey while also transferring nontarget species above the barrier. Since the only feasible site for a barrier is at the Route 133 bridge, the trap would need to be very efficient in collecting spawning run fish which utilize the fish sanctuary located upstream of the Route 133 bridge to Notre-Dam-de-Stanbridge.

5.3.11.b Nontarget Impacts

No unique impacts.

5.3.11.c Habitat Impacts

No unique impacts.

5.3.11.d Human Impacts

No unique impacts.

5.3.11.e Cost

The 1997 trapping effort of two side-by-side traps at the Old Mill Works Dam in Notre-Dame-de-Stanbridge cost approximately $5,600 (J. Gersmehl, Interoffice Memo, 1997). Adjusted for inflation (4% annual adjustment), the annual trapping cost for a similar effort would be $6,300 per year. This included the cost of two technicians, travel and the purchase of two traps. Traps were inspected two to three times a week for the entire sea lamprey spawning season (J. Gersmehl, Personal Communication, 2000). This trapping effort was for the collection and removal of sea lamprey only.

Trapping nontarget species at the Route 133 bridge in an attempt to facilitate a substantial spawning run will require a considerable investment in time. Costs associated with an intensive trapping effort will likely be much higher than the 1997 cost estimates. As with the Poultney and Hubbardton Rivers, contracting of trap operation with a local person, group or working cooperative agreement with Environment Canada could reduce costs.

Employment of a trap at the Old Mill Works Dam in Notre-Dame-de-Stanbridge is likely to have similar costs. Since a trap at this location would be placed against a barrier, the primary purpose of the trap is to remove sea lamprey and not to transfer nontarget species above the barrier. A trap incorporated into an electrical or low-head barrier at the Route 133 bridge would require a greater commitment in labor. Amortizing the estimate, the annual cost for sea lamprey trapping would be $1,900 to $7,200. See Table 16 for a comparison of amortized costs for sea lamprey control of the Pike River. See Appendix IV for a generalized comparison of control techniques considered for the Pike River

5.4.0 Morpion Stream Physical Description

Morpion Stream enters the Pike River just downstream of the dam at Notre-Dame-de-Stanbridge, Quebec, Canada (Figure 5). The stream has a mean width of 10 ft (3 m) and is 17.1 miles (27.5 km) in length (Dean and Zerrenner 2001).

For nearly all of its length, the Morpion Stream is channelized and receives nonpoint runoff from agriculture fields through numerous drainage ditches. An undetermined amount of groundwater seepage occurs throughout much of the Morpion Stream (G. Neuderfer, Personal Communication, 2000).

5.4.1 Biological Resources of Morpion Stream

Since very few Morpion Stream-specific biological inventories have been conducted, a more thorough understanding of the natural biota is obtained by using the Pike River biological resources as a surrogate. Refer to section 5.3.1 for a discussion of the biological resources of the Pike River and Morpion Stream.

5.4.2 Morpion Stream Water Quality

No recent and very little historic water quality information exists for Morpion Stream. Periodic surveys conducted primarily in the fall and spring from 1991 through 1996 elucidated fluctuating pH values (G. Neuderfer, Personal Communication, 1999, Anderson 1991, Anderson 1994, Anderson and Staats 1995, Anderson and Chipman 1996). Surveys of alkalinity showed this parameter to be relatively stable. Refer to Table 17 for a summary of Morpion Stream water quality survey results.

5.4.3 Morpion Stream Flows

No long term flow data are available for the Morpion Stream, and all data available are a result of a fall 1996 survey. During this two month period the flow ranged from 2.15 to 13.3 cfs (0.06 to 0.37 cms) (N. Staats, Unpublished Data, 1996). As a result of suspected groundwater seepage, tributaries, and drainage ditches, Morpion Stream flow increases from approximately 5 cfs to more than 13 cfs (0.14 to 0.36 cms) in the lowermost 5 miles (8 km) of stream (N. Staats, Unpublished Data).

5.4.4 Morpion Stream Sea Lamprey Habitat

There are no barriers preventing sea lamprey migration in Morpion Stream. The majority of sea lamprey ammocoetes in the Pike River are believed to be a result of successful

Table 17. Summary of Morpion Stream water quality surveys.

Date	Location	Temperature (°C)	pH	Alkalinity ($CaCO_3$)	Flow (cfs)
9/13/89	I 250 Bridge	15 - 17	7.85 - 8.10	102 - 105	N/A
9/13/89	No Specific Location Given	17 - 20	7.89 - 8.09	90 - 100	N/A
5/9 - 6/6/91*	No Specific Location Given	7 - 15	7.46 - 9.15	112 - 121	N/A
Aug. 1994	1st Bridge	13 - 20	7.71 - 8.25	143 - 144	N/A
Aug. 1995	1st Bridge	18 - 22	7.80 - 8.60	142 - 152	N/A
Aug. 1996	1st Bridge	22 - 27	7.87 - 8.43	155 - 166	N/A

* Maximum 24 hour difference reported.

Source: G. Neuderfer, Personal Communication, 1999
Anderson 1991, 1994
Anderson and Staats 1995
Anderson and Chipman 1996

spawning in Morpion Stream (Gersmehl 1994). Dean and Zerrenner (2001) found an abundant ammocoete population and determined that approximately one third of Morpion Stream is suitable ammocoete habitat and it provides a greater amount of optimal spawning habitat than found in the Pike River. Tributaries to Morpion Stream have unquantified populations of sea lamprey ammocoetes (Dean and Zerrenner 2001).

5.4.5 Morpion Stream Treatment History

To date, no efforts have been made to prevent sea lamprey spawning or to eliminate ammocoete populations in Morpion Stream.

5.4.6 Morpion Stream Estimate of Sea Lamprey Transformer Production

The 1999 estimate of transformer production for the wadeable waters of Morpion Stream was 1,863 individuals (Dean and Zerrenner 2001).

5.4.7.a TFM

Treatment of all available ammocoete habitat in Morpion Stream would require a 17.1 mile (27.5 km) TFM treatment. Ammocoetes are also found in tributaries to Morpion Stream but the size of the population is unknown (Dean and Zerrenner 2001). Since Morpion Stream has continually increasing flow as it progresses downstream, boost(s) would likely be required to maintain the desired MLC for the entire stream. Bars of TFM may be used in small tributaries of Morpion Steam as a way to maintain the desired MLC (section 4.4).

While Morpion Stream can be treated concurrently with the Pike River, it can also be treated separately. Treatment of Morpion Stream alone would require approximately 287 pounds (130 kg) (active ingredient) of TFM and a considerable staffing effort. Since Morpion Stream has had historic pH fluctuations, present water quality must be assessed prior to treatment. Dean and Zerrenner (2001) have estimated sea lamprey ammocoetes in the Pike River and Morpion Stream transform at 4 - 6 years of age.

5.4.7.b Nontarget Impacts

Silver and American brook lamprey have been documented in Morpion Stream and may suffer considerable mortalities as a result of TFM treatment. No river specific information is available on the ammocoete life stages of these two species. As a result, the overall impact a TFM treatment impacts are uncertain. Additional impacts are described in the Pike River TFM nontarget impacts section (5.3.7.b).

5.4.7.c Habitat Impacts

No unique impacts.

5.4.7.d Human Impacts

A TFM treatment on Morpion Stream would have similar human impacts as a Pike River treatment (section 5.3.7.d). Assuming, however, that the Morpion Stream is the only stream chemically treated in the Pike River watershed, the amount of chemical needed would be reduced when compared to a simultaneous treatment of the Pike River and Morpion Stream. This scenario would result in a smaller chemical plume in Lake Champlain, be subject to quicker dilution, and have a decreased probability of reaching the Philipsburg municipal water intake.

5.4.7.e Cost

The cost of 287 pounds (130 kg) (active ingredient) of TFM is approximately $9,300. No cost estimates have been made to ascertain labor requirements though it is likely to be somewhat lower than the 820 hour Poultney / Hubbardton treatment estimate (section 5.1.7.e). Costs would be incurred every 4 to 5 years, given the current rate of sea lamprey transformation, as long as sea lamprey continue to spawn in the stream. Amortizing these estimates, the annual cost for a TFM treatment of Morpion Stream would be between $5,960 and $7,450. This reflects a staffing cost estimate of $25.00/hour. See Table 18 for a comparison of amortized costs for sea lamprey control of Morpion Stream. Costs associated with treating Morpion Stream concurrently with the Pike River is discussed in section 5.3.7.e. See Appendix IV for a generalized comparison of control techniques considered for Morpion Stream.

5.4.8.a TFM : Bayer 73 (wettable powder)

Since Morpion Stream has a flow of under 100 cfs (2.80 cms), benefits associated with a TFM : Bayer 73 application cannot be realized. Due to the relatively small flows of Morpion Stream only TFM is likely to be applied there, either concurrently with a Pike River treatment of TFM or TFM : Bayer 73 mix (D. Nettles, Personal Communication, 2000). See sections 5.3.8.a-e for a review of a Pike River / Morpion Stream TFM : Bayer 73 treatment.

5.4.9.a Low-head and Adjustable Crest Barriers

A preliminary survey of Morpion Stream has identified an area that may be appropriate for the installation of a low-head barrier dam (Guilmette 1997). The location, approximately 490 ft (150 m) upstream of the first bridge crossing, appears to be far enough upstream to avoid any effects associated with high flows on the Pike River (Guilmette 1997). This location is also appropriate for an adjustable crest barrier.

A major concern with placing a low-head barrier dam on Morpion Stream is flooding. Guilmette (1997) suggested that the low stream grade may cause flooding as far upstream as the next bridge (approximately 3 miles; 4.8 km). Topographic surveys and hydrological analysis will be required to determine the extent of impacts. To mitigate concerns of flooding in the area, an adjustable crest barrier might be employed. Electricity and telecommunications are readily

Table 18. Amortization of Morpion Stream sea lamprey control options.

	Cost estimates for chemicals, construction of physical or electrical barriers and traps			Hours required to accomplish control				
Control Option	Cost Estimate Or Range	Benefit Duration	Cost / Year	Labor (Hours For Control)	Frequency	Costs / year *	Total Estimated Cost / Year **	Notes
TFM	$9,300	4 to 5 years	$1,860 to $2,325	<820	4 to 5 years	$4,100 to $5,125	$5,960 to $7,450	
TFM : Bayer 73	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Inappropriate for use in low flow streams
Low Head Barrier	$195,000	40 to 50 years	$3,900 to $4,875	See Trapping Below	Annual	$1,900 to $7,200	$5,800 to $12,075	Trapping required.
Adjustable Crest Barrier	$235,000 to $285,000	40 to 50 years	$4,700 to $7,125	See Trapping Below	Annual	$1,900 to $7,200	$6,600 to $14,325	Trapping required. Does not include electrical and telecommunications costs.
Electrical Barrier	$200,000	>20 years	$10,000	See Trapping Below	Annual	$1,900 to $7,200	$12,000 to $18,000	Trapping required. Total estimated costs includes $100 (min) to $800 (max) annual electrical costs. Does not include backup generator costs ($4,000 to $11,000) or telecommunications costs.
Trapping	$18,000 (max)	20 years	$900	$1,000 to $6,300	Annual	$1,000 to $6,300	$1,900 to $7,200	

* Labor Costs for TFM and TFM : Bayer 73 are estimated at $25.00 / hour.

** Total Estimated Cost Range is Total Minimum to Total Maximum.

available.

If a barrier is placed on Morpion Stream upstream from the first bridge crossing, approximately 0.12 miles (0.2 km) would remain available for use by ammocoetes in "acceptable but not preferred" sea lamprey spawning habitat. A low head or adjustable crest barrier will require an effective trap to reduce spawning sea lamprey redirection to Pike River spawning habitat.

5.4.9.b Nontarget Impacts

No unique impacts.

5.4.9.c Habitat Impacts

The low slope of Morpion Stream will result in an increase in water depth and the potential for a substantial impoundment upstream of the barrier. Slight decreases in water flow may increase the sedimentation and may result in a decrease in water and sediment quality.

Unless flooding occurs, a low-head barrier dam is not likely to cause profound changes to the surrounding landscape. During construction, habitat is likely to be altered or damaged but changes are likely to be small and mitigated easily.

5.4.9.d Human Impacts

In addition to impacts discussed in sections 4.1 and 4.1.1, upstream flooding may severely impact riparian areas.

5.4.9.e Cost

A preliminary cost estimate for a low-head barrier dam on Morpion Stream is $195,000 with the following breakdown; $17,000 for preliminary studies and permit procedures includes, but is not limited to, the differential level survey, topographic survey, soil investigation and a hydrologic / hydraulic study; $45,000 for land and easement acquisition; $17,000 for final design, contract drawings, specifications, cost estimates and construction service; $101,000 for the actual construction; and $15,000 for contingencies (Guilmette 1997). All cost estimates are rounded to the nearest $1,000 and are based on Guilmette (1997) estimates with a 4% annual inflation adjustment to reflect year 2000 costs.

Including an adjustable crest design into the barrier will add approximately $40,000 to $90,000 to the cost of the barrier (T. McAuley, Personal Communication, 2000). Since Morpion Stream is so small, the cost is likely to be on the low end of this range. Amortizing these estimates, the annual cost for a low-head or adjustable crest barrier on Morpion Stream would be $5,800 to $14,325. This includes annual trapping effort of $1,900 to $7,200 (section 5.4.11.e).

See Table 18 for a comparison of amortized costs for sea lamprey control of the Morpion Stream. See Appendix IV for a generalized comparison of control techniques considered for Morpion Stream.

5.4.10.a Electrical Barrier

An electrical barrier might be placed the under first bridge crossing Morpion Stream in the village of Notre-Dame-de-Stanbridge (Figure 5). The installation of an electrical barrier at this location would eliminate nearly all spawning habitat available to the sea lamprey. Lands adjacent to the bridge are a combination of agricultural and residential housing. The municipal offices for the town of Notre-Dame-de-Stanbridge are adjacent to the bridge and may provide a location for the construction of an operations outbuilding. Electrical power and telephone lines are readily available and the stream is only 49 ft (15 m) wide at this location. An electrical barrier will require an effective trap to prevent sea lamprey from utilizing Pike River spawning habitat.

5.4.10.b Nontarget Impacts:

When activated, an electrical barrier will prevent the passage of all fish resulting in an isolation of approximately 17.1 miles (27.5 km) of stream. No information is available as to specific fish species which utilize Morpion stream for spawning.

5.4.10.c Habitat Impacts

No unique impacts.

5.4.10.d Human Impacts

The surrounding area is used for picnicking and casual outdoor activities. However, since Morpion Stream drains heavily fertilized agriculture fields, water recreation is unlikely and preventing people from entering under the bridge would have little impact on human activity.

5.4.10.e Cost

Smith Root, Inc. (1999) has estimated the cost of the equipment required for an electrical barrier on Morpion Stream to be approximately $50,000 to $60,000. The actual construction costs associated with installing an electrical barrier can vary widely depending on the amount of construction that can be done in-house. Construction costs for the electrical barrier are estimated at approximately $150,000 (D. Smith, Personal Communication, 1999). Electrical costs are expected to be approximately $100 / sea lamprey spawning season. Additional costs will be realized if trapping is incorporated into the electrical barrier. A back up power source can add $4,000 to $11,000 to the cost of an electrical barrier (http://www.nooutage.com/automati.htm #Automatic Standby Generators). Amortizing these estimates, the annual cost for an electrical barrier on the Morpion Stream would be $12,000 to $18,000. This includes annual trapping effort of $1,900 to $7,200 (section 5.4.11.e). See Table 18 for a comparison of amortized costs for sea lamprey control of Morpion Stream. See Appendix IV for a generalized comparison of control techniques considered for Morpion Stream.

5.4.11.a Adult Trapping

Since Morpion stream is shallow and narrow [9.8 ft (3 m) mean width], it may be possible to effectively install a PAT or fyke net to capture spawning run sea lamprey. The proposed location for a trap is directly above the first bridge crossing in Notre-Dame-de-Stanbridge (Figure 5). This is the same area where Guilmette (1997) proposed a low-head barrier.

Installing a permanent trap into an electrical, low-head, or adjustable crest barrier is also possible on Morpion Stream. The incorporation of such a trap would help to mitigate some nontarget impacts associated with these barriers. Determination of spawning habitat use by nontarget species should be done before determining trap type and labor required to tend the trap.

5.4.11.b Nontarget Impacts

No unique impacts.

5.4.11.c Habitat Impacts

No unique impacts.

5.4.11.d Human Impacts

No unique impacts.

5.4.11.e Cost:

Costs associated with trapping Morpion Stream will be similar to those for the Pike River. The 1997 trapping effort on the Pike River cost approximately $5,600 (J. Gersmehl, Personal Memo, 1997). Adjusted for inflation (4% annual adjustment), the annual trapping cost for a similar effort would be $6,300 per year. Assessment of fish species which utilize Morpion Stream for spawning prior to the design of a trap or the commitment of an intensive trapping effort will allow for a more accurate cost estimate for trapping Morpion Stream.

Costs associated with an intensive trapping effort will likely be much higher than the 1997 cost estimates associated with PAT trapping when inspections were made 2 to 3 times a week. As with the Poultney and Hubbardton Rivers, contracting with a local person, group or a cooperative relationship with Environment Canada could reduce costs.

Amortizing these estimates, the annual cost for sea lamprey trapping would be $1,900 to $7,200. See Table 18 for a comparison of amortized costs for sea lamprey control of Morpion Stream. See Appendix IV for a generalized comparison of control techniques considered for Morpion Stream.

Acknowledgments

This Lake Champlain Basin Program provided the financial support for this project. We would like to thank Dave Nettles, Dave Tilton, and Craig Martin from the Lake Champlain Fish and Wildlife Resources Complex, Larry Nashett from New York Department of Environmental Conservation, and Barry Gruessner from the Lake Champlain Basin Program for providing technical review of the report. We are also indebted to Tim Mihuc, Lake Champlain Research Institute and Plattsburgh State University for providing office space. Finally, we would like to thank four anonymous reviewers for their thoughtful input.

This report was funded and prepared under the authority of the Lake Champlain Basin Special Designation Act of 1990, PL 100-596, through US Environmental Protection Agency (EPA) grant # LC991923-01 to the New England Interstate Water Pollution Control Commission (NEIWPCC). The views expressed do not necessarily reflect the views of the EPA, NEIWPCC, or the Lake Champlain Basin Program.

Bibliography

Ananthakrishnan, T. N., and A. Sen. 1998. Biocommunication in Insects. Science Publishers, Inc., Enfield, NH. 104 pp.

Anderson, J. K. 1994. Restoration and enhancement of salmonid fisheries in Lake Champlain. Vermont Department of Fish and Wildlife. Job Performance Report F-23-R-5, Job 1.

Anderson, J. K., and B. D. Chipman. 1996. Restoration and enhancement of salmonid fisheries in Lake Champlain. Vermont Department of Fish and Wildlife. Job Performance Report F-23-R-7, Job 1.

Anderson, J. K. 1991. Restoration and enhancement of salmonid fisheries in Lake Champlain. Vermont Department of Fish and Wildlife. Job Performance Report F-23-R-2, Job 1.

Anderson, J. K., and N. R. Staats. 1995. Restoration and enhancement of salmonid fisheries in Lake Champlain. Vermont Department of Fish and Wildlife. Job Performance Report F-23-R-6, Job 1.

Anderson, B. E., J. R. Guilmette, and J. B. Dudley. 1985. Preliminary feasibility study for sea lamprey barrier dams on Lake Champlain tributary streams. N. Y. S. Department of Environmental Conservation, Vermont Agency of Environmental Conservation.

Applegate, V. C., and E. L. King Jr. 1962. Comparative toxicity of 3-Trifluromethyl-4-nitrophenol (TFM) to larval lampreys and eleven species of fish. Trans. of the Am. Fish. Soc. 91(4): 342-345.

Applegate, V. C., and B. R. Smith. 1951. Movement and dispersion of a blocked spawning run of sea lampreys in the Great Lakes, p. 243-251. In: Sixteenth North American Wildlife Conference. Wildlife Management Institute. Wildlife Management Institute. 243-251pp.

Applegate, V. C. 1950. Natural history of the sea lamprey. Special Scientific Report-Fisheries, Report #55. U.S. Dept. of Interior, Fish and Wildlife Service. Washington, D. C.

Beaulieu, H. 1992. Liste des especes de la faune vertebree susceptibles d'etre designees menanees ou vulnerables. Ministere du Loisir, de la Chasse et de la Peche.

Bergstedt, R. A., and J. G. Seelye. 1995. Evidence for lack of homing by sea lampreys. Trans. of the Am. Fish. Soc. 124: 235-239.

Bergstedt, R. A. 1981. Laboratory determination of maximum swimming speed of migrating sea lampreys: a feasibility study. Administrative report #81-3. Great Lakes Fishery Laboratory, U.S. Dept. of Interior, Fish and Wildlife Service. Ann Arbor, MI.

Bills, T.D., L.L Marking, J.J. Rach, and G.E. House. 1990. Effects of TFM on the pink heelsplitter mussel (Potamilus altus). Report submitted to New York Department of Environmental Conservation, U.S. Fish and Wildlife Service National Fisheries Research Center, LaCrosse, WI.

Chandler, J. H., and L. L. Marking. 1975. Toxicity of the lampricide 3-trifluoromethyl-4-nitrophenol (TFM) to selected aquatic invertebrates and frog larvae. Investigations in Fish Control, #62. U.S. Dept. of the Interior, Fish and Wildlife Service.

Cormack, H. E. 1959. A discussion of the feasibility of using sound waves as a means of controlling the sea lamprey in the Great Lakes, with a bibliography. Fisheries Research Board of Canada. Manuscript Report Series (Biological) #673. Biological Station, London, Ontario.

Dean, M. J., and A. Zerrenner. 2001. Assessment of sea lamprey populations in the Pike River and Morpion Stream Quebec, Canada. Lake Champlain Basin Program Technical Report. Grand Isle, Vermont.

Dees, L. T. 1980. Sea Lamprey. U.S. Dept. of Interior, Fish and Wildlife Service. Washington D.C.

Dermott, R. M., and H. J. Spence. 1984. Changes in Populations and Drift of Stream Invertebrates Following Lampricide Treatment. Can. J. Fish. Aquat. Sci. 41:1695-1701.

Ebener, M. P. 1990. Results from trapping adult sea lamprey in tributaries of Lake Superior. Administrative Report 90-9. Great Lakes Indian Fish and Wildlife Commission. Biological Resources Division. Odanah, WI.

Environnement Quebec. 1993. Qualité des eaux de la rivière Richelieu. La Direction de la Qualitè des cours d'eau, Ministère de l'Environnement du Quebec.

EPA (U.S. Environmental Protection Agency). 1999. Reregistration eligibility decision (RED): 3-triflouromethyl-4-nitro-phenol and niclosamide. U.S. Environmental Protection Agency. Washington, DC. EPA 738-R-99-007. 167 pp.

Everhart, W. H., and W. D. Youngs. 1981. Principles of Fishery Science. Cornell University Press Ltd. United Kingdom.

Facey, D. E., and G. W. Labar. 1989. A survey of the fishes of Vermont waters of the southern

Lake Champlain basin. Technical Report #7. Nongame and Endangered Species Program. Vermont Fish and Wildlife Dept., Waterbury VT.

Farmer, G. J., and F. W. H. Beamish. 1973. Sea lamprey (*Petromyzon marinus*) predation on freshwater teleosts. J. Fish. Res. Board Can. 30: 601-605.

Ferguson, H. J. 1998. Soil survey of Rutland County, Vermont. U.S. Dept. of Agriculture. Government Document # A 57.38/45:R 93. Washington, D.C..

Fichtel, C. 1992. Unionid mussels of the Lower Poultney River; Report on the 1992 monitoring activities. Nongame and Natural Heritage Program. Vermont Fish and Wildlife Department.

Fisheries Management Subcommittee. 1994. Use of lampricides in a temporary program of sea lamprey control in Lake Champlain with an assessment of effects on certain fish populations and sportfishes. 1992 annual report to The Lake Champlain Fish and Wildlife Management Cooperative Technical Committee.

Fisheries Technical Committee, Lake Champlain Fish and Wildlife Management Cooperative. 1999. A comprehensive evaluation of an eight year program of sea lamprey control in Lake Champlain. U.S. Dept. of Interior, Fish and Wildlife Service, Washington, D.C..

Fiske, S., and R. Langdon. 1994. The long term effects of the lampricide TFM on non-target fish and macro invertebrate populations in Lewis Creek, Vermont. Vermont Department of Environmental Conservation, Biomonitoring and Aquatic Studies Unit. Waterbury, Vermont

Gersmehl, J. E., and C. F. Barren. 1985. Lake Champlain sea lamprey assessment report. U.S. Dept. of Interior, Fish and Wildlife Service. Montpelier, VT.

Gersmehl, J. E. 1996. Annual report to the Lake Champlain Fish and Wildlife Management Cooperative Technical Committee. U.S. Dept. of Interior, Fish and Wildlife Service. Essex Junction, VT.

Gersmehl, J. 1994. Results of a sea lamprey survey conducted on the Pike River, Quebec, Canada September 1993. U.S. Dept. of Interior, Fish and Wildlife Service. Essex Junction, VT.

Gilderhus, P. A., and B. G. H. Johnson. 1980. Effects of sea lamprey (*Petromyzon marinus*) control in the Great Lakes on aquatic plants, invertebrates, and amphibians. Can. J. Fish. Aquat. Sci. 37:1895-1905.

Godfrey, H. 1957. Mortalities among developing trout and salmon ova following shock by direct-current electrical gear. J. Fish. Res. Board Can.. 14: 153-164.

Gratton, L. 1995. Dossier de presentation pour la creation du refuge faunique de la riviere aux Brochets. Rapport presente a la direction regionale de Montreal de Ministere de l'Environnement et de la Faune et a Conservation Baie Missisquoi.

Gruendling, G. K., and D. J. Bogucki. 1986. Evaluation of the potential impact of lampricides (TFM and Bayer 73) on Lake Champlain wetlands. New York State Department of Environmental Conservation, Raybrook, NY.

Guilmette, J. R. 1997. Morpion Brook sea lamprey barrier dam: preliminary estimate. Restoration and enhancement of salmonid fisheries in Lake Champlain. Job Performance Report F-23-R-7, Job 2. Vermont Fish and Wildlife Department.

Hanson, L. H., and P. J. Manion. 1978. Chemosterilization of the sea lamprey *Petromyzon marinus*. Great Lakes Fisheries Committee. Technical Report 29:15 pp.

Hanson, L. H., and P. J. Manion. 1980. Sterility method of pest control and its potential role in an integrated sea lamprey (*Petromyzon marinus*) control program. Can. J. Fish. Aquat. Sci. 37:2108-2117.

Hardisty, M. W., and I. C. Potter [eds.]. 1971. The biology of the lamprey. Volume 1. Academic Press, New York and London.

Hilgert, P. J. 1992. Evaluation of a graduated electric field as a fish exclusion device. Puget Sound Power and Light Company, Final Report. Bellevue, Washington.

Howell, J. H., J. J. Lech, and J. L. Allen. 1980. Development of sea lamprey (*Petromyzon marinus*) larvicides. Can. J. Fish. Aquat. Sci. 37:2103-2107.

Hunn, J. B., and W. D. Youngs. 1980. Role of physical barriers in the control of sea lamprey (*Petromyzon marinus*). Can. J. Fish. Aquat. Sci. 37:2118-2122.

Hussain, M. 1998. Fate of the lampricide 3-trifluoromethyl-4-nitrophenol (TFM) in the environment. M.S. Thesis. Michigan State University.

Kanayama, R. K. 1963. The use of alkalinity and conductivity measurements to estimate concentrations of 3-Trifluromethyl-4- nitrophenol required for treating lamprey streams. Technical Report #7. Great Lakes Fisheries Commission. Ann Arbor, MI.

Kelso, J. R. M., and W. M. Gardner. 2000. Emigration, upstream movement and habitat use by sterile and fertile sea lampreys in three Lake Superior tributaries. N. Am. J. of Fish. Mgmt. 20:144-153.

King, E. V. L. J., and J. A. Gabel. 1985. Comparative toxicity of the lampricide 3-trifluoromethyl-4-nitrophenol to ammocetes of three species of lampreys.

Knipling, E. F. 1960. The eradication of the screw-worm fly. Scientific American. 203: 54-61.

Kynard, B., and E. Lonsdale. 1975. Experimental study of galvanonarcosis for rainbow trout immobilization. J. Fish. Res. Board Can. 32: 300-302.

Langdon, R., and S. Fiske. 1991. The effects of the lampricide TFM on non-target fish and macroinvertebrate populations in Lewis Creek, Vermont. Vermont Agency of Natural Resources, Department of Environmental Conservation, Biomonitoring and Aquatic Studies Unit.

Li, W. In review. Sex pheromone communication in the sea lamprey. Journal of Great Lakes Research.

Li, W., P. W. Sorensen, and D. D. Gallaher. 1995. The olfactory system of migratory adult sea lamprey (*Petromyzon marinus*) is specifically and acutely sensitive to unique bile acids released by conspecific larvae. The Journal of General Physiology. 105:569-587.

Lieffers, H. J. 1990. Effects of the lampricided 3-Trifluromethyl-4-nitrophenol on macroinvertebrate populations in a small stream. Technical Report #55. Great Lakes Fisheries Commission. Ann Arbor, MI.

McAuley, T. and R. Young. 1994. Performance evaluation of the McIntyre River experimental velocity barrier. Report to the Great Lakes Fishery Commission.

McCrimmon, H. R., and B. Bidgood. 1965. Abnormal vertebrae in the rainbow trout with particular reference to electrofishing. University of Guelph, Canada. Prog. Fish. Cult.. 27: 84-88.

Matson, T. O. 1990. Estimation of numbers for a riverine *Necturus* population before and after TFM lampricide exposure. Kirtlandia 45:33-38.

Mallatt, J., R. D. McCall, J. F. Bailey, and J. Seelye. 1994. Effects of lampricides on the gill ultrastructure of larval sea lamprey and rainbow trout fry. Canadian Journal of Zoology. 72:1653-1664.

Marking, L. L., and J. W. Hogan. 1967. Toxicity of Bayer 73 to fish. Investigations in fish control. Technical Report # 19. U. S. Department of Interior, Fish and Wildlife Service, Washington, D. C.

Myer, G. E., and G. K. Gruenling. 1979. Limnology of Lake Champlain. Report for the

Eutrophication Task Force, Lake Champlain Basin Study. New England River Basins Commission.

National Research Council of Canada (NRCC). 1985. TFM and Bayer 73 Lampricides in the aquatic environment. Publication # NRCC 22488 of the Environmental Secretariat. Ottawa, Canada.

Neuderfer, G. N. 1996a. Toxicity of the lampricide TFM (3-trifluoromethyl-4-nitrophenol) to juvenile and adult pocketbook mussels (*Lampsilis ventricosa*) and the channel darter (*Percina copelandi*). Job Performance Report F-23-R-7, Job 2. Vermont Fish and Wildlife Department.

Neuderfer, G. N. 1996b. Toxicity of the lampricide TFM (3-trifluoromethyl-4-nitrophenol) to the black sandshell mussel (*Ligumia recta*). Job Performance Report F-23-R-7, Job 2. Vermont Fish and Wildlife Department.

NYSDEC, USFWS, and VTDFW. 1990. Use of lampricides in a temporary program of sea lamprey control in Lake Champlain with an assessment of effects on certain fish populations and sportfisheries. Final Environmental Impact Statement. N.Y.S. Department of Environmental Conservation, Bureau of Fisheries. Ray Brook, NY.

Pennak, R. W. 1989. Fresh-water Invertebrates of the United States. Third Edition. John Wiley and Sons, Inc. New York, NY.

Porto, L. M., R. L. McLaughlin, and D. L. G. Noakes. 1999. Low-head barrier dams restrict the movements of fishes in two Lake Ontario streams. N. Am. J. of Fish. Mgmt. 19:1028-1036.

Schleen, L. P., R. J. Young, and G. T. Klar. 1998. Integrated management of sea lampreys in the Great Lakes 1997. Annual Report to Great Lakes Fishery Commission. Great Lakes Annual Meeting June 2-4, 1998.

Scholefield, R. J., and J. G. Seelye. 1990. Resistance to 3-Trifluromethyl-4-nitrophenol (TFM) in sea lamprey. Technical Report #56. Great Lakes Fisheries Commission. Ann Arbor, MI.

Sea Lamprey Barrier Transition Team. 2000. Sea lamprey barrier life cycle and operational protocols. Great Lakes Fisheries Commission. Ann Arbor, MI.

Seelye, J. G., L. L. Marking, E. L. King, Jr., L. H. Hanson, and T. D. Bills. 1987. Toxicity of TFM lampricide to early life stages of walleye. N. Am. J. of Fish. Mgmt. 7:598-601.

Seelye, J. G., and R. J. Scholefield. 1990. Effects of changes in dissolved oxygen on the toxicity of 3-Trifluromethyl-4-nitrophenol (TFM) to sea lamprey and rainbow trout. Technical Report #56. Great Lakes Fisheries Commission, Ann Arbor, MI.

Shank, C. C. 1999. The committee on the status of endangered wildlife in Canada (COSEWIC): a 21- year retrospective. Canadian Field Naturalist. 113:318-341.

Shanley, J. B., and J. C. Denner. Unpublished data. The hydrology of Lake Champlain Basin. United States Geological Survey. Montpelier, VT.

Simoneau, M. 1993. Qualite des eaux du bassin de la riviere Richhelieu, 1979 a 1992. Ministere de l'Envoronnement du Quebec.

Smith, C. L. 1985. The Inland Fishes of New York. N. Y. S. Dept. of Environmental Conservation, Albany, NY.

Smith Root, Inc. 1999. Barriers and Guidance Systems. Smith Root, Inc., Vancouver, WA.

Sower, S.A., O. Materne, and J. Connolly. In review. The physiology of reproduction in lampreys and applications for male lamprey sterilization. Sea Lamprey International Symposium, Sault Ste. Marie, MI. Journal of Great Lakes Research.

Speight, M. R., M. D. Hunter, and A. D. Watt. 1999. Ecology of insects: concepts and applications. Blackwell Science Ltd. Oxford, England.

Spencer, S. L. 1967. Internal injuries of largemouth bass and bluegills caused by electricity. Prog. Fish. Cult. 29: 168-169.

Swink, W. D. 1999. Effectiveness of an electrical barrier in blocking a sea lamprey spawning migration on the Jordan River, Michigan. N. Am. J. of Fish. Mgmt. 19:397-405.

Taylor, G. N., L. S. Cole, and W. F. Sigler. 1957. Galvanotaxic response of fish to pulsating direct current. J. of Wild. Mgmt. 21: 201-213.

Teeter, J. 1980. Pheromone communication in sea lamprey (*Petromyzon marinus*): implications for population management. Can. J. Fish. Aquat. Sci. 37:2123-2132.

Thompson, Z. 1853. Natural History of Vermont. C. E. Tuttle Co. Publisher. Rutland, VT. 286 pp.

Twohey, M. B., J. W. Heinrich, J. Kagel, W. D. Swink, and L. H. Hanson. 1997. Chemical hygiene and plan of operations for the sea lamprey sterilization facility at the Lake Huron Biological Station. U.S. Fish and Wildlife Service, Marquette Biological Station, Marquette, MI.

U.S. Fish and Wildlife Service and Canadian Department of Fisheries and Oceans. 1999. Standard operating procedures for application of lampricides in the Great Lakes Fishery Commission integrated management of sea lamprey (*Petromyzon marinus*) control program. SLC# 92-001.3.

Vermont Department of Environmental Conservation, The Lower Poultney River Citizens Committee. 1992. The Lower Poultney River: a Vermont Outstanding Resource Water. Vermont Agency of Natural Resources Management Plan. August, 1992.

Watson, W. C. 1876. The salmon of Lake Champlain and its tributaries. U.S. Commission of Fish and Fisheries. Commissioners Report for 1873 - 1875.

Watters, G. T. 1992. An annotated bibliography of the reproduction and propagation of the Unionidea (primarily of North America). Ohio Biological Survey, Columbus, OH.

Weisser, J.W., G.A. Baldwin, and R.J. Schuldt. 1994. Effect of the lampricide 3-Trifluromethyl-4-nitrophenol (TFM) on fish, aquatic insects and an amphibian in the Rand River, Ohio, 1987. Project Completion Report. U.S. Fish and Wildlife Service, Marquette Biological Station, Marquette, MI.

Zerrenner, A.E. 2001. Compensatory mechanisms in Lake Champlain larval sea lamprey (*Petromyzon marinus*) populations: implications for sea lamprey control. Master's thesis. University of Vermont, Burlington, VT.

APPENDIX I.

New York State Permit Requirements for Sea Lamprey Control

New York State Permit Requirements for Sea Lamprey Control with Chemical Lampricides

Outside Adirondack Park:

TFM or Bayer 73 Lampricide Application

1. TFM or Bayer 73 Permit - "Permit to Use Chemicals for the Control and Extermination of Undesirable Fish" pursuant to Title 6, New York Codes Rules and Regulations (NYCRR), Part 328.

2. DEC Wetlands Permit (if wetlands involvement) - "Freshwater Wetlands Permit" pursuant to Article 24, Environmental Conservation Law (ECL). "Water Quality Certification" issued in conjunction with Wetlands Permit pursuant to 6 NYCRR, Part 608.

Within Adirondack Park:

TFM or Bayer 73 Lampricide Application

1. TFM or Bayer 73 Permit - "Permit to Use Chemicals for the Control and Extermination of Undesirable Fish" pursuant to 6 NYCRR, Part 328.

2. APA Wetlands Permit (if wetlands involvement)- "Freshwater Wetlands Permit" pursuant to New York State Freshwater Wetlands Act and 9 NYCRR, Part 578.

Potential New York State Regulatory Issues
Relative to Construction of Sea Lamprey Control Barrier Dams

1. SEQR - Requirements of the State Environmental Quality Review Act must be addressed.

2. DEC or APA Wetlands Permit (if wetlands involvement) - "Freshwater Wetlands Permit" pursuant to Article 24, ECL. "Water Quality Certification" issued in conjunction with Wetlands Permit pursuant to 6 NYCRR, Part 608.

3. DEC Article 15 Permit - "Protection of Waters Permit" pursuant to Article 15, ECL. (No Article 15 permit is necessary if the project is New York State sponsored.)

4. Dam Safety Review - This occurs as a part of the Article 15 permitting process, and would be necessary even if the state sponsored the construction and no Article 15 permit was required.

5. Protected Native Plants - Protected Native Plants may be disturbed only on private land and only with landowner permission, pursuant to Article 9, Title 15, ECL.

6. Wild, Scenic & Recreational River System Permit (Permit required from APA if on private land in park; or from DEC if on state land in park or any land outside park) - pursuant to Article 15, Title 27 ECL; 6 NYCRR, Part 666.

7. Construction in Flood Hazard Areas - Requires state agencies to evaluate and reduce flood hazards for any construction projects in flood prone areas. Local municipalities may exert some jurisdiction in this area. Article 36, ECL.

8. NYS Office of Parks, Recreation and Historic Preservation Review - OPRHP does not issue a permit per se. However, it has authority to require surveys and modification in construction location / design, etc. to minimize risk of impacts to historic or archeological significant sites. If the project only requires state permits, the review will be in accord with §14.09 of the State Preservation Law. If the project requires an Army Corps of Engineers (ACOE) permit review will be in accord with §106 of the National Historic Preservation Act.

9. U.S. Army Corps of Engineers (ACOE) Permit - ACOE may require a permit under § 401 of the Clean Water Act or under Title 33, Code of Federal Regulations (33 CFR 330, Appendix A)

10. Local Building Permits - Building permits from local municipalities would likely be required.

APPENDIX II.

Vermont State Permit Requirements for Sea Lamprey Control

Permit Requirements for Chemical Lampricide Application and Other Control Methods in Vermont Waters:

1. Aquatic Nuisance Control Permit pursuant to Title 10 V.S.A., Chapter 47, Subchapter 1, Section 1263a.

2. Endangered and Threatened Species Permit persuant to Title 10 V.S.A., Chapter 123, Section 5408, where state-listed endangered and threatened species could potentially be affected by lampricides.

Additional Permit Requirements for Construction of Sea Lamprey Barrier Dams in Vermont Waters:

1. Stream Alteration Permit persuant to Title 10 V.S.A. Chapter 41, Subchapter 2.

2. A permit to obstruct the passage of fish pursuant to Title 10 V.S.A. Chapter 111, Section 4607.

3. Endangered and Threatened Species Permit persuant to Title 10 V.S.A., Chapter 123, Section 5408, if dam construction could potentially affect state-listed endangered and threatened species.

4. Wetlands Conditional Use Determination may be required pursuant to 10 V.S.A. Chapter 37, Section 905 (7-9), if the project will impact wetlands.

5. An individual permit may be required from the U.S. Army Corps of Engineers pursuant to Section 404 of the Clean Water Act.

6. Water quality certification may be required under Section 401 of the Clean Water Act.

7. Review by the Division of Historic Preservation if the project affects sensitive archealogical areas.

8. Permission must be granted from all landowners whose property will be affected by dam construction.

Vermont Aquatic Nuisance Control Permit Process for Use of Lampricides

The Aquatic Nuisance Control Program is managed by the Water Quality Division of the Vermont Department of Environmental Conservation (VTDEC). Permits are required to control nuisance plants, insects or other aquatic life, including lamprey in waters of the State of Vermont.

For use of lampricides, five criteria need to be met to obtain a permit. We must demonstrate that:

(1) there is no reasonable nonchemical alternative available;
(2) there is acceptable risk to the nontarget environment;
(3) there is negligible risk to public health;
(4) a long range management plan has been developed which incorporates a schedule of lampricide minimization; and
(5) there is public benefit to be achieved from the application of lampricides.

For use of biological controls (sterile males), structural controls (barrier dams), or chemicals other than pesticides (pheromones), three criteria need to be met. We must demonstrate that:

(1) there is acceptable risk to the nontarget environment;
(2) there is negligible risk to public health; and,
(3) There is either benefit to or no undue adverse effect upon the public good.

The permit review process generally takes 90 days for a final decision once a permit application is accepted as complete, but sea lamprey control is expected to receive greater than normal scrutiny and the process may extend beyond 90 days.

When an application is deemed complete, VTDEC will publish a notice of receipt and provide written notice to appropriate agencies and individuals. Public review and submission of written comments or requests for a public informational meeting will be solicited for a minimum of 20 days following publication.

VTDEC is required to hold at least one public informational meeting on the permit application if requested by a municipality or 25 or more persons. Due to the broad scope and high profile of the sea lamprey contol project, additional public informational meetings and comment periods are expected to be set to allow ample opportunity for public review of a draft decision and permit.

An Aquatic Nuisance Control Permit can be specified to be valid for up to five years, and can be renewed from time to time.

A final decision and permit may be appealed to the Vermont Water Resources Board within 30 days of the date the decision is issued.

APPENDIX III.

Quebec, Canada Permit Requirements for Sea Lamprey Control

Permits and Approvals Dam Construction, Quebec

Building a dam in Quebec requires a Certificate of Authorization according to the Environment Quality Act (R.S.Q. Q-2). A copy of the zone or use of the territory concerned must be supplied along with a certificate from the clerk or secretary/treasurer of the local municipality stating the realization of the project does not violate any municipal by-laws (J. Dubé, biologist Coordonnateur régional de l'application du Règlement sur les habitats fauniques, personal communication).

Permits and Approvals Trapping in Quebec

The town of Notre-Dame-de-Stanbridge owns the dam and mill. The municipality at Notre-Dame-de-Stanbridge indicate that permanent or portable trap could be placed inside the mill dependent upon necessary modifications to the mill. The municipality has requested that a plan be sent to them for review, including any modifications that may be required before hand. A site visit has been suggested with an engineer, and their municipal inspector.

Permits and Approvals Lampricides, Quebec

Using lampricides in Quebec requires a Certificate of Authorization according to the Environment Quality Act (R.S.Q. Q-2).

A copy of a map showing land use / land cover must be supplied along with a certificate from the clerk or secretary/treasurer of the local municipality stating the realization of the project does not violate any municipal by-laws.

Quebec Directive 017 form must be submitted.

Article 32 of the federal law on Fisheries in Canada forbids the cause of death of fish by means other than fishing unless authorized. Subsequent forms must be sent to Mr. Daniel Hardy the Chief of protection de l'habitat du poisson, Pêches et Océans Canada (J. Dubé, Personal Communication, 1999).

The firm that uses the lampricides must be certified in Quebec and the people participating in the operation must be formed (educated) by Quebec's school system. If not educated in the Quebec system, applicant must demonstrate their competency in applying pesticides.

APPENDIX IV

Comparison of Sea Lamprey Control Strategies by Stream

Appendix IVa.—Comparison of control strategies for sea lamprey control on the Poultney River.

Method	Annualized Cost	Feasibility	Effectiveness	Non-target impacts	Habitat impacts	Human impacts
TFM	$28,850[a]	High	High (if allowed to treat appropriately	Low (when mitigation is employed)	Low	Low (when mitigation is employed)
TFM/Bayer 73	$18,100[a]	Moderate	High (if allowed to treat appropriately)	Low (when mitigation is employed)	Low	Low (when mitigation is employed)
Electrical barrier	$23,135	Moderate	Moderate - High	High (fish migrations)	Low	Low
Low-head/ Adjustable crest barrier	$29,275	Low - Moderate	Moderate - High	High (fish migrations)	Moderate	Low
Adult trapping	$7,200	High	Low (poor site availability unless barrier established)	Low	Low	Low

[a] Includes simultaneous treatment of the Poultney and Hubbardton Rivers

Appendix IVb.—Comparison of control strategies for sea lamprey control on the Hubbardton River.

Method	Annualized Cost	Feasibility	Effectiveness	Non-target impacts	Habitat impacts	Human impacts
TFM	$6,850	Low	High (if allowed to treat appropriately	Low (when mitigation is employed)	Low	Low (when mitigation is employed)
TFM/Bayer 73	n/a					
Electrical barrier	$19,850	Low	Moderate - High	Moderate - fish migrations	Low	Low
Low-head/ Adjustable crest barrier	$13,275	Low - Moderate	Moderate - High	Moderate - fish migrations	Moderate	Low
Adult trapping	$7,200	High	Low - Moderate (inneffective without barrier)	Low	Low	Low

Appendix IVc.— Comparison of control strategies for sea lamprey control on the Pike River.

Method	Annualized Cost	Feasibility	Effectiveness	Non-target impacts	Habitat impacts	Human impacts
TFM	$40,125[a]	Moderate - High (spring treatment likely)	High	Low (when mitigation is employed)	Low	Low (when mitigation is employed)
TFM/Bayer 73	$34,925	Moderate - High (spring treatment likely)	High	Low (when mitigation is employed)	Low	Low (when mitigation is employed)
Electrical barrier	$33,000	Low	Moderate - High	Moderate - High (fish migrations)	Low	Low
Low-head/ Adjustable crest barrier	$38,040	Low	Moderate - High	Moderate - (fish migrations)	Low - Moderate	Moderate
Adult trapping	$7,200	High	Low	Low	Low	Low

[a] Include simultaneous treatment of Pike River and Morpion Stream.

Appendix IVd.—Comparison of control strategies for sea lamprey control on the Morpion Stream.

Method	Annualized Cost	Feasibility	Effectiveness	Non-target impacts	Habitat impacts	Human impacts
TFM	$7,450	Moderate - High	High	Low (when mitigation is employed)	Low	Low (when mitigation is employed)
TFM/Bayer 73	n/a					
Electrical barrier	$18,000	Moderate	Moderate - High	Low	Low	Low
Low-head/ Adjustable crest barrier	$14,325	Moderate	Moderate -High	Low	Low - Moderate	Low - Moderate
Adult trapping	$7,200	High	Low - Moderate	Low	Low	Low