

Assessment of Sea Lamprey Habitat and the Sea Lamprey Population of the Pike River and Morpion Stream, Quebec, Canada



**Lake Champlain
Basin Program**

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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.
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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
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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
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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.
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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.
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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

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TABLE OF CONTENTS

List of Tables	iii
List of Figures	iv
Executive Summary	vi
Introduction.....	1
Methods.....	5
Study Sites	5
Pike River.....	5
Morpion Stream	5
Habitat Classification.....	6
Wadable Water Section.....	6
Non-Wadable Water Section	6
Larval Sampling.....	8
Wadable Water Section.....	8
Non-Wadable Water Section	9
Adult Spawning Phase and Nest Assessment	9
Laboratory Processing.....	10
Results.....	10
Pike River - Wadable Section	10
Habitat Assessment.....	10
Nest Count	17
Larval Abundance	17
Population Characteristics	17
Pike River - Non-Wadable Water Section	17
Morpion Stream	23
Habitat Assessment.....	23
Nest Count	23
Larval Abundance	23
Population Characteristics	33
Discussion.....	33
References.....	43
Appendix.....	45

LIST OF TABLES

Table 1.	History of lampricide application in Lake Champlain tributaries and deltas, and construction of sea lamprey spawning barriers as part of the eight-year experimental control program 1990-1997	3
Table 2.	Habitat classification types for larval and adult spawning sea lamprey.....	7
Table 3.	Area of sea lamprey habitat types and percent of each habitat type in wadable and non-wadable waters of Pike River and wadable waters of Morpion Stream during 1999.....	11
Table 4.	Distance (m) to Pike River transects (transect 1 begins at the dam in Notre-Dame de Stanbridge), length (m) of habitat type at each transect and area of habitat types between transects during 1999	12
Table 5.	Sea lamprey ammocoete density (ammocoetes/m ²) and abundance, and transformer density and production (transformer/m ²) in type I and type II habitat in wadable and non-wadable waters section of the Pike River during 1999. Numbers in parentheses represent standard error.....	18
Table 6.	Distance (m) to Morpion Stram transects (transect 1 begins at the mouth of Morpion Stream in Notre-Dame de Stanbridge), length (m) of habitat type at each transects and area of habitat type between transects during 1999	24
Table 7.	Sea lamprey and American brook lamprey ammocoete density (ammocoetes/m ²) and abundance, and transformer density (transformer/m ²) and production in type I and type II habitat in Morpion Stream during 1999. Numbers in parentheses represent standard error.....	26

LIST OF FIGURES

Figure 1.	Lake Champlain basin and major tributaries with inset of Pike River/Morpion Stream	4
Figure 2.	Distance of habitat type (m) at each transect in wadable waters section of Pike River during 1999	14
Figure 3.	Area of type I habitat between each transect in the wadable waters section of Pike River during 1999	15
Figure 4.	Area of type II habitat between each transect in the wadable waters section of Pike River during 1999	16
Figure 5.	Area of spawning habitat between each transect in the wadable waters section of Pike River during 1999	19
Figure 6.	Total estimated production (larval abundance) of sea lamprey in the wadable waters section of Pike River during 1999	20
Figure 7.	Length frequency of larval sea lamprey collected in 1999 in the wadable waters section of Pike River	21
Figure 8.	Age frequency for Pike River larval sea lamprey collected in 1999 with sample sizes.....	21
Figure 9.	Length at age for Pike River larval sea lamprey collected in 1999 with 95% confidence intervals and sample sizes	22
Figure 10.	Weight at age for Pike River larval sea lamprey collected in 1999 with 95% confidence intervals and sample sizes	22
Figure 11.	Distance of habitat type (m) at each transect in the wadable waters section of Morpion Stream during 1999	27
Figure 12.	Area of type I habitat between each transect in Morpion stream during 1999	28
Figure 13.	Area of type II habitat between each transect in Morpion Stream during 1999.....	29
Figure 14.	Area of spawning habitat between each transect in Morpion Stream during 1999.....	30

Figure 15.	Number of sea lamprey nests between each transect in Morpion Stream during 1999.....	31
Figure 16.	Total estimated production (larval abundance) of sea lamprey from Morpion Stream during 1999	32
Figure 17.	Longitudinal distribution of sea lamprey and American brook lamprey ammocoetes in Morpion Stream during 1999.....	34
Figure 18.	Length frequency of sea lamprey collected in 1999 in Morpion Stream	34
Figure 19.	Age frequency for Morpion Stream larval sea lamprey collected in 1999 with sample sizes	35
Figure 20.	Length at age for Morpion Stream larval sea lamprey collected in 1999 with 95% confidence intervals and samples sizes.....	35
Figure 21.	Weight at age for Morpion Stream larval sea lamprey collected in 1999 with 95% confidence intervals and sample sizes	36
Figure 22.	Length frequency for American brook lamprey collected in 1999 in Morpion Stream	36
Figure 23.	Length at age for Morpion Stream larval American brook lamprey collected in 1999 with 95% confidence intervals and sample sizes.....	37
Figure 24.	Weight at age for Morpion Stream larval American brook lamprey collected in 1999 with 95% confidence intervals and sample sizes.....	37
Figure 25.	Age frequency for Morpion Stream larval American brook lamprey collected in 1999 with sample sizes	38

EXECUTIVE SUMMARY

The Lake Champlain Fish and Wildlife Management Cooperative began an experimental sea lamprey control program in 1990 that would quickly and substantially reduce abundance of sea lamprey over an eight-year period (FEIS 1990). The effectiveness of the eight-year experimental program may have been reduced due to the contribution of an uncontrolled sea lamprey population in Pike River and its tributary, Morpion Stream, located in Quebec, Canada. If a long-term sea lamprey control program is developed, it is essential to understand the relative contribution of sea lamprey from Pike River and Morpion Stream to the overall sea lamprey population in Lake Champlain.

In this study, sea lamprey ammocoete populations were quantified in Pike River and Morpion Stream by first classifying habitat into one of four types at 100 transects in the wadable waters of each stream and at 16 transects in non-wadable waters of Pike River. Sea lamprey ammocoetes were then sampled in the wadable waters using an AbP-2 backpack electro-fisher in optimal (type I) and sub-optimal (type II) habitat. Similarly, in non-wadable waters of Pike River, sea lamprey ammocoetes were sampled using a standard deep-water electro-fishing boat. Mean ammocoete densities from sampled habitats were extrapolated for the total available habitat to determine the abundance of ammocoetes and transformers. Sea lamprey nests were also counted throughout each stream as an index of adult abundance.

Suitable ammocoete habitat (type I and II) in Pike River represents 22% of the total wadable section or approximately 69,500 m² of habitat. Approximately 33% of Morpion Stream (41,082 m²) is suitable for sea lamprey ammocoetes. The Pike River had an estimated ammocoete population of $55,671 \pm 27,317$ (95% CI) and an estimated transformer population of $2,264 \pm 4,635$ (95% CI) during 1999. Morpion Stream had an estimated ammocoete population of $76,595 \pm 48,182$ (95% CI) and estimated transformer population of $1,863 \pm 1,831$ (95% CI) during 1999. Only one sea lamprey ammocoete was captured in the deep-water section of the Pike River, which extrapolated to 10,063 ammocoetes in this section. Three hundred forty seven sea lamprey nests were counted in Pike River and 221 nests were counted in Morpion Stream.

The percent contribution of sea lamprey transformers from Pike River and Morpion Stream cannot be determined because quantitative assessment surveys have not been conducted on other tributaries. Sea lamprey ammocoete abundance in Pike River and Morpion Stream appears high enough for these streams to be included in a long-term sea lamprey control program.

INTRODUCTION

Sea lamprey (*Petromyzon marinus* Linnaeus) is a primitive vertebrate that has gained attention because of its prehistoric origin and its detrimental effects as an exotic species in freshwater ecosystems. The sea lamprey has a unique life history: as larvae (also known as ammocoetes), the sea lamprey lives as a burrowing filter feeder in stream sediments; ammocoetes then metamorphose into a parasitic fish that inhabits cool, deep lakes where they feed on fish; after 12 to 18 months sea lamprey adults return to tributaries to spawn and then die. In the 1800s, it is believed that sea lamprey gained access from the Atlantic Ocean to the Great Lakes, Finger Lakes, and Lake Champlain via canals (Lawrie 1970). It has also been argued that sea lamprey could be endemic to Lake Ontario, the Finger Lakes and Lake Champlain, having gained access via the St. Lawrence River (Smith 1972).

Commercially fished species, recreational fisheries and other native fishes have been adversely affected in freshwater ecosystems as a result of the destructive nature of the sea lamprey. The decline of fish populations led to efforts to control the sea lamprey in the 1950s in the upper three Great Lakes with the goal of reducing or eradicating their populations. Since the beginning of the sea lamprey control program, efforts of governmental agencies to control sea lamprey have evolved into a multi-million dollar program, expanding to the lower Great Lakes, Finger Lakes and Lake Champlain. Sea lamprey control is a collaboration of federal, state, and provincial government agencies, private interest groups, and the scientific community.

In 1973, the Lake Champlain Fish and Wildlife Cooperative (Cooperative) was created to increase communication and collaboration on fishery management issues between the U.S. Fish and Wildlife Service, New York Department of Environmental Conservation, and Vermont Fish and Wildlife Department. In the mid 1970s, the Cooperative began an extensive salmonid stocking program in attempts to develop a diverse salmonid fishery and populations of native salmonids. Unfortunately, the Cooperative's goals were inhibited due to mortality caused by the sea lamprey (Fishery Technical Committee 1999).

In 1990, the Cooperative began an eight-year experimental sea lamprey control program that would quickly and substantially reduce the abundance of sea lamprey over

an eight-year period (FEIS 1990). As part of the program, the effects of sea lamprey population reduction on the characteristics of salmonid fisheries and sports fisheries, and the growth and economy of the region were monitored. During the control program, fourteen Lake Champlain tributaries were treated with 3-trifluoromethyl-4-nitrophenol (TFM) and five tributary deltas were treated with a granular bayluscide (niclosomide) (Table 1). Tributaries selected for treatment contained high densities of sea lamprey ammocoetes, were amenable to chemical treatment based on stream size and discharge, and did not harbor a known population of Vermont listed endangered northern brook lamprey (*Ichthyomyzon fossor*) (Vermont tributaries). Similarly, for a delta to be scheduled for treatment, high densities of sea lamprey ammocoetes had to be present. In addition to chemical control, dams were re-furbished as sea lamprey barriers on Lewis Creek and the Great Chazy River to reduce the quantity of available habitat for spawning sea lamprey, thus reducing the length of stream requiring lampricide treatment. The Cooperative is currently planning a long-term sea lamprey control program on Lake Champlain.

The effectiveness of the eight-year experimental control program may have been reduced due to the presence of untreated sea lamprey populations in several tributaries, including the Pike River and its tributary, Morpion Stream (Figure 1). Field observations suggest that sea lamprey produced in the Pike River and Morpion Stream have re-colonized other treated and untreated streams such as the Great Chazy River, Missisquoi River and Lewis Creek (J. Gersmehl, U.S. Fish and Wildlife Service, unpublished data). Until this study, comprehensive quantitative data have not been collected on the sea lamprey populations in Pike River and Morpion Stream or other Lake Champlain tributaries. Quantitative data are required from all known sea lamprey producing streams to understand the overall contribution of these streams to Lake Champlain. This information will allow the Cooperative to prioritize streams for control, thus optimizing the overall cost effectiveness of the program.

The objectives of this project were to: 1) quantify sea lamprey ammocoete and adult habitat in the Pike River and Morpion Stream, 2) quantify sea lamprey ammocoete and transformer abundance in Pike River and Morpion Stream, 3) assess the longitudinal distribution of the sea lamprey ammocoete population in Pike River and Morpion Stream,

Table 1. History of lampricide application in Lake Champlain tributaries and deltas, and construction of sea lamprey spawning barriers as part of the eight-year-experimental control program 1990-1997.

Tributary	State	TFM stream treatment years	Bayluscide on delta treatment years	Sea lamprey barrier construction
Stone Bridge Brook	VT	1991		
Trout Brook	VT	1995		
Lewis Creek	VT	1990, 1994		1992
Hubbardton River	VT	1992, 1996		
Poultney River	VT	1992, 1996		
Mount Hope Brook	NY	1991, 1995		
Putnam Creek	NY	1990, 1994		
Beaver Brook	NY	1990		
Boquet River	NY	1990, 1994	1991, 1995	
Ausable River	NY	1990, 1994	1991, 1995	
Little Ausable River	NY	1990, 1994	1991	
Salmon River	NY	1990, 1994	1991, 1995	
Saranac River	NY	1992	1991, 1995	
Great Chazy River	NY	1992, 1996		1995

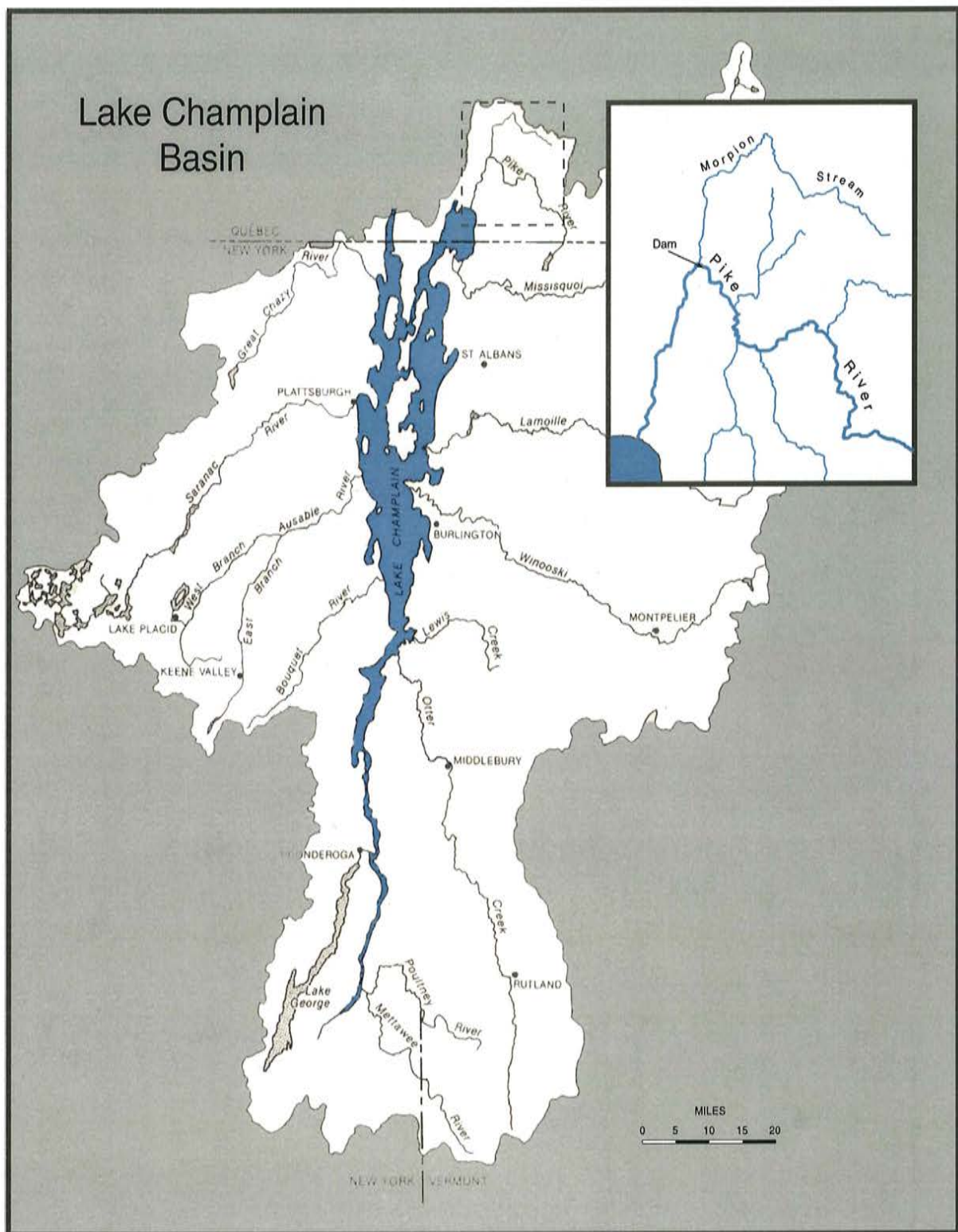


Figure 1. Lake Champlain basin and major tributaries with inset of Pike River/Morillon Stream.

and 4) quantify sea lamprey spawning abundance using a multiple mark-recapture population estimate. Unfortunately, objective 4 was not completed due to high stream discharge that reduced the capture efficiency of the equipment. As an alternative, sea lamprey nests were counted to obtain an index of the adult population and location of spawning.

METHODS

Study Sites

Pike River

The Pike River is a tributary of the northeastern end of Lake Champlain that drains into Missisquoi Bay, Quebec, Canada (N 45° 04' 50", W 73° 06' 12"). Sea lamprey have access to 13.2 km of the Pike River until they are blocked by a dam at Notre Dame-de-Stanbridge. Pike River has a wadable waters section 8.6 km long and a non-wadable section 4.6 km long. The mean stream width of the wadable section is 40 m and 63 m for the non-wadable section. In addition to sea lamprey, the Pike River has populations of silver lamprey (*Ichthyomyzon unicuspis*) and American brook lamprey (*Lampetra appendix*) (Gersmehl 1994). A sea lamprey database exists for the Pike River, comprised of larval lamprey length and weight for several sampling years, adult trapping data for one year, and nest counts for a section of the Pike River from 1982 to the present.

Morpion Stream

Morpion Stream is a tributary of the Pike River entering at Notre Dame-de-Stanbridge, Quebec, Canada (N 43° 2.5' 32", W 73° 10' 58"). Sea lamprey have access to 29.5 km of Morpion Stream. Morpion Stream has an average width of 3 m. In addition to sea lamprey, Morpion Stream had a population of silver and American brook lamprey (Gersmehl 1994). A sea lamprey database exists for Morpion Stream on larval lamprey length and weight for several sampling years. Morpion Stream has one known tributary, Barbe-Santere that produces sea lamprey.

Habitat Classification

Wadable Waters Section

Habitat was classified along 106 transects perpendicular to flow on the Pike River and 86 transects on Morpion Stream using methods described by Twohey et al. (1996). Transects on the Pike River began at the start of the wadable section in the town of Pike River, Quebec and ended at the first lamprey barrier in Notre Dame-de-Stanbridge. Transects on Morpion Stream began at its confluence with the Pike River in Notre Dame-de-Stanbridge and ended 1 km away from the stream's origin (lack of access on private lands prohibited the entire stream from being sampled). Distances between transects were determined using a random numbers table; however, numbers were bounded by $\pm 50\%$ of the length of 100 evenly spaced transects. The minimum distance between transects was 20 m. The distance between transects in the field was determined using a hip chain that had an accuracy of $\pm 0.02\%$ on flat terrain to $\pm 2.0\%$ on rugged terrain with heavy brush (Twohey et al. 1996). Each transect was marked and numbered with a 1 m length of re-bar driven into the bank.

Habitat was classified at every transect into one of four categories (Table 2): type I - optimum ammocoete habitat; type II - adequate ammocoete habitat; type III - unsuitable ammocoete habitat; and type IV - sea lamprey spawning habitat. At each transect, length of habitat was measured to the nearest 0.01 m. Habitat less than 0.01 m was not recorded. Habitat was classified visually and by touching the substrate (Twohey et al. 1996).

Non-Wadable Water Section

Sixteen transects were allocated evenly (287.5 m apart) and perpendicular to flow for 4.6 km of the non-wadable section for habitat classification and estimation of larval density (Fodale et al. 1998). Transects began 143.8 m ($1/2$ the distance between two transects) below the beginning of the non-wadable water section. Transects were located with a handheld GPS receiver in the deep-water electro-fishing boat. At each transect, an Ekman dredge was used to obtain substrate at five points equally spaced across the transect. Habitat classification followed the wadable waters criteria.

Table 2. Habitat classification types for larval and adult spawning sea lamprey.

Habitat type	Description/identification
Type I	Preferred larval habitat that usually consists of a mixture of sand and silt substrate. Often, some cover (detritus, aquatic vegetation) exists. The silty substrate usually is formed in an area of deposition. Components of type I habitat are consistent from river to river.
Type II	Acceptable, but not preferred larval habitat. Substrate compositions are often shifting sand, and may contain some gravel and very little silt. Substrate is soft enough for larvae to burrow. Components of type II are consistent from river to river.
Type III	Unacceptable habitat, larvae cannot burrow into it. Substrate is often bedrock or hardpan clay but may include rubble and coarse gravel. Interstices in coarse substrates may contain some type I or type II material, but these areas are dismissed if the length (along transect) is less than the minimum recordable measure (0.1 m).
Type IV	Type III habitat that is usable by adult spawning sea lamprey for nest construction. Nest construction requires gravel 15-115 mm in diameter.

Larval Sampling

Wadable Waters Sections

Larval lamprey were collected from Morpion Stream during July 20 to August 5, 1999 and from Pike River during August 18 to September 28, 1999 using an AbP-2 backpack electro-fisher at standard settings (Fodale et al. 1998; Appendix A). Sampling began at the downstream end of Morpion Stream and the upstream end of the Pike River. Electro-fishing plots had an area of 2.5-5 m² that was measured to the nearest 0.01 m² and sectioned off with wooden stakes. Each plot was electro-fished in one pass at 1.5 m²/minute. Type I was selected at every other transect if 2.5-5 m² of type I habitat was available. Type II habitat was selected at every eighth transect if 2.5-5 m² of type II habitat was available. Type II plots were also sampled at additional transects when habitat was available. All electro-fishing plots were sampled within 10 m upstream or downstream of a transect. If 2.5 m² of continuous type I habitat did not exist, then sub-plots 1 m² or greater were sampled and summed. Sub-plots were at least 1 m long and 0.3 m wide. If a total of 2.5 m² of type I habitat was not present, then type I habitat was sampled at the next unscheduled transect. If 2.5 m² of type I was absent at the unscheduled transect, then a type II plot was sampled. If all habitat was type III, a new transect was selected and type I was sampled if available. Plot locations at transects were selected using a technique that removes operator bias (Appendix B).

Temperature and conductivity were measured and recorded at each transect sampled for larval lamprey. Temperature was measured in Celsius and conductivity was recorded with a Corning handheld conductivity meter in ohms. All lamprey collected were placed in a plastic freezer bag and stored at - 5 °C for 2-4 months until processed. In order to calculate density in the wadable waters section, the number of ammocoetes/m² and transformers/m² was divided by a correction factor of 0.48 as described by Fodale et al. (1998). The corrected densities for type I and II habitats were extrapolated for the total estimated quantity of these habitat types to estimate ammocoete and transformer abundance. Confidence intervals were calculated for the estimate of ammocoete and transformer abundance using the variation in ammocoete and transformer density.

Non-Wadable Water Section

At each transect in the non-wadable water section larval lamprey were sampled using a standard deep-water electro-fisher at standard settings (Bergstedt and Genovese 1994; Fodale et al 1998; Appendix A). The deep-water electro-fisher samples with a 0.61 m² bell placed on the stream bottom and applies pulsed DC current within the bell. Stunned ammocoetes are brought to the surface with suction. A single sample is termed a drop and four drops equal a plot. Five plots were equally spaced across a transect for sampling sea lamprey ammocoetes. Plot spacing began 2 - 6 m from the left shore facing upstream. At each plot an Ekman dredge was used to determine habitat type. If the habitat was type III, then a new plot was selected. Four drops were made for sampling ammocoete density at each plot and a mean plot density was calculated. The total area of each sampling plot was 2.44 m² (4 drops x area of bell or 0.61m²). Each drop was electro-fished for 30 seconds achieving a voltage gradient in the bell of 0.7 volts/cm. The pump was run for an additional 30 seconds with the electro-fisher power off to allow the pump to clear. GPS coordinates, temperature and conductivity were recorded at each plot. All lamprey captured were stored in zip-lock bags and frozen at - 5 °C until dissection.

Adult Spawning Phase and Nest Assessment

Sea lamprey nests were counted in Pike River and Morpion Stream to obtain an estimate of the total number of sea lamprey nests and their spatial distribution within each stream. A mark-recapture population estimate was not performed due to high stream discharge that created low capture efficiency of the nets for spawning sea lamprey. The nest of the sea lamprey is shaped to form a crescent, typically 0.3-1 m in diameter, with the convex side facing upstream (Applegate 1950). Nest construction requires gravel 15-115 mm diameter; however, rubble, clamshells, clumps of clay and woody debris may be utilized when gravel is scarce (Morman et al. 1980). Nest location was recorded with respect to location between transects. Additionally, thirty-one nests in the Pike River and 11 nests in Morpion Stream were sampled for presence of viable sea lamprey eggs.

A crew of two to three people walked from the start of the wadable section in the Pike River, to the dam at Notre Dame-de-Stanbridge, counting each nest and determining

its location within the river. In Morpion Stream, crews of one or two people counted nests beginning at the start of the wadable section and ending at transect 86.

Laboratory Processing

Lamprey were removed from the freezer to thaw for thirty minutes before processing. Each lamprey was identified to species with assistance from a taxonomist (John Gersmehl). Additionally, life stage (ammocoetes or metamorphosing larvae) was determined from external features. Lamprey were measured (total maximum length) to the nearest millimeter and weighed (wet weight) to 0.01 gram using a AND ek-120a balance. Condition factor was calculated for each lamprey using the equation $CF = \text{weight/length}^3 \times 10^6$ (Youson et al. 1993).

After length and weight were obtained, each lamprey was assigned an age by examining statoliths (Volk 1986). Statoliths are located within the otic capsule of the ammocoete. Each lamprey has two otic capsules posterior to the eyespot and anterior to the brachial basket. Both otic capsules were removed and sliced in half in order to remove the statolith. Each pair of statoliths from a lamprey was placed in a Falcon Becton Dickinson flexible plate, 96 well, flat bottom container. Each well of the container was filled with 2 milliliters of 100% glycerol. Each well had an individual alphanumeric code to identify a lamprey to its assigned age.

One person assigned ages to all statoliths using an Olympus SZ11 (40-110x) dissecting scope and a transmitted light source. Statoliths were readable only if the light source originated from the bottom of the dissecting scope. Age was assigned by counting the number of opaque bands (annuli) (Volk 1986). One year was added to the assigned age of metamorphosing ammocoetes because during the year of metamorphosis larvae do not lay annuli on the statolith (Medland and Beamish 1991).

RESULTS

Pike River - Wadable Section

Habitat Assessment

Suitable larval sea lamprey habitat (type I and II) represents 21.3% of the total wadable section or approximately 69,500 m² of habitat (Tables 3 and 4; Figures 2, 3, 4

Table 3. Area of sea lamprey habitat types and percent of each habitat type in the wadable and non-wadable waters of Pike River and wadable waters of Morpion Stream during 1999.

Stream section	Habitat type			
	Type I	Type II	Type III	Spawning
Pike River/wadable waters				
Area (m ²)	16,972	52,470	258,007	5,828
% Area	5.1	15.7	77.4	1.7
Pike River/non-wadable waters				
Area (m ²)	251,563	28,750	7,188	
% Area	87.5	10	2.5	
Morpion Stream/wadable waters				
Area (m ²)	21,420	19,662	78,005	5,503
% Area	17.2	15.8	62.6	4.4
Total area	289,955	100,882	343,200	11,331
% Total area	38.9	13.5	46	1.5

Table 4. Distance (m) to Pike River transects (transect 1 begins at the dam in Notre-Dame de Stanbridge), length (m) of habitat type at each transect and area of habitat types between transects during 1999.

Transect	Distance (m)	Distance of Habitat Along Transect (m)					Area of Habitat Between Transect n and n-1 (m ²)				
		Type I	Type II	Type III	Spawning	Stream Width	Type I	Type II	Type III	Spawning	Total
1	109.0	0.6	2.1	25.3	7.3	35.4	66.5	232.8	2759.9	798.0	3857.2
2	40.0	0.6	31.0	1.2	0.0	32.8	24.4	1238.6	48.8	0.0	1311.8
3	48.0	4.0	60.7	3.2	0.0	67.9	190.4	2914.0	153.8	0.0	3258.1
4	105.0	10.2	38.3	3.4	0.0	51.9	1073.1	4020.0	352.3	0.0	5445.4
5	82.0	3.1	37.5	2.1	0.0	42.7	250.2	3076.9	175.1	0.0	3502.1
6	96.0	1.2	29.6	7.2	0.0	38.0	117.1	2840.8	688.2	0.0	3646.1
7	85.0	0.0	1.1	31.4	0.0	32.5	0.0	90.8	2670.8	0.0	2761.6
8	66.0	5.5	31.4	6.4	4.9	48.2	362.4	2073.8	422.8	322.1	3181.2
9	63.0	12.2	7.3	20.7	0.0	40.3	768.8	461.3	1306.9	0.0	2536.9
10	87.0	0.3	5.5	21.4	0.0	27.2	26.5	477.7	1857.8	0.0	2362.1
11	99.0	0.8	0.0	30.0	0.0	30.8	75.5	0.0	2974.8	0.0	3050.3
12	138.0	0.0	0.0	37.8	0.0	37.8	0.0	0.0	5220.3	0.0	5220.3
13	86.0	0.9	5.8	23.8	0.0	30.5	78.7	498.5	2046.4	0.0	2623.6
14	109.0	10.2	11.0	30.8	0.0	51.8	1113.9	1197.1	2626.9	0.0	4937.9
15	103.0	0.5	26.1	16.5	0.0	43.0	47.1	2686.5	1696.8	0.0	4430.4
16	84.0	0.0	1.1	35.5	0.0	36.6	0.0	89.7	2985.4	0.0	3075.0
17	71.0	0.0	0.9	33	1.0	34.9	0.0	0.0	0.0	0.0	0.0
18	110.0	3.4	36.5	5.8	0.0	45.6	369.1	4010.1	637.6	0.0	5016.8
19	42.0	5.5	20.0	9.0	5.3	39.8	230.6	839.2	378.0	224.2	1672.1
20	90.0	22.6	15.9	14.5	0.0	52.9	2031.7	1427.7	1304.1	0.0	4763.6
21	70.0	13.4	35.1	4.9	0.0	53.4	939.6	2455.8	341.7	0.0	3737.0
22	74.0	10.5	32.9	14.0	0.0	57.5	778.8	2438.1	1038.4	0.0	4255.3
23	43.0	1.5	40.1	10.5	0.0	52.2	65.6	1725.0	452.6	0.0	2243.1
24	67.0	0.0	3.8	33.1	0.0	36.9	0.0	255.5	2217.7	0.0	2473.2
25	54.0	1.7	0.8	30.7	0.0	33.1	90.6	41.2	1655.6	0.0	1787.4
26	54.0	1.4	1.5	32.3	0.0	35.2	74.1	82.4	1746.2	0.0	1902.7
27	90.0	0.0	0.3	37.5	0.0	37.8	0.0	27.5	3377.1	0.0	3404.5
28	96.0	0.6	1.4	36.6	0.0	38.6	58.6	131.8	3514.3	0.0	3704.7
29	46.0	1.2	9.9	32.5	0.0	43.6	56.1	456.1	1494.5	0.0	2006.7
30	54.0	0.0	0.0	40.6	0.0	40.6	0.0	0.0	2191.0	0.0	2191.0
31	63.0	0.0	0.3	39.4	0.0	39.7	0.0	19.2	2479.3	0.0	2498.5
32	75.0	0.0	0.5	40.0	45.5	0.0	0.0	0.0	0.0	0.0	0.0
33	64.0	0.0	0.8	40.9	0.0	41.6	0.0	48.8	2616.2	0.0	2665.0
34	95.0	0.0	0.3	35.1	0.0	35.4	0.0	29.0	3332.8	0.0	3361.8
35	69.0	4.7	9.2	37.1	0.0	50.9	326.3	631.5	2557.5	0.0	3515.3
36	115.0	1.2	0.3	40.0	0.0	41.5	140.3	35.1	4595.8	0.0	4771.2
37	100.0	0.0	2.7	30.2	2.7	35.7	0.0	274.6	3020.1	274.6	3569.2
38	101.0	2.0	1.5	38.4	3.5	45.5	200.3	154.1	3882.2	354.3	4590.9
39	103.0	0.0	0.8	37.1	2.1	40.0	0.0	78.6	3817.7	220.0	4116.2
40	52.0	0.0	1.5	29.9	0.0	31.4	0.0	79.3	1554.6	0.0	1633.9
41	58.0	0.0	0.6	37.5	0.0	38.1	0.0	35.4	2176.3	0.0	2211.7
42	89.0	0.0	0.3	30.2	0.0	30.5	0.0	27.2	2633.6	0.0	2660.8
43	82.0	0.0	0.6	31.7	0.0	32.3	0.0	50.0	2601.6	0.0	2651.6
44	48.0	0.0	0.0	39.4	0.0	39.4	0.0	0.0	1889.0	0.0	1889.0
45	97.0	0.0	0.0	34.5	2.1	36.6	0.0	0.0	3343.8	207.1	3550.9
46	111.0	0.0	0.3	36.2	0.0	36.5	0.0	33.9	4012.7	0.0	4046.5
47	86.0	0.0	11.6	28.8	0.0	40.4	0.0	996.9	2479.3	0.0	3476.2
48	89.0	1.2	0.0	29.6	0.0	30.8	108.6	0.0	2633.6	0.0	2742.2
49	59.0	0.0	0.3	31.6	0.0	31.9	0.0	18.0	1862.9	0.0	1880.9
50	58.0	0.0	4.6	36.8	0.0	41.3	0.0	265.4	2132.1	0.0	2397.5
51	39.0	0.6	1.8	45.5	0.0	47.9	23.8	71.4	1772.7	0.0	1867.9

Table 4. (Continued).

Transect	Distance (m)	Distance of Habitat Along Transect (m)					Area of Habitat Between Transect n and n-1 (m ²)				
		Type 1	Type 2	Type 3	Spawning	Stream Width	Type 1	Type 2	Type 3	Spawning	Total
52	63.0	0.3	0.6	42.7	0.0	43.6	19.2	38.4	2690.7	0.0	2748.3
53	98.0	0.0	0.5	44.8	0.0	45.3	0.0	44.8	4394.8	0.0	4439.6
54	40.0	0.0	2.7	35.5	13.7	52.0	0.0	109.8	1421.6	549.1	2080.5
55	71.0	0.0	0.9	34.2	0.0	35.1	0.0	65.0	2425.9	0.0	2490.8
56	40.0	0.5	2.6	31.6	0.0	34.6	18.3	103.7	1263.0	0.0	1385.0
57	39.0	0.3	2.6	33.9	0.0	36.8	11.9	101.1	1320.6	0.0	1433.6
58	47.0	0.0	0.2	31.7	0.0	31.9	0.0	7.2	1491.2	0.0	1498.3
59	98.0	0.0	0.0	34.3	0.0	34.3	0.0	0.0	3363.3	0.0	3363.3
60	67.0	0.0	0.0	29.1	4.9	34.0	0.0	0.0	1952.0	327.0	2279.0
61	110.0	6.7	3.7	41.5	0.0	51.9	738.3	402.7	4563.8	0.0	5704.7
62	43.0	0.9	5.9	36.9	0.0	43.8	39.4	255.8	1587.2	0.0	1882.4
63	84.0	0.0	0.3	37.2	0.0	37.5	0.0	25.6	3126.3	0.0	3151.9
64	92.0	3.7	1.4	32.2	0.0	37.2	336.8	126.3	2961.0	0.0	3424.0
65	55.0	0.2	0.2	33.1	1.8	35.2	8.4	8.4	1820.5	100.7	1937.9
66	71.0	0.0	0.0	30.5	0.0	30.5	0.0	0.0	2166.0	0.0	2166.0
67	88.0	0.0	0.9	25.0	4.9	30.8	0.0	80.5	2201.3	429.5	2711.4
68	130.0	1.4	0.0	23.6	9.8	34.8	178.5	0.0	3073.5	1269.1	4521.0
69	115.0	0.6	21.7	10.2	0.0	32.5	70.2	2490.8	1175.3	0.0	3736.3
70	48.0	0.3	0.0	25.8	0.0	26.1	14.6	0.0	1237.3	0.0	1252.0
71	48.0	1.4	3.4	24.1	0.0	28.8	65.9	161.1	1156.8	0.0	1383.8
72	46.0	1.7	7.3	21.7	0.0	30.7	77.2	336.8	996.3	0.0	1410.3
73	54.0	0.8	1.8	25.9	0.0	28.5	41.2	98.8	1400.2	0.0	1540.3
74	125.0	0.9	0.6	30.5	0.0	32.0	114.4	76.3	3813.3	0.0	4004.0
75	66.0	0.0	1.4	52.3	0.0	53.7	0.0	90.6	3453.0	0.0	3543.6
76	52.0	0.0	0.2	31.4	0.0	31.6	0.0	7.9	1633.9	0.0	1641.9
77	53.0	0.0	0.6	30.4	0.0	31.0	0.0	32.3	1608.8	0.0	1641.1
78	51.0	0.0	5.0	27.3	0.0	32.3	0.0	256.7	1392.5	0.0	1649.2
79	64.0	0.0	1.2	29.6	0.0	30.8	0.0	78.1	1893.8	0.0	1971.9
80	82.0	0.0	1.5	34.6	0.0	36.2	0.0	125.1	2839.2	0.0	2964.3
81	94.0	2.6	1.2	35.1	0.0	38.9	243.7	114.7	3297.7	0.0	3656.2
82	62.0	0.5	0.5	34.8	0.0	35.7	28.4	28.4	2156.2	0.0	2212.9
83	50.0	0.3	0.0	33.9	0.0	34.2	15.3	0.0	1693.1	0.0	1708.4
84	82.0	0.0	0.3	38.7	0.0	39.0	0.0	25.0	3176.9	0.0	3202.0
85	66.0	0.0	0.0	41.6	0.0	41.6	0.0	0.0	2748.3	0.0	2748.3
86	48.0	0.0	0.6	44.8	0.0	45.5	0.0	29.3	2152.5	0.0	2181.8
87	116.0	4.3	12.8	50.9	0.0	68.0	495.4	1486.3	5909.7	0.0	7891.4
88	104.0	0.0	0.6	47.0	3.1	50.6	0.0	63.5	4885.9	317.3	5266.6
89	105.0	0.0	0.5	46.7	0.0	47.1	0.0	48.0	4900.9	0.0	4948.9
90	81.0	3.1	12.2	30.8	0.0	46.1	247.1	988.4	2495.7	0.0	3731.2
91	102.0	0.0	0.2	38.7	0.0	38.9	0.0	15.6	3951.8	0.0	3967.4
92	106.0	1.2	0.6	32.8	0.0	34.6	129.3	64.7	3476.2	0.0	3670.2
93	45.0	1.5	3.1	35.5	0.0	40.1	68.6	137.3	1599.3	0.0	1805.2
94	83.0	1.2	0.2	34.3	2.6	38.3	101.3	12.7	2848.5	215.2	3177.7
95	111.6	0.0	0.0	34.3	0.0	34.3	0.0	0.0	3830.1	0.0	3830.1
96	108.0	0.6	0.3	29.1	0.0	30.0	65.9	32.9	3146.4	0.0	3245.3
97	122.0	0.0	1.2	24.3	1.2	26.7	0.0	409.4	2958.8	148.9	3517.1
98	80.0	1.2	0.6	38.1	0.0	39.9	97.6	48.8	3001.8	0.0	3148.3
99	44.0	0.9	0.0	42.1	0.0	43.0	40.3	0.0	1852.3	0.0	1892.6
100	111.0	17.1	6.4	52.2	0.0	75.7	1896.3	711.1	5790.4	0.0	8397.8
101	63.0	6.6	50.0	2.1	0.0	58.7	413.2	3151.9	134.5	0.0	3699.7
102	49.0	2.9	9.8	47.1	0.0	59.8	142.0	478.3	2309.5	0.0	2929.8
103	55.0	4.7	5.5	35.8	0.0	46.1	260.1	302.0	1971.5	0.0	2533.6
104	91.0	14.3	7.3	44.4	0.0	66.0	1304.8	666.3	4039.2	0.0	6010.2
105	74.0	0.0	0.8	57.5	0.0	58.3	0.0	56.4	4255.3	0.0	4311.8
106	91.0	0.0	0.0	56.7	0.0	56.7	0.0	0.0	5163.5	0.0	5163.5

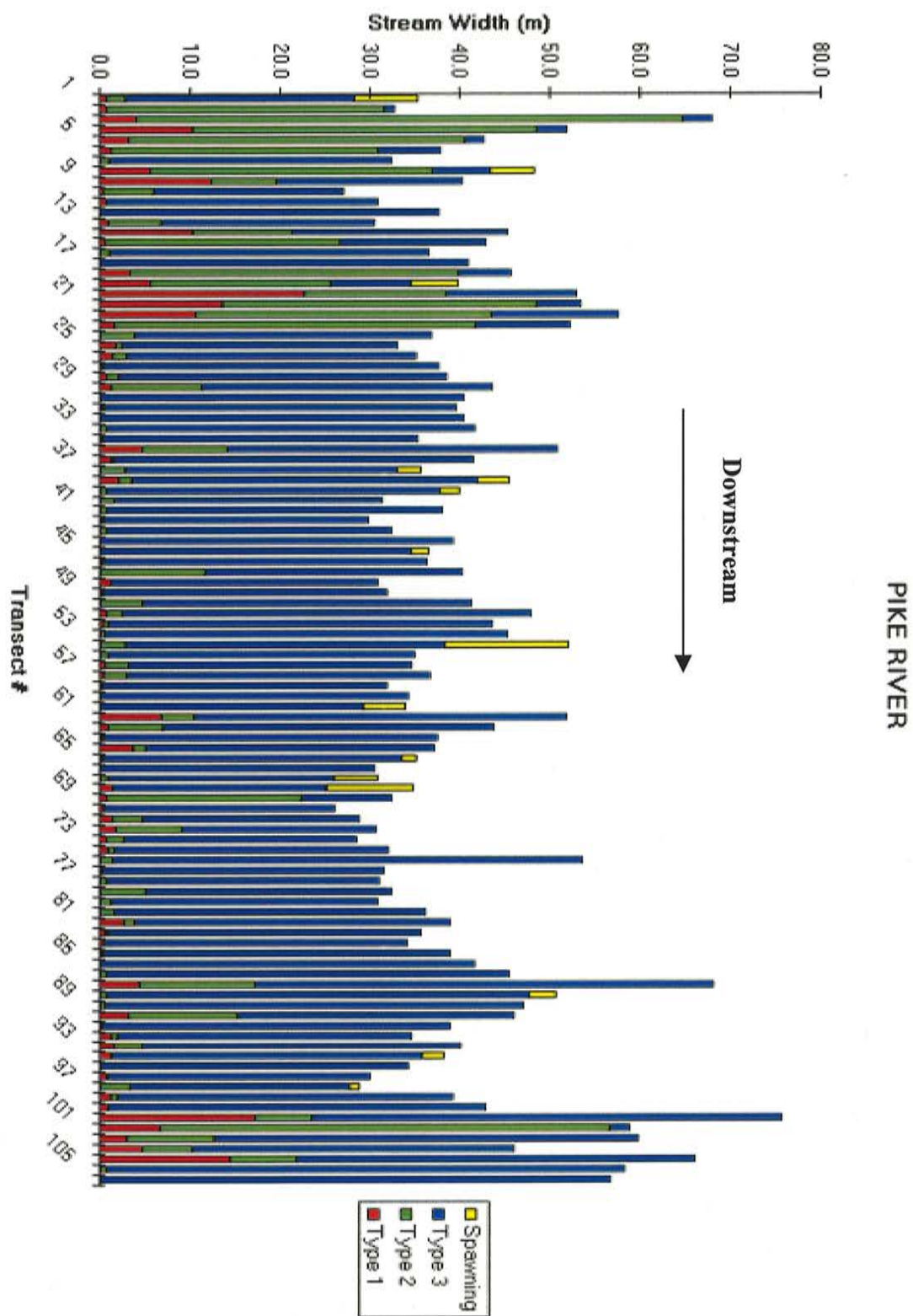


Figure 2. Distance of habitat type (m) at each transect in the wadable waters section of Pike River during 1999.

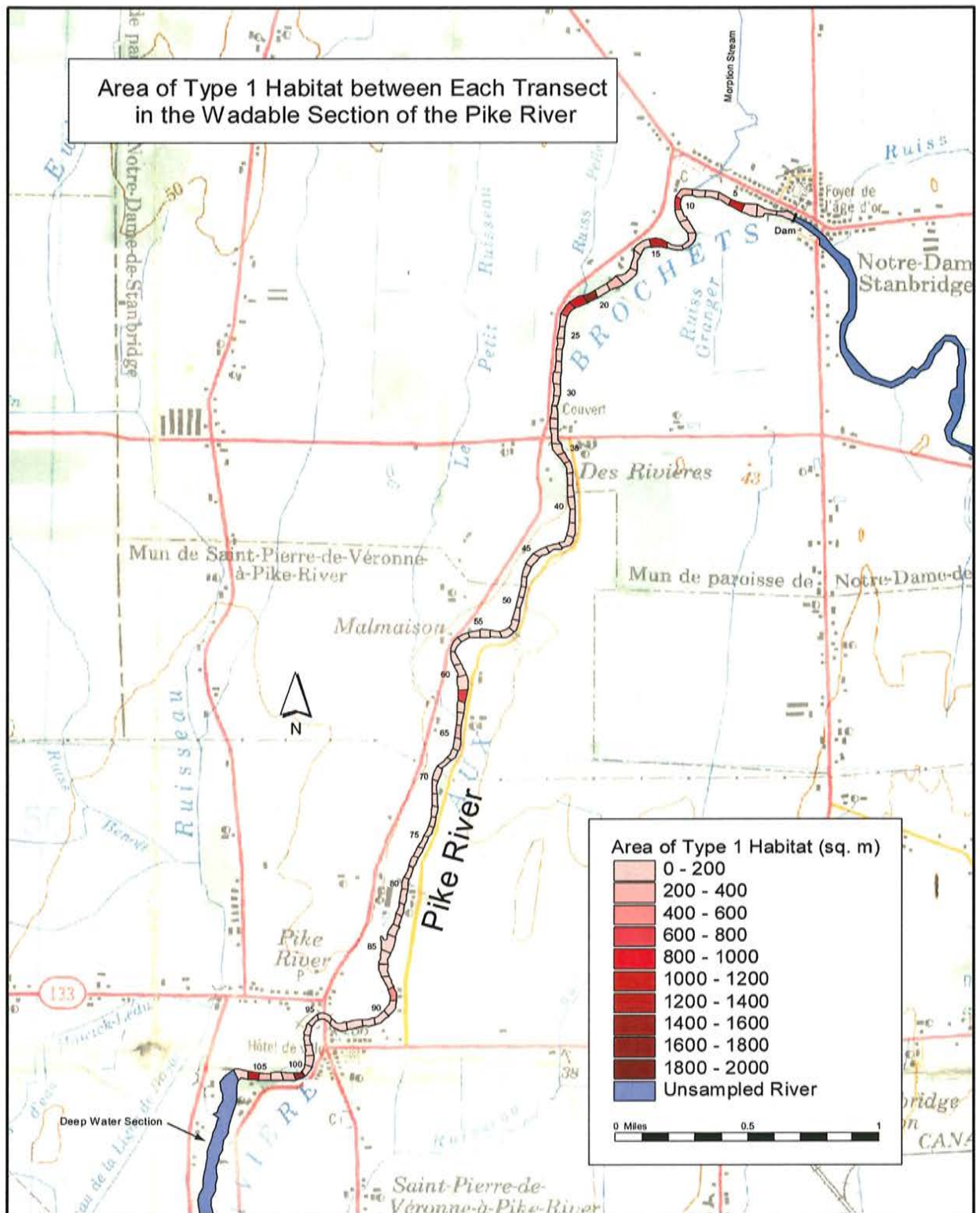


Figure 3. Area of type I habitat between each transect in the wadable waters section of Pike River during 1999.

and 5). More than 75% of the wadable section is type III habitat. Less than 2% of the total river area consists of spawning habitat. The majority of spawning habitat is at the upstream end of the wadable section.

Nest Count

In the Pike River, 347 nests were counted. One hundred thirty five nests (39%) were located between transect 1 and 18. Between transect 1 and 60, 230 nests (66%) were counted. The remaining 117 nests (34%) were located between transect 60 and 106. Of 31 nests assessed, 58% contained eggs or newly hatched larvae.

Larval Abundance

At 37 different transects 44 plots were electro fished. Three quarters of the plots (33) were sampled in type I habitat and the remaining 11 plots were in type II habitat. Sampled type I habitat totaled 133.6 m² and sampled type II habitat totaled 49.6 m².

A total of 138 sea lamprey larvae were collected in the Pike River. Mean ammocoete density in type I habitat was over 3 times higher than in type II habitat. However, area of type II habitat was larger, thus ammocoete total abundance was similar between the two habitat types (Table 5; Figure 6). Mean density of metamorphosing larvae was slightly higher in type II habitat. The Pike River had an estimated ammocoete population of $55,671 \pm 27,317$ (95% CI) and produced an estimated $2,264 \pm 4,635$ (95% CI) transformers in 1999. No silver or American brook lamprey were collected from Pike River.

Population Characteristics

Length frequency of the Pike River larval sea lamprey population has a bimodal shape (Figure 7). Over 72% of sea lamprey collected were age 3 (Figure 8). No young-of-the-year or age 1 sea lamprey were collected. Growth in length of Pike River lamprey was linear (Figure 9), while growth in weight was exponential (Figure 10). Only 3 transformers were collected, all of which were age 5.

Pike River – Non-Wadable Water Section

In the non-wadable water section, 70 of the 80 drops were taken in type I habitat and the remaining 10 drops were in type II. Only one sea lamprey was collected from type I habitat. At 15% efficiency the estimated ammocoete abundance in the non-wadable section of the Pike River from this one ammocoete was 10,063.

Table 5. Sea lamprey ammocoete density (ammocoetes/m²) and abundance, and transformer density and production (transformers/m²) in type I and type II habitat in wadable and non-wadable waters section of the Pike River during 1999. Numbers in parentheses represent standard error.

Habitat type/life stage	Mean density (ammocoetes/m ²)	Total area (m ²)	Total abundance
Wadable waters/ammocoetes			
Type I	1.79 (0.38)	16,972	30,363
Type II	0.45 (0.12)	52,470	23,835
Non-wadable waters/ammocoetes			
Type I	0.04	251,563	10,063
Type II	0	28,750	0
Wadable waters/transformers			
Type I	0.026 (0.17)	16,972	442
Type II	0.035 (0.03)	52,470	1,822

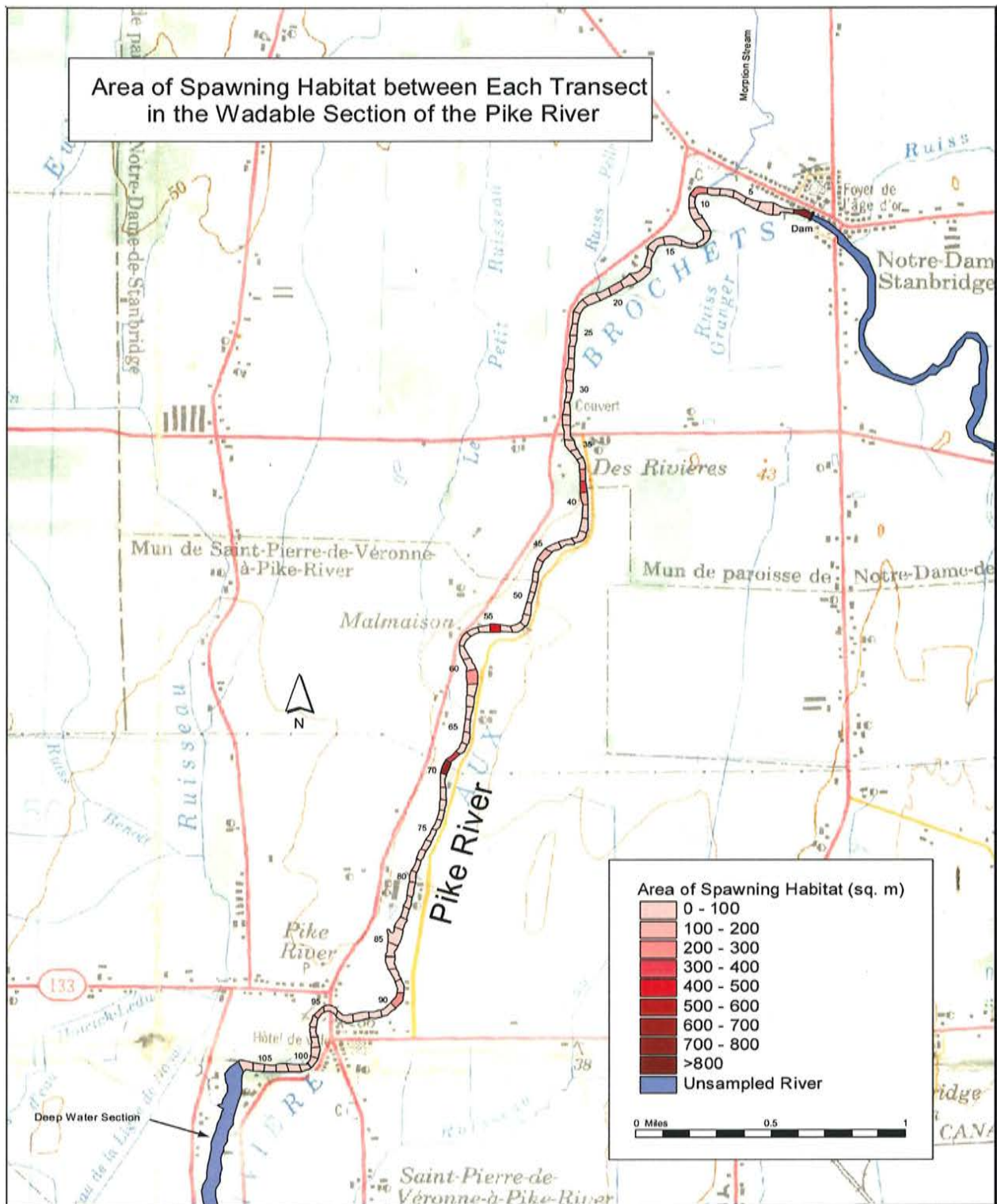


Figure 5. Area of spawning habitat between each transect in the wadable waters section of Pike River during 1999.

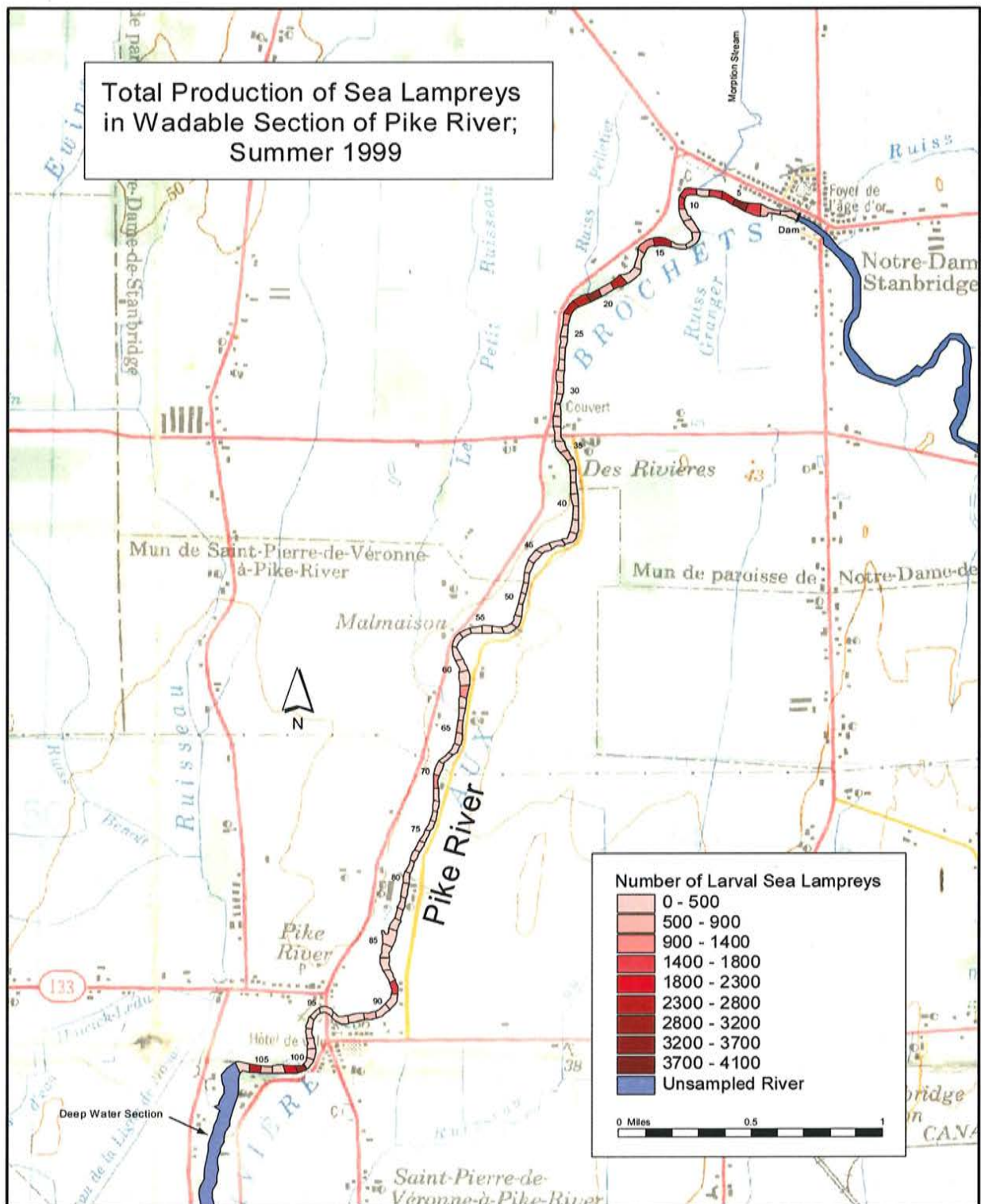


Figure 6. Total estimated production (larval abundance) of sea lamprey in the wadable waters section of Pike River during 1999.

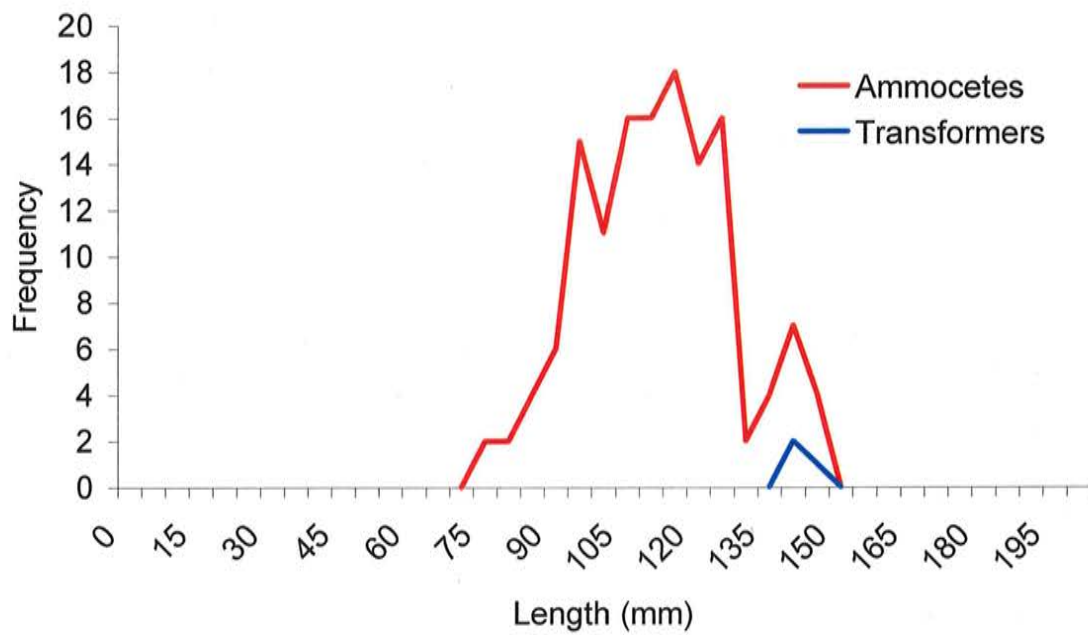


Figure 7. Length frequency of larval sea lamprey collected in 1999 in the wadable waters section of Pike River.

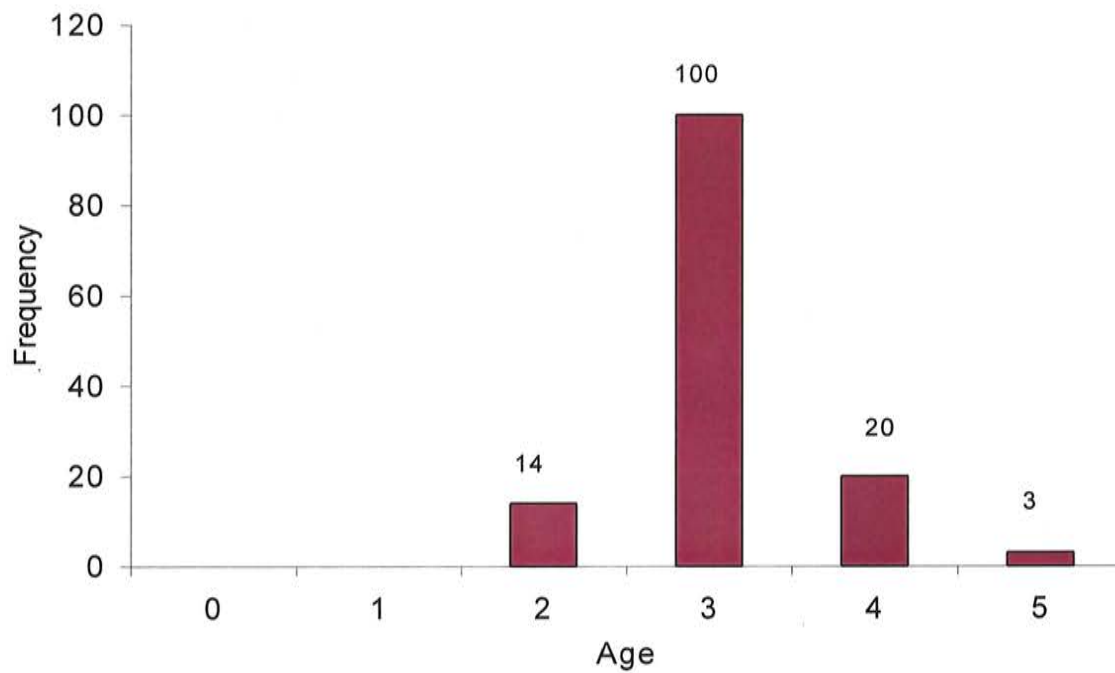


Figure 8. Age frequency for Pike River larval sea lamprey collected in 1999 with sample sizes.

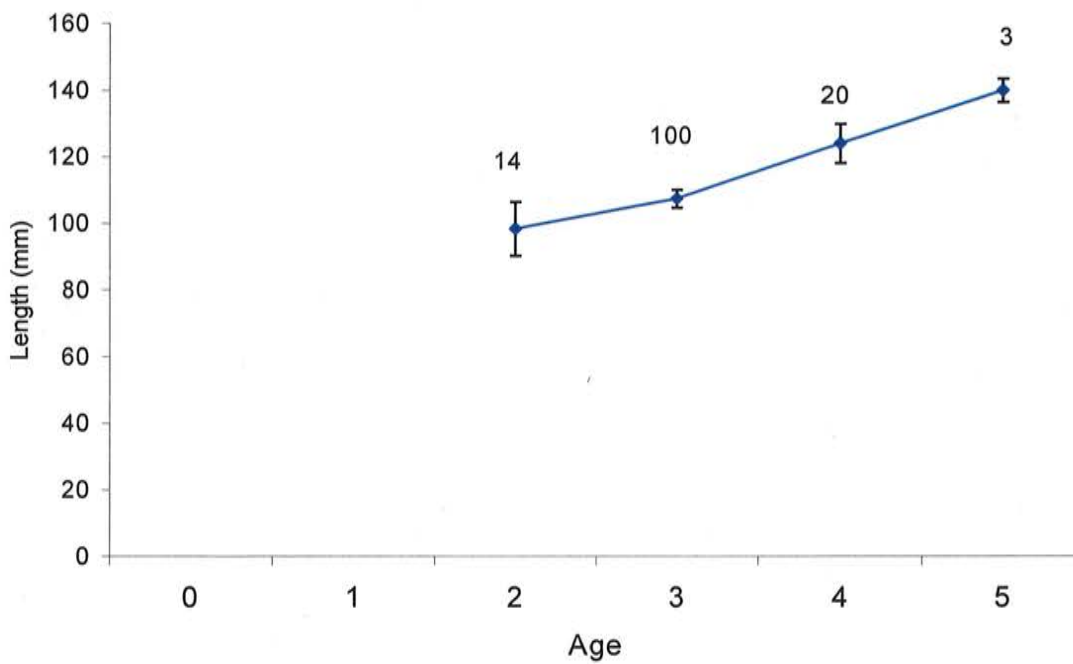


Figure 9. Length at age for Pike River larval sea lamprey collected in 1999 with 95% confidence intervals and sample sizes.

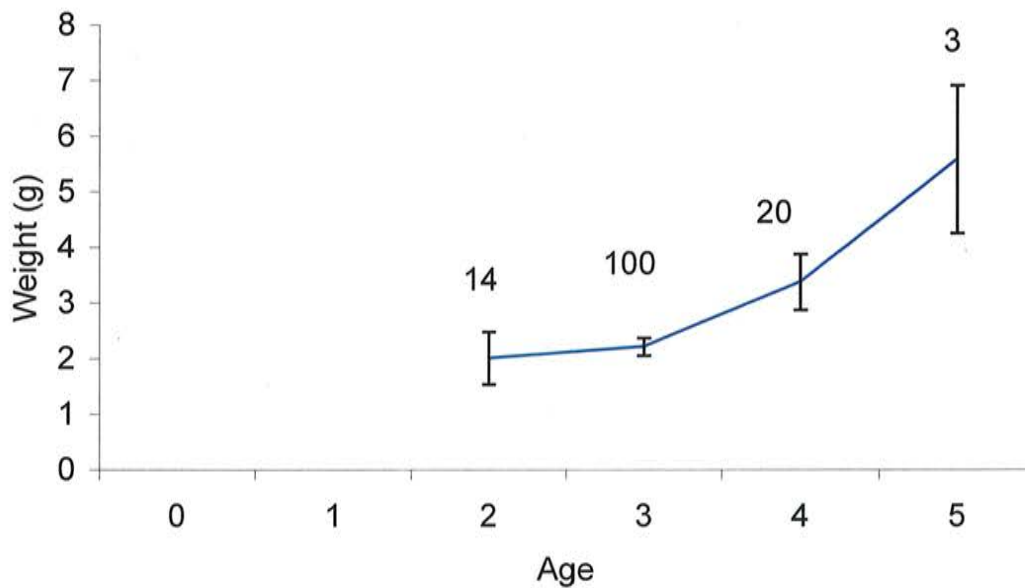


Figure 10. Weight at age for Pike River larval sea lamprey collected in 1999 with 95% confidence intervals and sample sizes.

Morpion Stream

Habitat Assessment

Approximately one third ($41,082 \text{ m}^2$) of habitat in Morpion Stream is suitable for larval lamprey (Table 3, 6; Figure 11, 12, 13,). Although Morpion Stream is 10% of the width of Pike River, it is 27.5 km long, resulting in a greater quantity of type I habitat than in the wadable waters section of Pike River and a similar quantity of spawning habitat (Figure 14).

Nest Count

In Morpion Stream 221 nests were counted. Nests were present between transect 1 and 81, 23.6 km upstream from the confluence with the Pike River. The vast majority of nests (95%) were located downstream of transect 44 (Figure 15). Of the 11 nests examined, 82% (9) contained eggs or newly hatched larvae.

Larval Abundance

Thirty-four plots at 31 transects were sampled for larval lamprey. Twenty-seven plots were sampled in type I habitat (111.2 m^2 sampled) and the remaining 7 plots (26.8 m^2 sampled) were in type II habitat. A total of 146 sea lamprey were collected from both habitat types. Ammocoete density in type I habitat was approximately three times higher than in type II (Table 7; Figure 16). Ammocoete density in Morpion Stream type I habitat was 53% higher than in Pike River type I habitat.

Morpion Stream type II density was 67% higher than Pike River. However, Pike River ammocoete abundance was higher in type II habitat due to a larger area of this substrate. Production of metamorphosing larvae from Morpion Stream was similar to that in the Pike River. Morpion Stream had an estimated ammocoete population of $76,595 \pm 48,182$ (95% CI) and produced an estimated $1,863 \pm 1,831$ (95% CI) transformers in 1999.

American brook lamprey represented 33% of the lamprey population in Morpion Stream. Morpion Stream had an estimated American brook lamprey ammocoete population of $23,636 \pm 14,737$ (95% CI). No American brook lamprey were collected from type II habitat. No silver lamprey were collected in Morpion Stream. American

Table 6. Distance (m) to Morpion Stream transects (transect 1 begins at the mouth of Morpion Stream in Notre-Dame de Stanbridge), length (m) of habitat type at each transects and area of habitat type between transects during 1999.

Transect	Distance (m)	Distance of Habitat Along Transect (m)					Area of Habitat Between Transect n and n-1(m ²)					Total
		Type I	Type II	Type III	Spawning	Stream Width	Type I	Type II	Type III	Spawning		
1	245	0.0	3.2	4.7	0.0	7.9	0.0	783.8	1157.0	0.0	1940.8	
2	287	1.2	0.9	4.9	0.0	7.0	349.7	262.3	1398.7	0.0	2010.7	
3	328	1.8	4.9	3.2	0.0	9.9	599.5	1598.5	1049.0	0.0	3247.0	
4	418	0.2	1.7	7.3	0.0	9.2	63.8	701.3	3060.4	0.0	3825.5	
5	232	0.2	0.0	7.2	0.0	7.3	35.4	0.0	1663.2	0.0	1698.6	
6	357	0.0	0.0	6.1	0.0	6.1	0.0	0.0	2178.2	0.0	2178.2	
7	383	0.0	0.0	7.6	0.0	7.6	0.0	0.0	2921.0	0.0	2921.0	
8	386	0.0	0.0	8.4	0.0	8.4	0.0	0.0	3238.3	0.0	3238.3	
9	326	0.0	4.4	4.7	0.0	9.2	0.0	1442.0	1541.5	0.0	2983.5	
10	385	0.0	0.0	7.2	0.0	7.2	0.0	0.0	2760.1	0.0	2760.1	
11	361	0.3	0.9	7.3	0.0	8.5	110.1	330.4	2643.1	0.0	3083.6	
12	350	0.0	0.5	7.8	0.0	8.2	0.0	160.2	2722.7	0.0	2882.9	
13	240	2.1	0.3	7.0	0.0	9.5	512.5	73.2	1684.0	0.0	2269.7	
14	274	0.0	0.2	6.4	0.0	6.6	0.0	41.8	1755.3	0.0	1797.1	
15	308	1.5	1.2	5.9	0.0	8.7	469.8	375.8	1832.2	0.0	2677.9	
16	163	0.0	0.0	7.5	0.0	7.5	0.0	0.0	1218.3	0.0	1218.3	
17	341	0.3	0.0	7.0	0.0	7.3	104.0	0.0	2392.6	0.0	2496.6	
18	287	1.5	3.1	3.8	0.0	8.4	437.8	875.5	1094.4	0.0	2407.7	
19	169	1.1	1.2	0.6	5.0	7.9	180.4	206.2	103.1	850.7	1340.5	
20	417	2.3	0.8	2.6	0.0	5.6	954.1	318.0	1081.3	0.0	2353.4	
21	416	0.9	2.0	2.3	0.0	5.2	380.7	824.9	951.8	0.0	2157.4	
22	246	0.0	0.0	0.0	3.2	3.2	0.0	0.0	0.0	788.0	788.0	
23	379	0.5	2.4	3.1	0.0	5.9	173.4	925.0	1156.2	0.0	2254.6	
24	400	0.3	0.0	6.1	0.0	6.4	122.0	0.0	2440.5	0.0	2562.5	
25	352	0.0	0.0	3.7	0.0	3.7	0.0	0.0	1288.6	0.0	1288.6	
26	205	0.3	0.0	5.3	0.0	5.6	62.5	0.0	1094.4	0.0	1157.0	
27	336	0.0	0.0	3.8	0.0	3.8	0.0	0.0	1281.3	0.0	1281.3	
28	426	6.6	0.0	0.2	0.0	6.7	2794.1	0.0	65.0	0.0	2859.1	
29	145	5.9	0.6	0.5	0.0	7.0	862.6	88.5	66.4	0.0	1017.4	
30	249.0	5.9	0.0	0.0	0.0	5.9	1481.2	0.0	0.0	0.0	1481.2	
31	386.9	0.9	1.7	0.0	1.1	3.7	354.1	649.2	0.0	413.1	1416.4	
32	424.0	0.8	0.0	4.6	0.0	5.3	323.4	0.0	1940.2	0.0	2263.6	
33	233.4	0.0	0.0	4.3	0.0	4.3	0.0	0.0	996.8	0.0	996.8	
34	284.0	0.0	0.0	4.3	0.0	4.3	0.0	0.0	1212.9	0.0	1212.9	
35	206.0	0.0	0.0	4.9	0.0	4.9	0.0	0.0	1005.5	0.0	1005.5	
36	367.5	0.0	1.5	2.3	0.0	3.8	0.0	560.6	840.8	0.0	1401.4	
37	272.8	0.0	0.2	3.4	0.0	3.5	0.0	41.6	915.4	0.0	957.0	
38	157.0	0.0	0.0	4.0	0.0	4.0	0.0	0.0	622.6	0.0	622.6	
39	192.5	0.0	0.0	3.2	0.0	3.2	0.0	0.0	616.6	0.0	616.6	
40	352.0	4.3	1.8	0.0	0.0	6.1	1396.0	644.3	0.0	0.0	2040.3	
41	203.8	0.0	0.0	1.2	2.4	3.7	0.0	0.0	248.7	497.4	746.1	
42	380.6	0.0	2.0	2.3	0.0	4.3	0.0	754.7	870.8	0.0	1625.5	
43	152.0	0.0	1.1	2.6	0.0	3.7	0.0	162.3	394.1	0.0	556.4	
44	322.5	0.3	0.9	4.3	0.0	5.5	98.4	295.1	1377.4	0.0	1770.9	
45	181.9	2.9	1.1	1.2	0.0	5.2	527.2	194.2	222.0	0.0	943.3	
46	360.9	0.0	0.0	3.7	0.6	4.3	0.0	0.0	1321.2	220.2	1541.4	
47	363.0	0.0	0.2	3.5	0.0	3.7	0.0	55.4	1273.5	0.0	1328.9	
48	340.3	0.0	0.0	2.7	0.0	2.7	0.0	0.0	934.3	0.0	934.3	
49	370.0	0.6	1.7	2.9	0.0	5.2	225.7	620.8	1072.3	0.0	1918.9	
50	327.5	0.0	0.6	3.1	0.0	3.7	0.0	199.8	999.1	0.0	1198.9	
51	372.8	0.7	0.0	3.0	0.0	3.7	261.0	0.0	1118.4	0.0	1379.4	

Table 6. (continued.)

Table 6. (continued.)

Transect	Distance (m)	Distance of Habitat Along Transect (m)					Area of Habitat Between Transect n and n-1(m ²)					Total
		Type 1	Type 2	Type 3	Spawning	Stream Width	Type 1	Type 2	Type 3	Spawning		
52	249.1	5.0	0.0	0.0	0.0	5.0	1245.5	0.0	0.0	0.0	1245.5	
53	352.8	0.0	2.3	0.2	0.0	2.5	0.0	811.4	70.6	0.0	882.0	
54	162.5	2.4	1.7	0.0	0.0	4.1	390.0	276.3	0.0	0.0	666.3	
55	351.0	1.7	1.8	0.8	0.0	4.3	596.7	631.8	280.8	0.0	1509.3	
56	260.0	3.4	0.0	0.0	0.0	3.4	884.0	0.0	0.0	0.0	884.0	
57	425.3	0.8	2.7	0.0	0.0	3.5	340.2	1148.3	0.0	0.0	1488.6	
58	244.1	0.5	0.0	3.5	0.0	4.0	122.1	0.0	854.4	0.0	976.4	
59	159.1	1.4	0.0	2.7	0.0	4.1	222.7	0.0	429.6	0.0	652.3	
60	156.0	0.0	0.0	0.5	1.2	1.7	0.0	0.0	78.0	187.2	265.2	
61	459.0	0.0	0.0	3.2	0.0	3.2	0.0	0.0	1468.8	0.0	1468.8	
62	241.0	0.0	0.0	2.5	1.1	3.6	0.0	0.0	602.5	265.1	867.6	
63	463.0	0.6	0.2	1.6	0.0	2.4	277.8	92.6	740.8	0.0	1111.2	
64	333.0	0.0	0.0	2.2	0.0	2.2	0.0	0.0	732.6	0.0	732.6	
65	267.0	0.0	0.0	1.2	1.8	3.0	0.0	0.0	320.4	480.6	801.0	
66	195.0	0.8	1.1	3.1	0.0	5.0	156.0	214.5	604.5	0.0	975.0	
67	270.0	0.0	0.0	4.4	0.0	4.4	0.0	0.0	1188.0	0.0	1188.0	
68	354.0	1.8	1.2	0.8	0.0	3.8	637.2	424.8	283.2	0.0	1345.2	
69	280.6	0.0	0.1	3.2	0.0	3.3	0.0	28.1	898.0	0.0	926.1	
70	213.4	0.6	3.3	0.0	0.0	3.9	128.1	704.3	0.0	0.0	832.4	
71	286.9	0.8	0.0	2.5	1.0	4.3	229.5	0.0	717.2	286.9	1233.6	
72	191.6	0.0	0.0	1.2	0.0	1.2	0.0	0.0	229.9	0.0	229.9	
73	282.5	1.8	0.7	1.2	0.0	3.7	508.5	197.8	339.0	0.0	1045.3	
74	209.7	0.0	0.0	0.8	1.9	2.7	0.0	0.0	167.8	398.4	566.2	
75	213.1	0.3	0.2	2.4	0.0	2.9	63.9	42.6	511.5	0.0	618.1	
76	312.5	0.0	0.0	3.0	1.6	4.6	0.0	0.0	937.5	500.0	1437.5	
77	177.5	0.0	0.0	3.1	0.0	3.1	0.0	0.0	550.3	0.0	550.3	
78	179.7	0.0	1.6	1.0	0.0	2.6	0.0	287.5	179.7	0.0	467.2	
79	252.8	0.0	0.0	1.1	1.3	2.4	0.0	0.0	278.1	328.7	606.8	
80	167.5	0.0	0.2	2.8	0.0	3.0	0.0	33.5	469.0	0.0	502.5	
81	287.2	0.0	0.4	2.2	1.0	3.6	0.0	114.9	631.8	287.2	1033.9	
82	281.9	0.2	0.4	2.2	0.0	2.8	56.4	112.8	620.1	0.0	789.3	
83	347.5	1.5	3.9	0.0	0.0	5.4	521.3	1355.3	0.0	0.0	1876.5	
84	336.9	2.4	0.0	0.0	0.0	2.4	808.5	0.0	0.0	0.0	808.5	
85	200.9	2.6	0.0	0.0	0.0	2.6	522.4	0.0	0.0	0.0	522.4	
86	237.2	3.5	0.0	0.0	0.0	3.5	830.2	0.0	0.0	0.0	830.2	

Table 7. Sea lamprey and American brook lamprey ammocoete density (ammocoetes/m²) and abundance, and transformer density (transformers/m²) and production in type I and type II habitat in Morpion Stream during 1999. Numbers in parentheses represent standard error.

Habitat type/life stage	Mean density (ammocoete/m ²)	Total area (m ²)	Total abundance
Sea lamprey ammocoetes			
Type I	2.47 (0.62)	21,420	52,959
Type II	0.83 (0.44)	19,662	16,385
American brook lamprey ammocoetes			
Type I	1.10 (0.34)	21,420	23,636
Wadable waters/transformers			
Type I	0.09 (0.04)	21,420	1,863

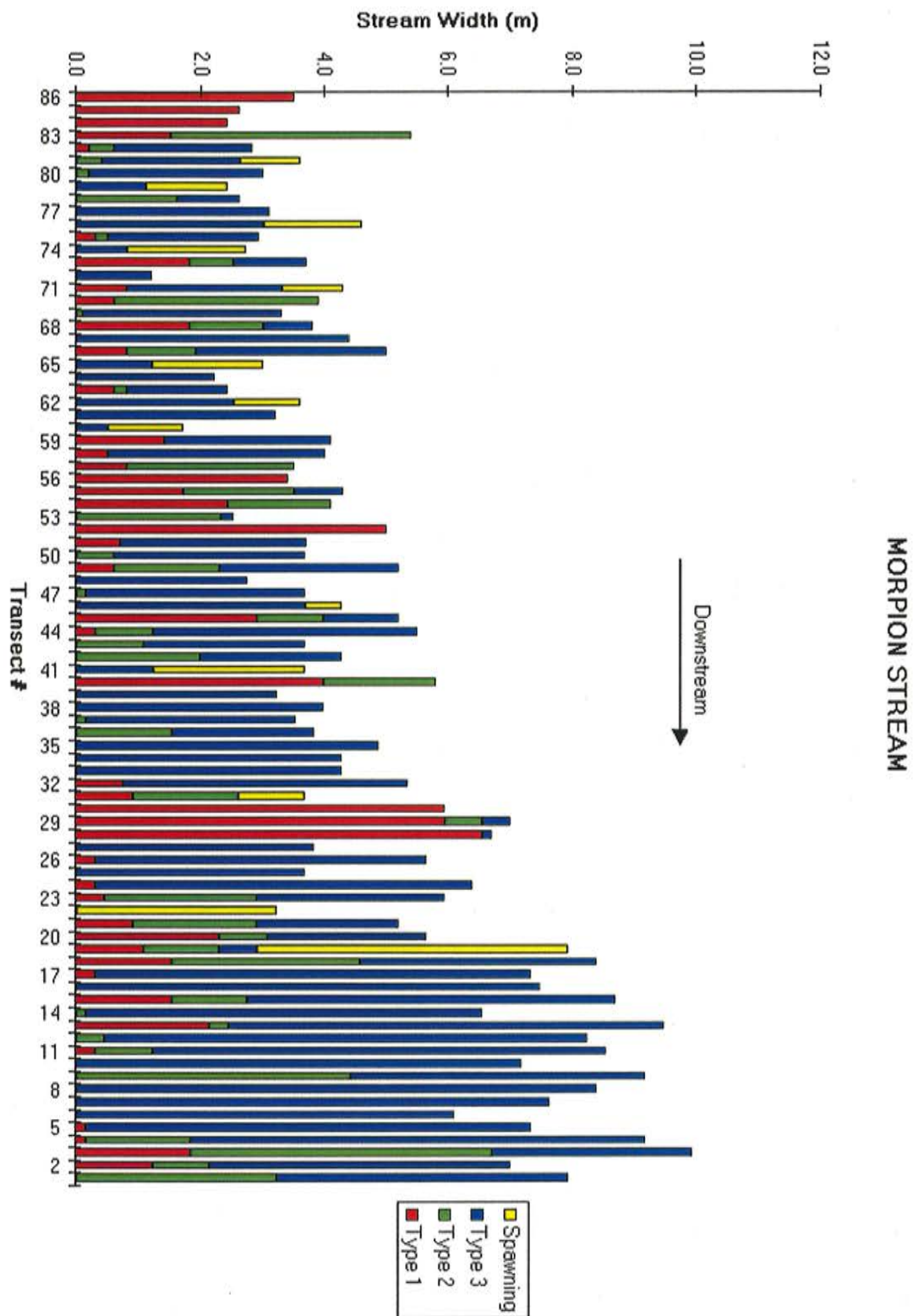


Figure 11. Distance of habitat type (m) at each transect in the wadable waters section of Morpion Stream during 1999.

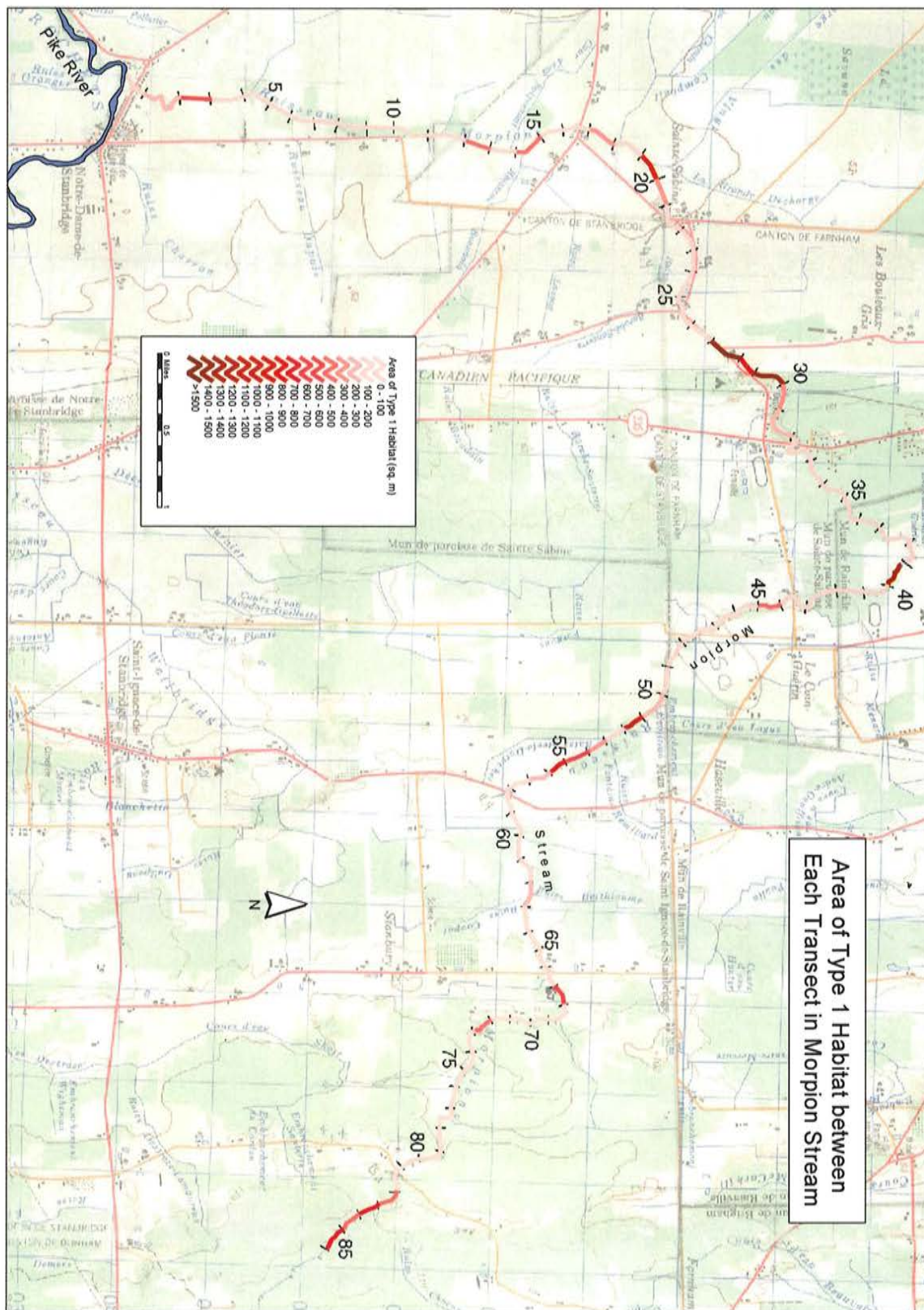


Figure 12. Area of type I habitat between each transect in Morpion Stream during 1999.

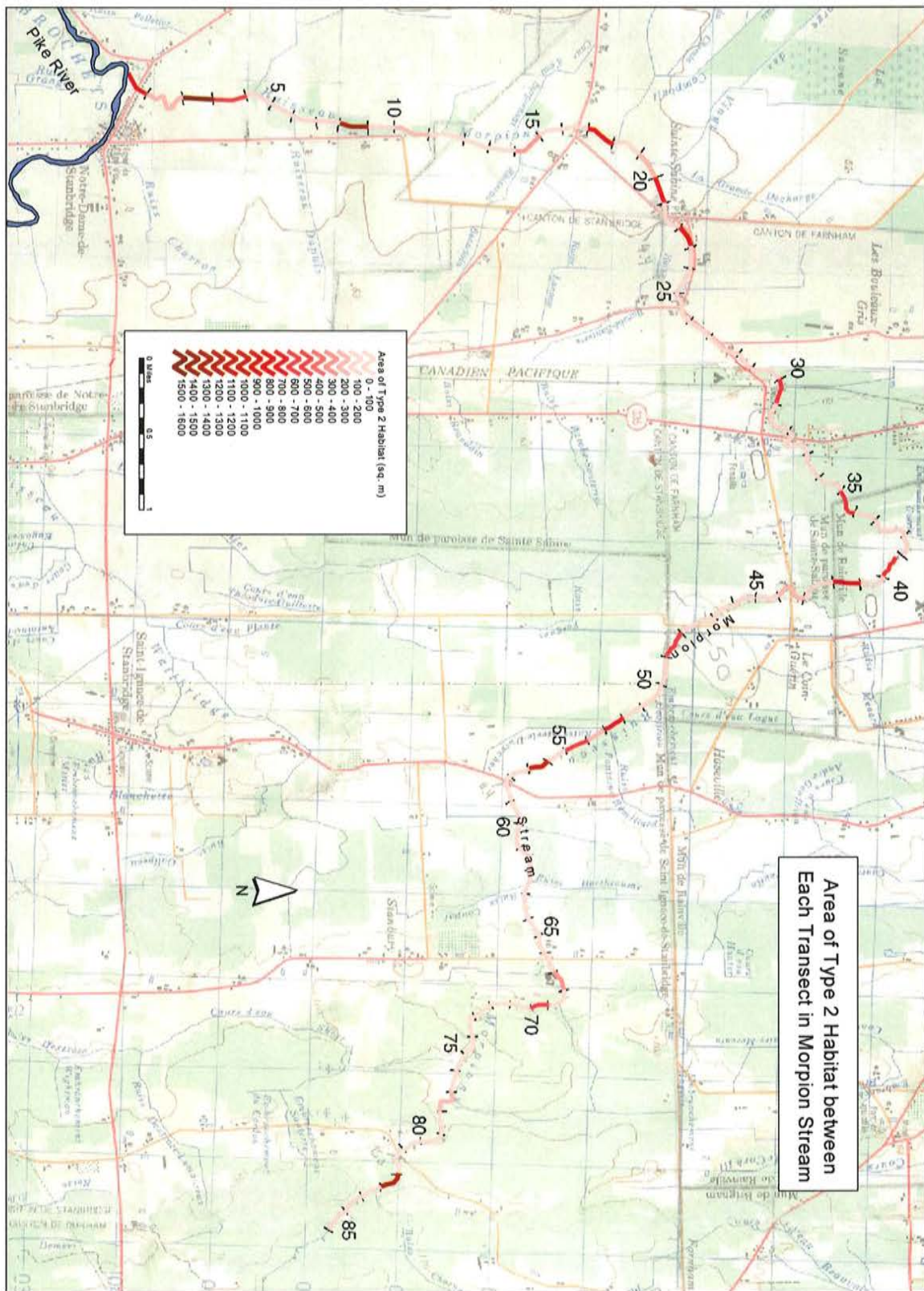


Figure 13. Area of type II habitat between each transect in Morpion Stream during 1999.

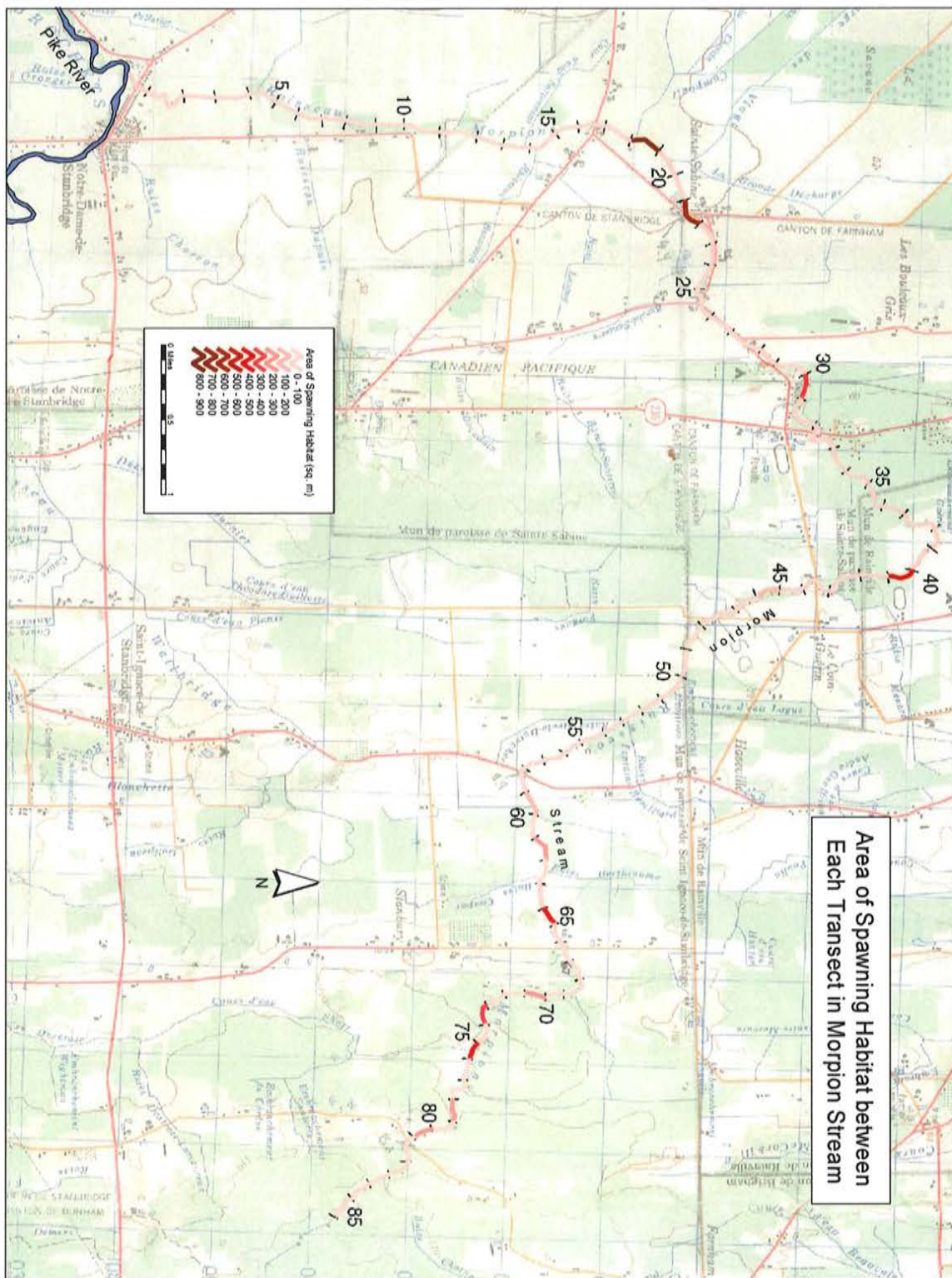


Figure 14. Area of spawning habitat between each transect in Morpion Stream during 1999.

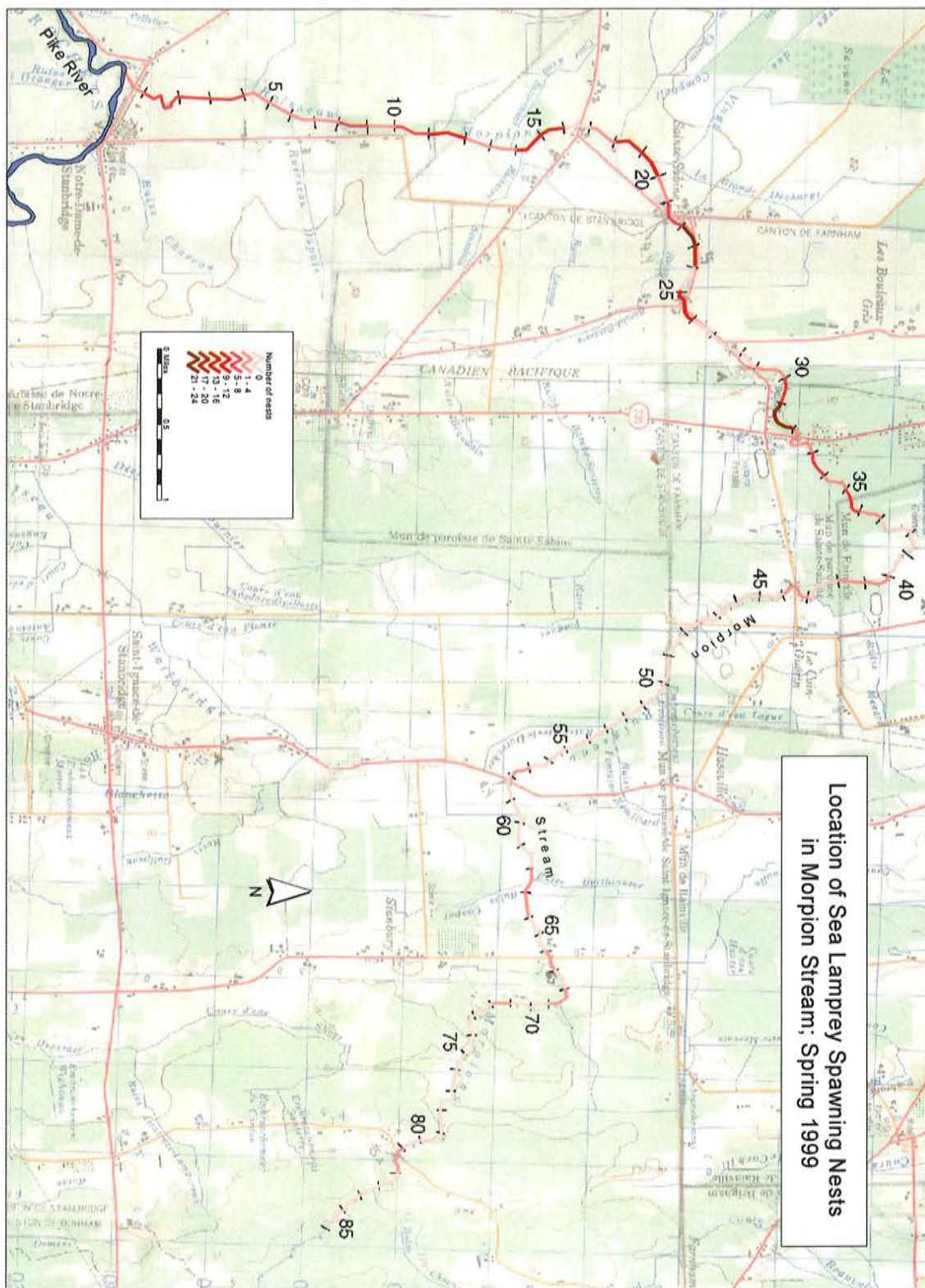


Figure 15. Number of sea lamprey nests between each transect in Morpion Stream during 1999.

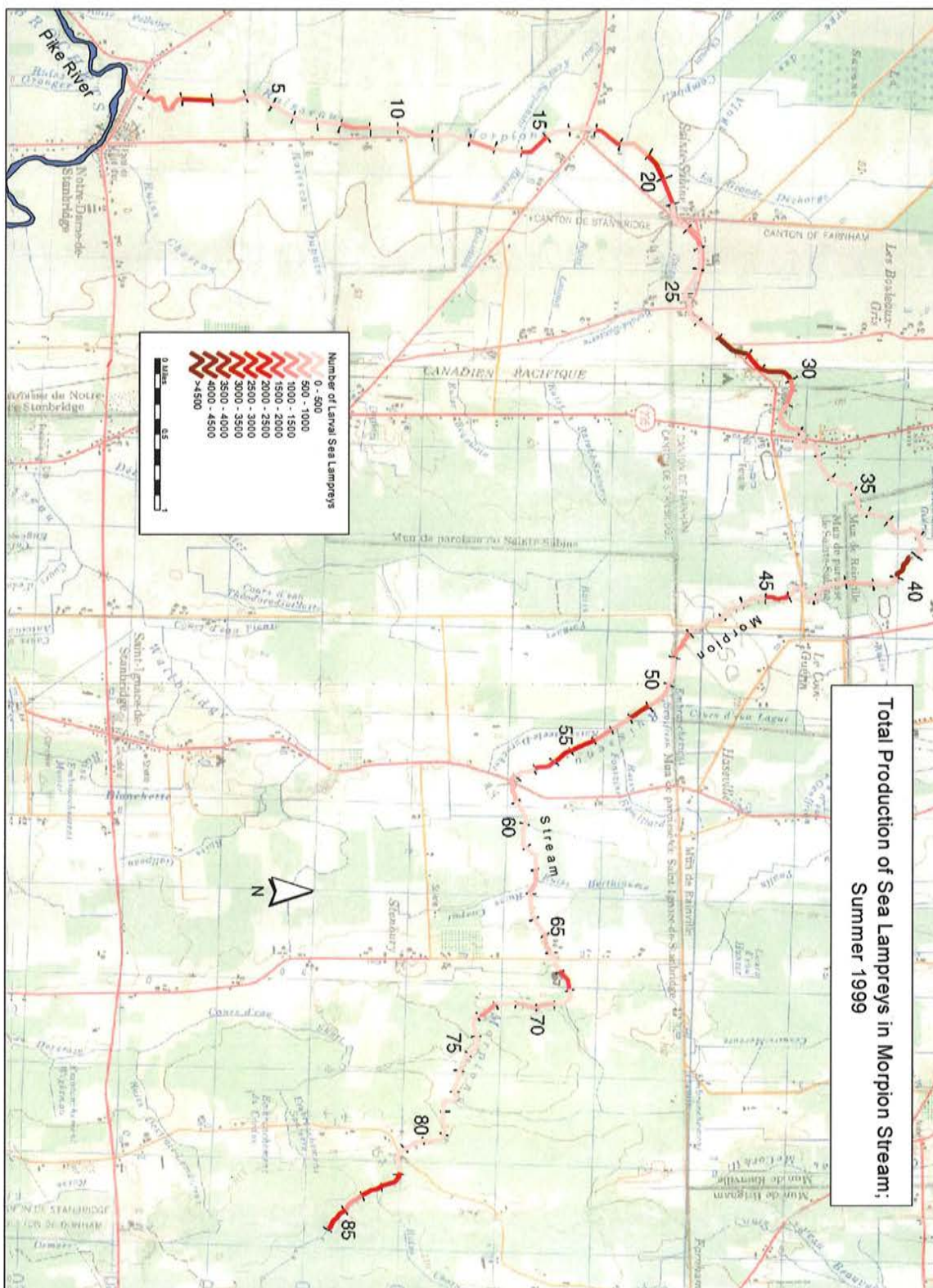


Figure 16. Total estimated production (larval abundance) of sea lamprey from Morpion Stream during 1999.

brook lamprey and sea lamprey have similar spatial distributions, however, American brook lamprey are restricted to the center portion of the stream (Figure 17).

Population Characteristics

The length frequency distribution for the Morpion Stream sea lamprey population has seven modes (Figure 18). These seven modes represent the five ammocoete age classes and metamorphosing larvae present in Morpion Stream (Figure 19). Growth in length is linear, whereas growth in weight is exponential (Figures 20 and 21). Morpion Stream had relatively strong age 1, 2 and 3 cohorts, while few old age classes were collected. Of 143 sea lamprey collected from Morpion Stream, 4 were sea lamprey transformers.

The length frequency distribution for the American brook lamprey population is skewed to the left or towards younger larvae (Figure 22). As with the sea lamprey population, growth in length for brook lamprey is linear, while growth in weight is exponential (Figures 23 and 24). Age 0 lamprey of both species are clearly under-sampled by the electro-shocker (Figures 19 and 25).

DISCUSSION

Sea Lamprey Distribution and Abundance

Sea lamprey ammocoetes were found in the Pike River from its mouth to the dam in Notre Dame-de-Stanbridge and throughout most of Morpion Stream. Although abundant ammocoete habitat occurred above river kilometer 25 on Morpion Stream, no ammocoetes were observed, possibly due to an absence of spawning habitat upstream of this reach and/or its long distance to the lake.

Ammocoetes may be present in the watershed in areas not surveyed during this study. The dam in Notre Dame-de-Stanbridge had structural repairs during 1999 and is believed to serve as a sea lamprey barrier. Prior to the repair, however, spawning sea lamprey may have been able to navigate through the dam and gain access to spawning habitats upstream. The reach above Notre Dame-de-Stanbridge to the Bedford Dam, Quebec, has not been surveyed for ammocoetes. Walbridge Stream, a tributary below Bedford Dam, should also be surveyed. Morpion stream has one tributary, Barbe-Santere, with a known

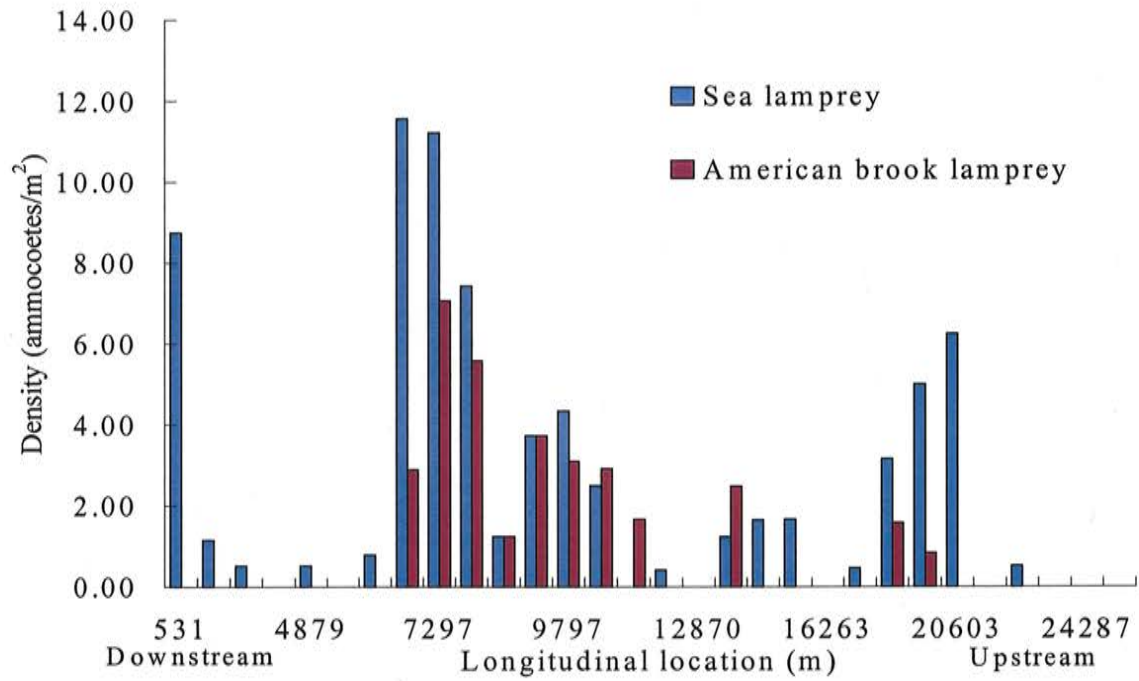


Figure 17. Longitudinal distribution of sea lamprey and American brook lamprey ammocoetes in Morpion Stream during 1999.

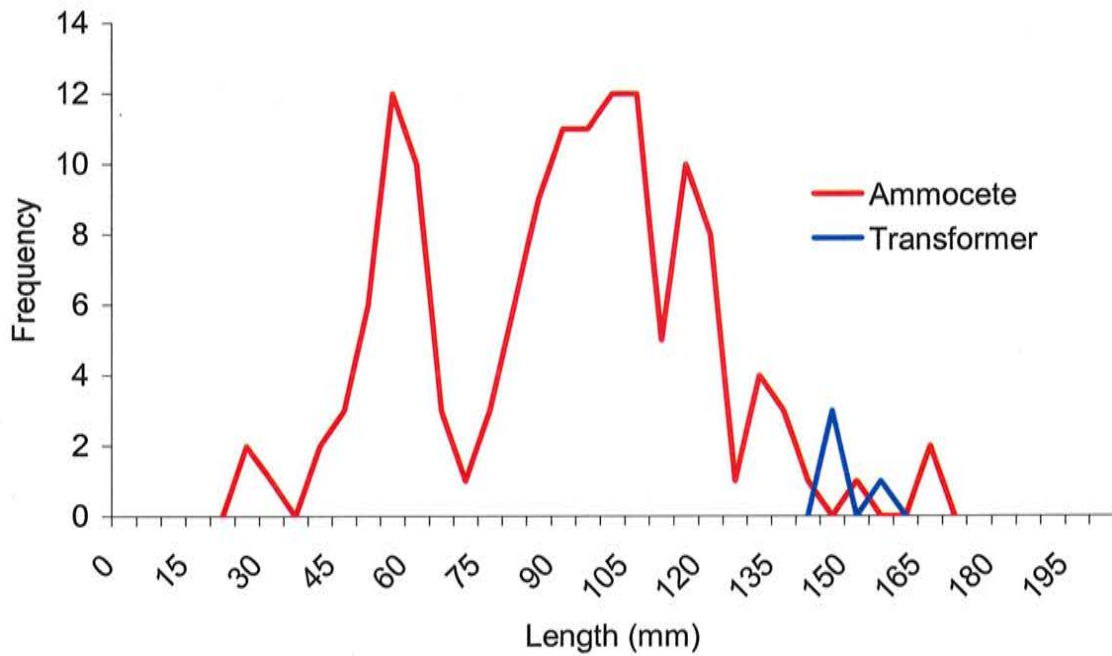


Figure 18. Length frequency of sea lamprey collected in 1999 in Morpion Stream.

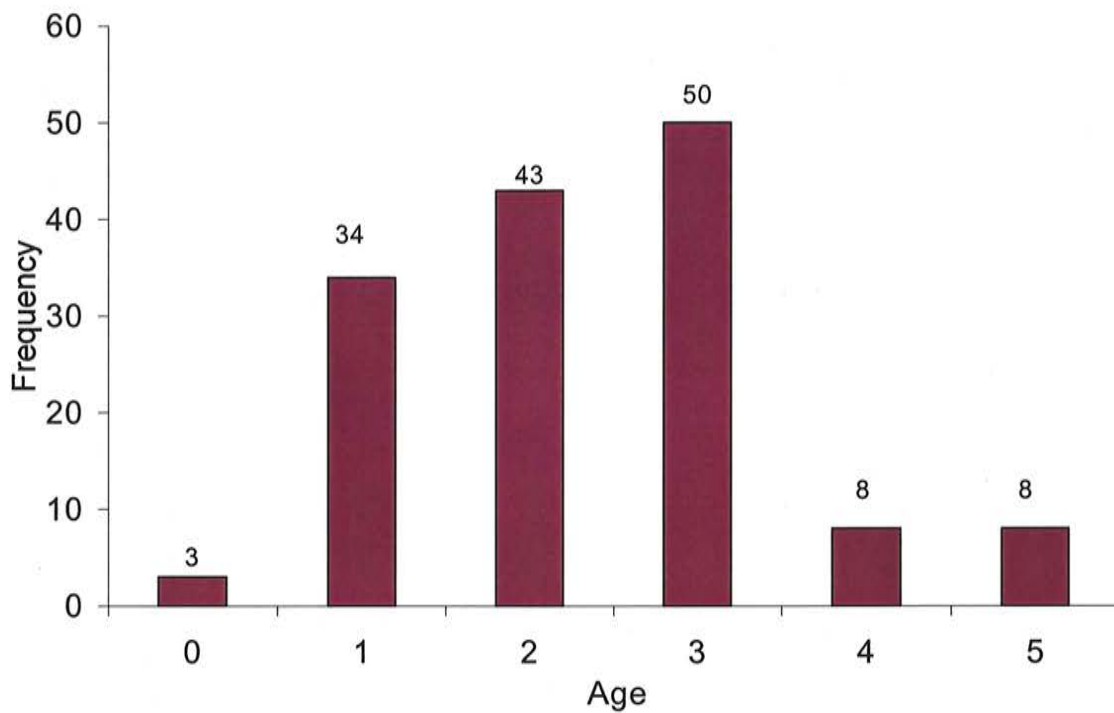


Figure 19. Age frequency for Morpion Stream larval sea lamprey collected in 1999 with sample sizes.

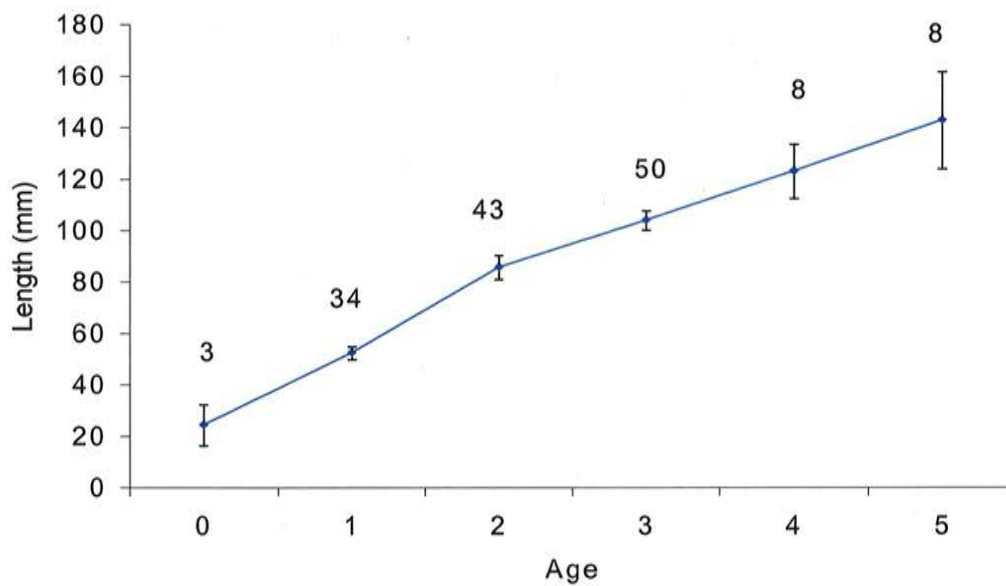


Figure 20. Length at age for Morpion Stream larval sea lamprey collected in 1999 with 95% confidence intervals and sample sizes.

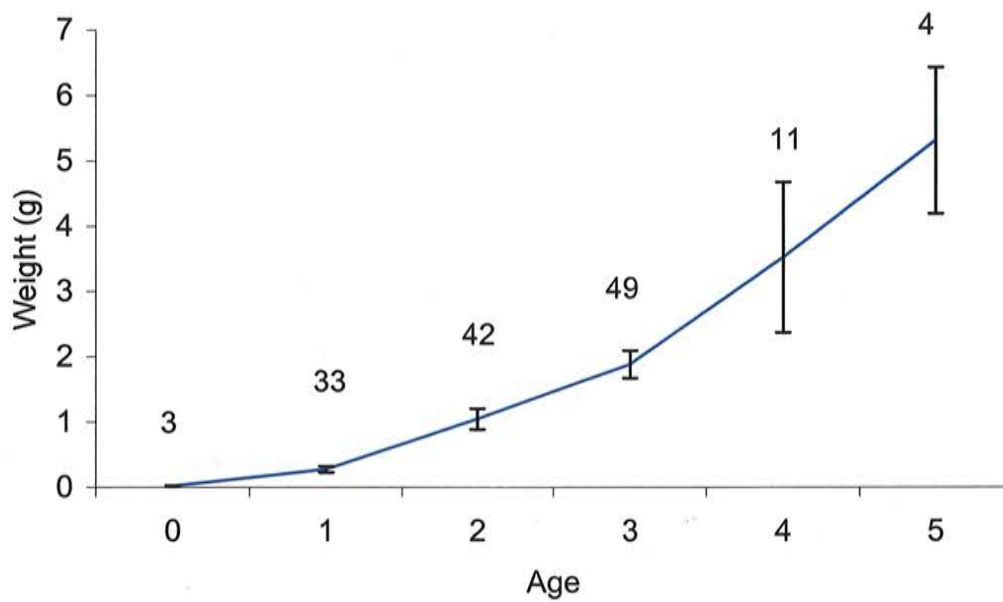


Figure 21. Weight at age for Morpion Stream larval sea lamprey collected in 1999 with 95% confidence intervals and sample sizes

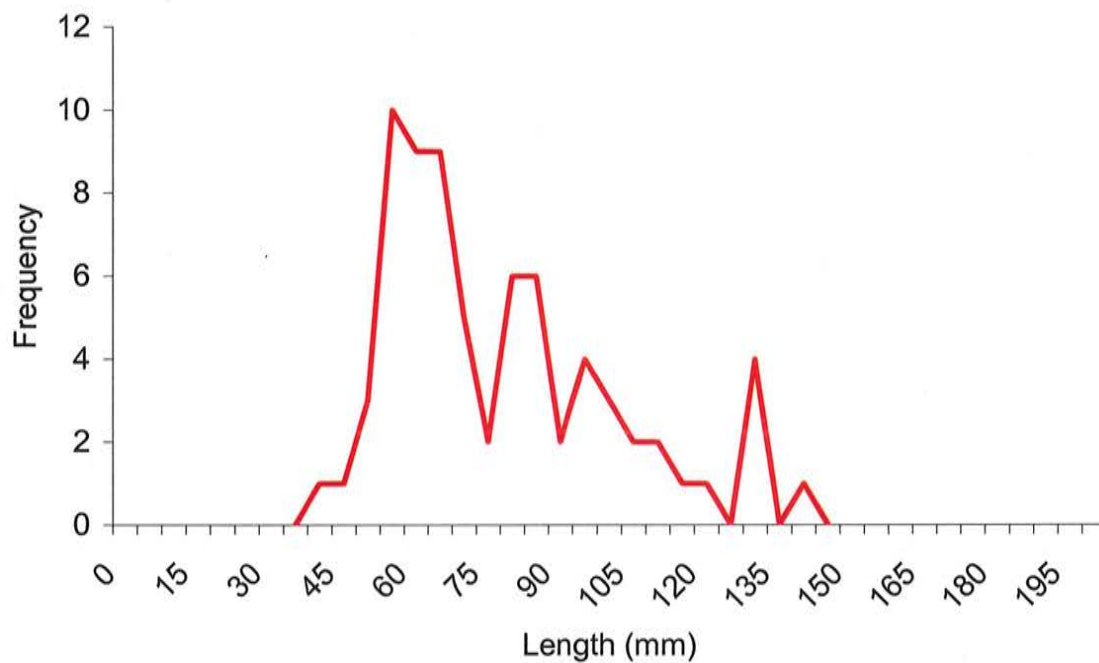


Figure 22. Length frequency for American brook lamprey collected in 1999 in Morpion Stream.

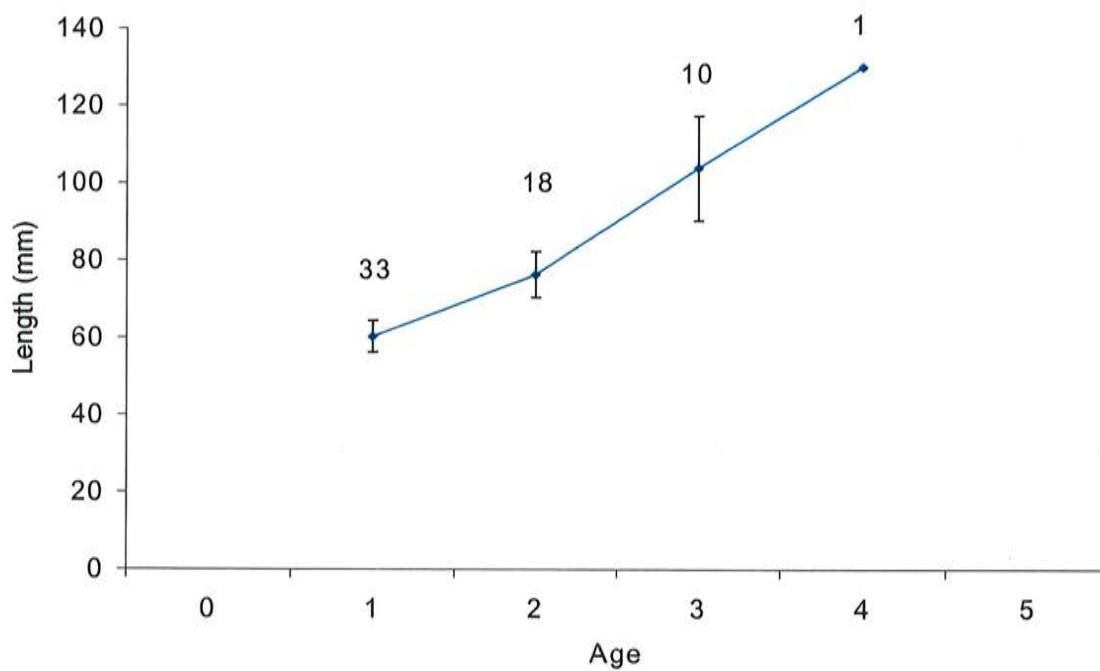


Figure 23. Length at age for Morpion Stream larval American brook lamprey collected in 1999 with 95 % confidence intervals and sample sizes.

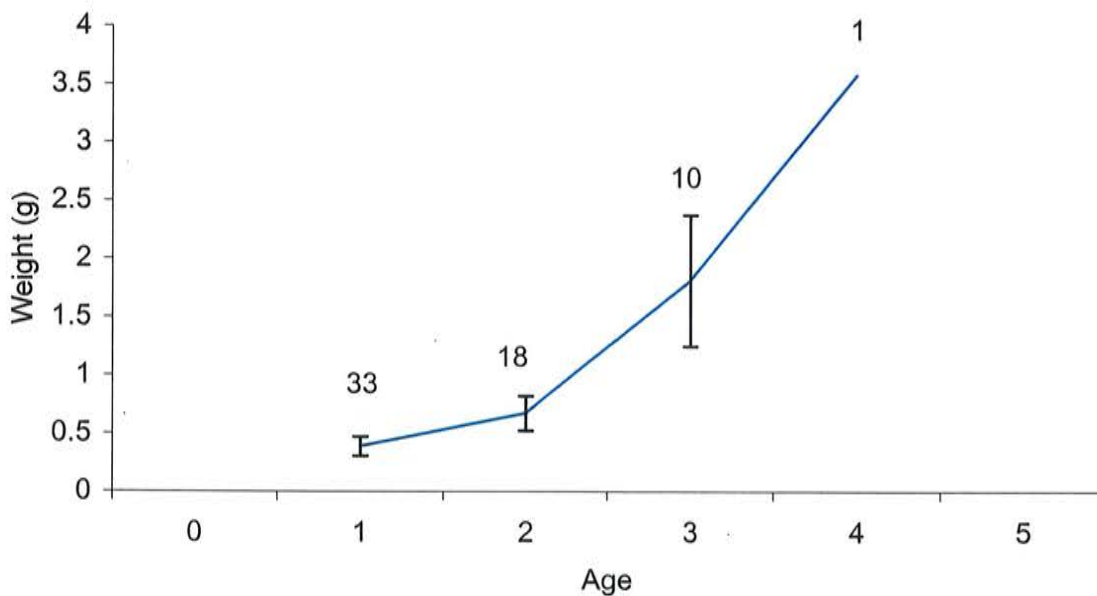


Figure 24. Weight at age for Morpion Stream larval American brook lamprey collected in 1999 with 95% confidence intervals and sample sizes.

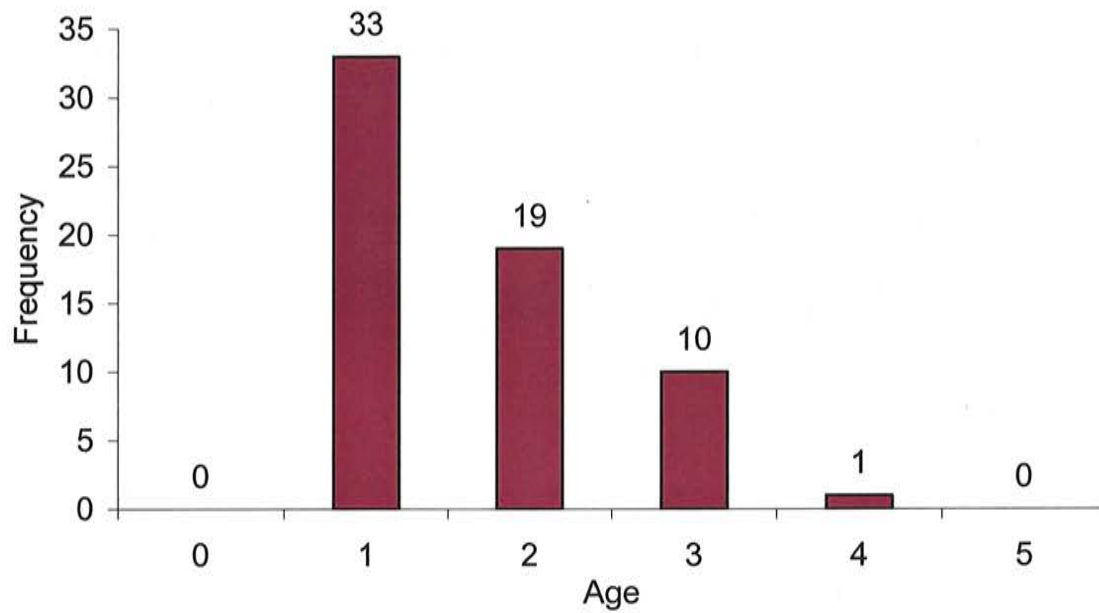


Figure 25. Age frequency for Morpion Stream larval American brook lamprey collected in 1999 with sample sizes.

sea lamprey ammocoete population. Similar sized tributaries of Morpion Stream were observed during this study that may also have sea lamprey ammocoete populations. All tributaries of Morpion Stream should be surveyed to investigate whether sea lamprey ammocoetes are present.

Sampling methodologies used by this project were designed to provide statistically reliable estimates of ammocoete density. When combined with measures of habitat, these data were used to estimate ammocoete abundance. In the non-wadable reach of the Pike River, one sea lamprey ammocoete was collected with the deep-water electro fishing boat. An abundance estimate based on one individual is unreliable. Currently, the efficiency of the deep-water electro fishing boat has not been determined for the range of sampling conditions encountered in this study, such as length of ammocoetes captured in different depths, conductivities and substrate types (Bergstedt and Genovese 1994). Once these relationships are determined, surveys should be conducted to validate the estimate of larval abundance in the non-wadable reach of Pike River.

During 1999, five year-classes of ammocoetes were present in Morpion Stream, while Pike River was missing age 1 and had a low proportion of age 2 ammocoetes, relative to other year classes. Observations during 1998 indicate that sea lamprey ammocoetes hatched from nests located in Pike River. The 1998 year class could either have migrated out of Pike River to the delta or experienced high mortality. It is unlikely that the entire year class of ammocoetes migrated to the delta because other older age classes were collected in the river. Ammocoete location within a stream, known as longitudinal distribution, is influenced by two factors: spawning location and the continuous passive downstream movement of ammocoetes (Hardisty and Potter 1971). Initial downstream movement of ammocoetes occurs when larvae reach 7 mm total length and once their yolk sac is nearly absorbed; a mass dispersal distributes ammocoetes in available habitat downstream from spawning grounds (Hardisty and Potter 1971). With the exception of re-distribution of newly emerged ammocoetes, minimal downstream movement occurs in streams with low stream gradient, low discharge and low water velocity (Leach 1940; Potter 1970). These hydrological and morphological features are typical of lamprey-infested reaches of the Pike River.

Conversely, streams with high gradients typically have higher water velocities, creating a marked distribution of year classes in a downstream direction; young-of-the-year occur furthest upstream and ammocoetes increases in age in a downstream direction (Hardisty 1944). These data support prior studies that suggested sea lamprey ammocoetes in the Pike River originated from Morpion Stream (Gersmehl 1994). These findings may have large implications for developing control alternatives in the Pike River watershed.

Future ammocoete surveys are needed on the Pike River delta to determine whether a sea lamprey population exists, including the age 1 and 2 ammocoetes that were absent from the Pike River during this study. If these year classes are absent from the delta, then successful reproduction in Pike River likely did not occur during this study.

Few sea lamprey transformers were captured during this study. Age 3 ammocoetes were the dominant year class in the Pike River, which may lead to a higher abundance of sea lamprey transformers once this age class attains an adequate size and age for metamorphosis. Transformer abundance in the Pike River probably varies annually because of its unstable age distribution. Until quantitative assessment surveys (QAS) are conducted on Lake Champlain sea lamprey producing streams, transformer production from Pike River and Morpion Stream to Lake Champlain cannot be accurately ranked relative to transformer production from other streams. Evaluation surveys should be conducted on known and suspected Lake Champlain sea lamprey producing streams. After evaluation, streams should be prioritized for QAS surveys based on preliminary sea lamprey abundance estimates.

Adult Abundance

Nest counts were used as an index of adult sea lamprey abundance. Although this technique provides spatial spawning distributions, it does not provide an estimate of adult abundance. Unfortunately, the quantitative relationship between adult abundance (spawners/m²) and number of nests has not been determined. From these data, sea lamprey appear to spawn throughout the wadable section of Pike River and Morpion Stream; however, the majority of nests in the Pike River were counted in upper reaches; and in Morpion Stream, the majority of nests were counted in downstream reaches.

Recommendations for Future QAS Surveys

All ammocoetes were frozen prior to measuring length and weight. Freezing may have reduced the measurement accuracy on these biological characteristics due to loss of fluids. In future studies where statolith dissection is required, length and weight should be measured before freezing. After length and weight are obtained, ammocoetes should be placed into individually numbered plastic bags and then frozen.

In this study, additional type II plots were sampled in the Pike River; their selection was based on the crew leader's discretion. The non-random selection of type II plots may have biased the larval density estimate in this habitat type. Future QAS surveys should avoid non-random selection of sampling plots.

Management Implications

The proposed alternative in the Draft Supplemental Environmental Impact Statement for a long-term program of sea lamprey control is an extensive, integrated, long-term control program for sea lamprey in Lake Champlain. This alternative will apply, "a tributary-specific approach where viable control techniques are screened for applicability in each infested stream system" (DSEIS 2001). The tributary specific approach for the Pike River is the application of TFM or a TFM/niclosamide combination at the dam in Notre-Dame-de-Stanbridge, Quebec. The approach for Morpion Stream is the construction of a low-head barrier dam or electrical barrier near its confluence with the Pike River and the application of TFM in conjunction with the Pike River treatment. If a barrier is not constructed, TFM will be applied at river mile 17.1 in conjunction with the Pike River treatment.

Data from this study suggest that construction of a semi-permanent trap or low-head barrier in Morpion Stream – near its confluence with the Pike River – may dramatically reduce sea lamprey production in the Pike River, thereby eliminating the need for control actions on this river. Improvements in water quality and ammocoete production in tributaries not surveyed in this study, may decrease the effectiveness of the proposal. Additional studies would be needed to determine if spawning activity in Pike River results in a year-class failures or whether ammocoetes use larval habitats that were unsampled by this study, primarily the Pike River delta.

If a semi-permanent trap or low-head barrier is constructed in Morpion Stream, then larval assessment surveys should be conducted every three to four years to evaluate the effectiveness of these control actions. If adult sea lamprey in the Pike River successfully spawn and recruit ammocoetes into the parasitic-phase sea lamprey population, then the Pike River may require consideration of other control techniques.

Poor water quality in the Pike River and Morpion Stream has probably suppressed the sea lamprey population and natural reproduction in the the Pike River. During the 1990s, a wastewater treatment facility in Bedford improved water quality in the Pike River. Improvements are expected to continue with the implementation of better municipal and agricultural waste management; fish managers should be aware that sea lamprey may begin to successfully reproduce in the Pike River once water quality improves.

Lampricides could be applied to the Pike River and Morpion Stream every four years as a possible management action. Following treatments, compensatory mechanisms may lead to faster growth and earlier metamorphosis than was reported in this study, requiring more frequent application of lampricides (Zerrenner and Marsden in review). Growth, size and age at metamorphosis should be compared to the data from this study if these streams are treated with lampricides. Managers should also be aware that an American brook lamprey population is present in Morpion Stream; information about their distribution could be used to reduce impacts of lampricides on this vulnerable species.

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APPENDIX

A. Standard electro-fishing settings for AbP-2 backpack electro-fisher in wadable waters and AbP-2 deepwater electro-fisher in non-wadable waters.

Wadable waters

Slow Pulse		Fast Pulse		Burst	Volt Range 100-250
Rate	Duty Cycle	Rate	Duty Cycle		
3 pps	25%	30 pps	25 %	3 : 1	125

Non-wadable waters

Slow Pulse		Burst	Volt Range 100-250
Rate	Duty Cycle		
3 pps	10%	2 : 2	To achieve 0.6 to 0.8 V/cm

- B. Procedure to determine electro-fishing plot location and dimensions (taken directly from Twohey et al. 1996).

A procedure is provided for selection of plots and sub-plots to limit operator bias in selection process.

Rules

- The electrofished plot must be within 10m (upstream or downstream) of the transect.
- Plots must be at least 1m^2 in area, and must be at least 0.3m wide in any dimensions.

Procedure

1. Select potential plot (contiguous area of the desired habitat type) that intersects the transect line.
 - a.) Select the largest potential plot that intersects the transect. If two potential plots are of equal size, chose the one that is centered closest to the transect line. If they are situated equally with respect to the transect line, then randomly select one over the other (coin toss or other method).
 - b.) When the selected area of contiguous habitat is larger than 5m^2 , select the width (perpendicular to the transect) of at least 1m (if available) then exclude a portion of the potential area that lay along the transect (parallel to transect) I in the following manner:
 - 1.) Divide the potential area into 2 or more sub areas, and for each sub-area expand the width outward from the transect until 5m^2 is obtained, the width being at least 1m (when available). Select one of the 5m^2 sub-areas
 - b. any random technique (coin toss or other method).
 - 2.) When the potential area is too small to divide into 2 areas (5m^2 each), constrict the available area on the longest dimension, and if constricting along the bank to bank dimension, randomly select left or right (coin toss or other method).
- c.) If additional area is needed, continue to select the next largest area of contiguous habitat (sub plot) that intersects the transect line until a total of

5 m² are is obtained.

1.) Use method 1b. to constrict area if it is in excess of what is needed.

Substitute all references to "5m²" to desired area.

2. If additional area is needed, randomly (coin toss or other method) choose to look in the upstream or downstream direction.
 - a.) Select habitat area that is the next closest to the transect line.
 - b.) If two potential plots are situated equally with respect to the transect line, then randomly select one over the other (coin toss or other method).
 - c.) If the potential plot is larger than needed, constrict the size by the method in step 1b., or 1c.
 - d.) Continue to select habitat area until the total area selected is equal to 5m² or there is no more area in the selected direction that is within 10m of the transect.
3. If additional area is need, look in the other direction from the transect and follow steps 2.a-d.
4. If less than 2.5m² of habitat has been sampled, and there is no more available at the transect:
 - a. For type II - Do not seek additional habitat.
 - b. For type I - make up the remaining area from the next unscheduled transect (next transect in direction of travel). Use rules 1-3 to select the plot area. Sample at unscheduled transects are not sub-plots of the previous transect. Data is recorded on the form for the new unscheduled transect.
5. If less than 2.5m² can be selected at the unscheduled transect then select a maximum of 5m² of type II habitat (at the unscheduled transect) using rules 1 - 3.