GREAT LAKES FISHERY COMMISSION

2004 Project Completion Report[1]

Movement and population size of sea lamprey in Lake Champlain and its tributaries

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Introduction

Sea lamprey (*Petromyzon marinus*) is a non-native nuisance aquatic species in Lake Champlain and the Great Lakes that has had a devastating impact on native fish. Sea lamprey are parasitic, and feed on blood and body fluids of large fishes, particularly salmonids and coregonids. Large fish can generally withstand several attacks, and can be found with up to a dozen or more wounds in various stages of healing. However, the combined effects of overfishing, habitat degradation, and sea lamprey ultimately caused the extirpation of lake trout (*Salvelinus namaycush*) in lakes Ontario, Erie, Huron, and Michigan, and contributed to the decline of coregonid species such as lake whitefish (*Coregonus clupeaformis*).

Control of sea lamprey populations focuses on the vulnerable larval stage. Lamprey ascend streams to spawn in spring, and then die; the hatched larvae, or ammocoetes, reside in soft sediments for four to seven years before migrating to the lake where they become parasitic on other fishes. Adult lamprey can be blocked from migrating upstream by barrier dams or electric weirs; however, these devices also affect non-target migratory species, and studies suggest that lamprey that are prevented from migrating upstream will return to the lake and ascend another tributary (Applegate and Smith 1951). TFM, a larval lampricide, has been used since 1957 to reduce lamprey populations throughout the Great Lakes, and is applied to tributaries in a two-to-four year cycle at an annual cost of over $15 million. The control program permitted the successful re-establishment of lake trout populations through stocking; in addition, all of the Great Lakes now have economically important sport fisheries for exotic salmonids.

An experimental sea lamprey (*Petromyzon marinus*) control program was initiated in Lake Champlain in 1990 by the three state and federal agencies in the basin. Thirteen tributary systems that contained larval sea lamprey were treated twice, four years apart, with TFM. The experimental control program was successful in reducing parasitic phase lamprey populations and salmonid wounding rates, increasing catch per unit effort, and increasing angler catch of lake trout (Marsden et al. 2003). Lamprey control was suspended in Vermont as of 1996 while an Environmental Impact Statement was prepared. The EIS was accepted in 2001, but application of TFM in Vermont was delayed until 2002 due to low water conditions in fall, 2001.

As in the Great Lakes, the agencies involved in lamprey control in Lake Champlain are committed to developing and implementing an optimally effective future lamprey control program. In addition to evaluating contributions of individual streams to the parasitic population, several information needs must be addressed. For example, Lake Champlain is divided into four distinct basins by geographic features and man-made causeways; the extent of lamprey movement among these basins is unknown. In addition, assessment of the level of treatment necessary to achieve effective control, and evaluation of the effectiveness of control, would be greatly facilitated by estimation of the number and survival of transformers.

Currently, streams are prioritized based on annual assessments of larval densities in each stream. This does not take into consideration potential differences in the survival of sea lamprey from each stream; some streams may not warrant control because ammocoete survival to the transformer phase is low, or lamprey fail to thrive or survive after they transform into the

parasitic phase. In Lake Champlain, some lamprey-producing streams drain directly into the Main Lake where cold-water habitat and salmonid prey are abundant, whereas other streams such as the Poultney River drain into a warm, semi-riverine habitat, over 35 miles from coldwater habitat and salmonid prey. Thus, relative production of transformers among streams may not correlate with relative contributions of each stream to the parasitic population. The possibility that source-sink dynamics exist in sea lamprey populations depends upon a lack of homing to natal streams by spawning adults. Previous work on homing indicates that sea lamprey do not return to their natal stream (Applegate and Smith 1951, Bergstedt and Seeleye 1995).

The goal of this work was to provide population estimates of transformer sea lamprey within individual tributaries and the number migrating into Lake Champlain using a mark-recapture study, and to provide information about among-basin movements of lamprey. Specifically, the objectives were as follows:

1. Estimate the population size of transformer sea lamprey entering Lake Champlain before and after lampricide treatment.
2. Estimate the production of transformer lamprey in four tributaries of Lake Champlain and their relative contribution to the parasitic population in Lake Champlain.
3. Estimate the extent of sea lamprey exchange among basins of Lake Champlain.

Methods

The study was focused on four tributary streams to Lake Champlain: the Poultney River which drains into the South Lake, Lewis Creek which drains into the Main Lake, the Malletts Creek system which drains into Malletts Bay, and the Pike River/Morpion Stream system which drains into Missisquoi Bay and subsequently into the Inland Sea (Figure 1). Focal streams were selected on the basis of our ability to capture a significant proportion of the out-migrating transformers, based on previous experience sampling these streams; the Poultney River was initially included in the study because of its particular biological and political importance in the basin.

Capture and tagging methods - transformers

Metamorphosing larval lamprey were collected during late summer and fall out-migration, 2001 and 2002, in tributary streams using an ApBII backpack electrofishing unit, a Honda gas-powered DC current backpack, a canoe georator electroshocking unit, and fyke nets. During September, transformers were collected by electroshocking throughout each stream where larval habitat was present. In 2001, we sampled the focal streams and, to increase the number of tagged transformers, we also sampled and tagged transformers in Saranac River, Putnam Creek, Mill Brook (in Port Henry, NY), and the Winooski River (Figure 1). In October 2001, fyke nets were installed in the four focal streams, as close to the mouth of each tributary as possible. In the Poultney and Malletts Creek, the nets were located several kilometers upstream of the mouth because of deep-water inaccessibility near the mouth. Four to five fyke nets were deployed across the stream, perpendicular to the current, and wire mesh wings were installed on either side of the

nets to direct lamprey toward the nets. In the Poultney River, permitting restrictions allowed only 75% of the flow to be blocked by the nets and wings, so substantial escapement past the nets likely occurred. A large mesh (2.5 cm) screen of plastic and/or wire was installed a few meters upstream of each fyke net to reduce clogging of the nets by leaves and debris. Each set of nets was visited a minimum of twice per week, usually at least three times per week.

In 2002, we sampled three of the focal streams and Putnam Creek. Poultney River was not sampled via electroshocking due to logistical problems with distance and low sample sizes achieved in 2001-2002 using electroshocking. The primary mode of sampling in 2002 was electroshocking; fyke nets were also set in Morpion Stream, Malletts Creek, and the Poultney River. There was much more rainfall in 2002 than there had been in the fall of 2001, thus water flows were significantly higher during the sampling season in 2002 than they had been the previous season. This was detrimental to the electroshocking effort by limiting habitat that could be effectively sampled, and to the fyke netting effort because high water events were much more frequent and limited the sampling period significantly. Consequently, the fyke net sampling period was dramatically shorter in the fall of 2002 than it had been in 2001. Morpion Stream was sampled from November 13 through November 22, 2002; the Poultney River was sampled from November 8 through November 18, 2002, and Malletts Creek from October 25 through December 23, 2002.

Each transformer was measured (total length) and marked using an individually-numbered alpha-numeric coded wire tag (Bergstedt et al. 1993). Tag loss rates with these tags inserted into dorsal musculature near the insertion of the dorsal fin is approximately 1%, and the tags have no apparent effect on mortality (Bergstedt et al. 1993). All animals were checked for tags using a tag detector after the first collection date prior to inserting a tag. After tagging, transformers were released at or near the capture site (if electroshocked), or downstream of the fyke nets. The transformers were randomly mixed during processing, so each lamprey was not necessarily returned to the same exact location in the river from which it was captured. When large numbers of transformers were collected in cold weather, the transformers were transported to the USFWS office in Essex, VT where they were tagged, held in an aerated, cooled tank overnight, and then released the next day.

Population estimates – transformer phase

For the recapture phase, riffle-fyke nets of 0.6 cm mesh were installed as close to the mouth of each tributary as possible to collect transformers during their out-migration to the lake. In 2001, fyke nets for each river were installed during the first two weeks in October, and removed during the middle two weeks of December, with the exception of Malletts Creek. This set was left in until the first week in March, at which point it was pulled due to high water, and then reset four weeks later farther upstream. The second set for Malletts Creek was finally pulled in mid-May. Each net was rectangular at the mouth, 1 m tall by 1.5 m wide. Four to five nets were typically spread across the thalweg of each river, and then 0.6 cm seine material or hardware cloth was attached as wings at either side of each net and angled upstream to the stream bank to direct migrating transformers into the nets. All sets were checked a minimum of two or three times per week for the duration of the set. In Lewis Creek, the nets were set on sandy substrate, and subsequent scouring occurred under the nets and wings after several weeks. The set for Malletts

Creek was in a pool, so there was very little flow through the area and scouring was minimal. Morpion Stream was set in a shallow riffle area of very rocky substrate, and scouring under the nets was a minimal problem here as well. However, flooding events were problematic, frequently damaging the nets and reducing the efficiency of the set. Special permit restrictions for the Poultney River stipulated that the fyke nets would be checked at least every other day, and that no more than 75% of the water column would be blocked. In late October, a diversion wing was installed on the open side of the fyke nets about 10-15 m upstream to divert downstream migrants into the nets, but still allowed for upstream migration around the nets. This greatly improved the fishing efficiency of the set. Transformers were checked for tags, then measured for length and weight. All transformers were then tagged (if they were not recaptures) and released downstream of the fyke nets.

In 2002, due to the low recaptures achieved in 2001, alternative methods to assess transformer populations were used. In Putnam Creek, we collected and marked transformers as in 2001. The collection phase utilized the TFM treatment of the river in late October. All transformers were tagged 30 days prior to the treatment, which allowed them time to return to their habitat and randomly redistribute themselves. Within 24 hours after the TFM treatment, field crews walked the section of the river where tagged lamprey had been released. Any transformers that were visible and within reach with dip nets were collected and checked for tags. Because the coded wire tags are internal, there was no concern for bias towards marked animals in the recapture phase.

In the Little Ausable River and Malletts Creek, removal plots were set up to determine density within plots, and then the densities of these plots were extrapolated to the rest of the tributary to achieve a population estimate; these methods were modified from Zippin (1956). Three plots were selected in the Little Ausable, two in Malletts Creek; the plots ranged in size from 67 m^2 to 175 m^2. Each plot was blocked off using minnow seine material of less than 0.6 cm mesh. A pass was then made through using the canoe georator at a constant rate to maintain equal effort through the plot. All larval lampreys were collected (including transformers) and enumerated at the end of the pass. These lampreys were set aside and kept alive until the end of the day. After approximately 20-30 minutes, second and then third passes was made at the same pace to maintain equal effort. After three passes, the variation in the catch was evaluated to determine if a fourth pass was necessary as identified by Zippin (1956). For all but one plot, a fourth pass was required. A population estimate based on the number of lamprey removed from each pass was then calculated.

At the end of the removal passes, all lamprey that were large enough (> 100mm) were marked using coded wire tags, similar to the transformers for the mark-recapture studies, and released back into the plot. The field crew returned 1-3 days later and made a final pass through the plot, using the same effort as with the first passes. The number of lamprey collected were enumerated and checked for tags. This then completed a mark-recapture estimate, providing a second population estimate for the plot for comparison against the removal estimate.

In Malletts Creek, a third estimate was calculated on transformers by using a mark-recapture on the entire upstream section. In addition to the transformers marked and released in the plots,

electroshocking was conducted on the rest of the upper part of the tributary to tag more transformers. Fyke nets were then installed at the downstream section of the electroshocking area to serve as the recapture point, similar to the methods used for Malletts Creek in 2001. The fyke nets were installed in mid-October, and removed in mid-January.

USFWS personnel conducted quantitative assessment sampling (QAS; Slade et al. 2003) to assess larval lamprey populations in Lake Champlain tributaries in 2001 and 2002. We used these estimates to compare with our independent population estimates in order to evaluate the different methods of population estimation.

Recapture methods – parasitic phase

Parasitic phase sea lampreys were collected from Lake Champlain by local anglers, who find lamprey attached to their fish, boats, and fishing equipment (such as downrigger cannonballs). With the assistance of Lake Champlain Sea Grant Extension, we designed and implemented a public outreach effort that targets retail bait and tackle stores, marinas, charter captains, sport fishing/conservation clubs, individual license holders, and angling tournament organizations. Major components of the effort included design and distribution of a web site (http://**www.uvm.edu/snr/lamprey**), pamphlet, and poster. Over three thousand of the pamphlets were distributed to marinas, bait and tackle stores, the Yankee Sportsman's Classic fishing and hunting show, the Plattsburgh Rotary Club Derby, Lake Champlain International (LCI) Fishing Derby, and the Bass fishing derby. The pamphlet and posters included information about the web site, and provided contact information including email addresses for questions about the project. We set up 16 lamprey collection stations around the Lake Champlain shoreline; the addresses and contact information for the stations were available on the web site. At each station there was a set of plastic bags, waterproof tags, and plastic bucket filled with brine and with a fluorescent label providing instructions. The anglers were asked to fill in the date of collection on a tag, indicate where they caught the lamprey on a map on the reverse side of the tag, and (optionally) add their name and address and how they caught the lamprey. The anglers then placed the tag and lamprey(s) in a plastic bag, filled it with brine, and left it in the bucket. We checked buckets approximately once per week or in response to a call from the marina or store where the bucket is kept. All returned lamprey were measured for length and weight when the sample was intact. We also set up collection stations and distributed information by pamphlet, poster, and word of mouth at each of the major fishing derbies during the summers of 2002 and 2003. At the LCI Derby we had project participants stationed at five of the ten weigh stations in 2002, and visited the other stations throughout the 3-day derby; most stations were visited in 2003, and all weigh station captains were aware of the study and assisted in lamprey collecting. To increase angler participation, we offered prizes for the most lamprey returned, the lamprey returned from the greatest distance, and lamprey picked from a random drawing of tag numbers.

Recapture methods – migratory and spawning phase

Spawning phase sea lamprey were recaptured in the permanent barrier trap on the Great Chazy River and in portable assessment traps (PATs) as they returned to tributary streams in spring, 2003 and 2004, and by catching spawning pairs on nests. This sampling effort was conducted in

cooperation with USFWS annual assessment efforts. Portable assessment traps are wire mesh boxes with an inverted funnel in the side facing downstream; adults migrating upstream are diverted into the funnel and become trapped. One PAT was placed in the center of a stream channel, and the remaining width of the stream was blocked off with wire mesh wings, supported by stakes and, in some high-flow streams, reinforced wire fencing. The traps were modified from the traditional design; the trap chamber was removable, and was inserted into an open iron frame (Figure 2). The wings were fastened directly to the edge of the frame, and the frame was anchored to the streambed with stakes and rocks. To check the traps, the trap chamber was removed, taken to the shore, opened and emptied, then replaced. PATs were set in 17 streams in 2003 and 9 streams in 2004, set from the first or second week in April to the middle of June. Traps were checked every two or three days; set periods varied among streams. All non-target species in the traps were identified, counted, and released upstream of the trap if alive.

Migrating lamprey were collected by hand in Lewis Creek on two nights in May in 2003 and in 2004 as they attempted to climb portions of a sloping falls in the river. Spawning lamprey were captured on nests by walking upstream until an occupied nest was found, then removing the lamprey by hand. Loss of sighted lamprey was estimated to be less than 10%; the proportion of nests or spawning pairs that were not seen was highly variable due to environmental conditions (lighting, water turbidity, etc). Spawning lamprey were collected from 7 tributaries around the lake basin in 2003, and from 4 tributaries in 2004.

Data analysis - transformer abundance estimates

We used standard Lincoln- Petersen methodology with the Chapman modification to account for small sample sizes for the whole-stream mark-recapture estimates for Malletts Creek in 2001 and 2002, and Putnam Creek in 2002 (Chapman 1951). In 2002, population estimates for the Little Ausable River and Malletts Creek were also generated using the Zippin removal method (Zippin 1958). For the plot mark-recapture methodology, the Chapman modification was used to find an estimate of the population in each plot.

The total population for a tributary was calculated for the estimates from the removal and mark-recapture plots by calculating the average population estimate among the plots along with a pooled estimate of variance among the plots. These values were then multiplied by the total habitat area in the tributary to estimate the larval population in the tributary. The total habitat area for all of the methods used in this study (where needed) was used from the values found in the QAS survey. The plots were randomly selected without deference to Type I or Type II habitat, and so the total habitat area includes both Type I and Type II for the surveys. All population estimates were generated with 80% confidence intervals.

Data analysis - tributary and size-specific distribution of parasitic phase

Distribution and movements of parasitic phase lamprey were described using data from angler recoveries of tagged parasites and in-stream recapture of tagged migratory and spawning lamprey. To examine movement among basins, we compared location of initial capture and tagging with location of recapture at the parasitic and spawning phases. Insufficient numbers of tagged lamprey were recovered to test whether transformer size influences the likelihood of survivorship to spawning; or to examine length, weight, and age data for possible correlations

between growth, age, and stream of origin and/or season of out-migration.

Results

Capture and tagging of transformers

Overall, 4,125 transformers were marked and released with coded wire tags between 12 September 2001 and 27 November 2003 (Table 1). In 2001-2002, 2,653 transformers were tagged and released in nine different tributaries. A total of 1,367 transformers were collected using electroshocking, marked and released. Fyke nets were set on four tributaries in 2001 (Lewis and Malletts Creeks, Poultney River, and Morpion Stream, Quebec), from 4 October 2001 through 22 December 2001. The Malletts Creek set was left in through 5 March 2002. Nets were reset in two tributaries (Lewis and Malletts Creeks) on 27 March 2002 through 22 April 2002. A total of 622 transformers were marked and released from the fyke nets (490 from Morpion Stream).

In 2002-2003 we tagged 1,564 transformers in five streams (Table 1). Transformers tagged in Lewis Creek were held in an aerated, chilled-water aquarium for up to 30 days because the creek was treated with TFM on Oct. 22; the transformers were released in Lewis Creek on October 28. Forty-six transformers died in the chiller tank during the holding period, and are not included in the total of tagged lamprey. The transformers tagged in Putnam Creek were used as part of an independent population estimate for comparison to the QAS. The creek was later treated with TFM and thus it is assumed that none of these transformers survived to become parasites.

Transformer abundance estimates

With the exception of Malletts Creek, the attempts at independent population abundance estimates for transformers in 2001 were not successful. Due to time constraints and the distribution of the population in Morpion Stream, only eleven transformers were collected by electroshocking and marked. This was not enough to estimate the population of Morpion Stream. Recaptures in the fyke nets in Lewis Creek and the Poultney River were not sufficient to generate a valid population estimate. Three tagged transformers were recaptured in the Malletts Creek fyke nets, which provided enough data to generate a population estimate of 1,427 ± 593 transformers, comparable to the QAS estimate for that same population of 1,045 ± 321 transformers. The 80% confidence intervals for these two estimates were 667 - 2,187 and -617 – 1,472, respectively (Figure 3D).

The 2002 Putnam Creek estimate for the mark-recapture was 1,151 ± 196 transformers with 80% confidence intervals of 765-1,536. QAS results for this same population were 2,471 ± 1,426 with 80% confidence intervals of -454-4,489 (Figure 3B).

Removal estimates for the ammocoete population in the Little Ausable River in 2002 were found to be 249,737 ± 25,029 with 80% confidence intervals of 217,650 – 281,824. Plot mark recapture estimates were found to be 136,557 ± 3,164 with 80% CI of 132,501- 140,612. The 2001 QAS estimate for the larval population was estimated to be 310,619 ± 118,932 with 80% CI of 152,037– 469,201 (Figure 3A).

Removal estimates for the transformer population in Malletts Creek in 2002 were found to be 3,948 ± 239 with 80% CI of 3,642 - 4,254. Plot mark-recapture estimates were found to be 3,646 ± 54 with 80% CI of –3,576 - 3,715. The whole-stream mark-recapture estimate was found to be 1,564 ± 284 with 80% CI of 1,201 - 1,928. The transformer population could not be estimated by QAS methods in 2002 (Figure 3C).

Recapture of parasites and spawning phase lamprey

Of the 4,125 transformers marked and released, 41 tags were recovered during the two recapture phases (parasite and migratory/spawning adult). Six tags were recovered during the parasitic recapture phase – five in 2001 and one in 2002. Thirty-five tags were recovered during the adult migratory/spawning phase – 16 in 2001 and 19 in 2002. The outreach program was very successful in contacting and educating anglers about the study, and in generating cooperation from marinas and tackle stores that allowed use of their facilities as drop-off sites for lamprey. As a result, 896 parasitic phase lampreys were turned in by anglers to be checked for tags in 2001 and 531 were turned in during the 2002 tag year recovery program. Migratory/spawning adult capture efforts yielded 1,376 lampreys from the 2001 year class and 1,603 from the 2002 year class (Table 2).

Distance between mark and recapture sites were calculated as the shortest distance between the mouth of the natal tributary and the collection point in the lake, or the mouth of the spawning stream. Tagged parasitic phase lamprey traveled up to 64 km from their tagging site; five were tagged and recaptured in the main basin of the lake, and one had moved from Morpion Stream (draining into Missisquoi Bay) to the Inland Sea (Table 3). Lamprey recaptured as spawners traveled straight-line distances of 0 to 90 km from their natal tributary; only 9 (26%) lamprey from three streams returned to the same stream they were tagged in. Of the remaining spawners, 5 (14%) spawned in the same basin, but not their natal tributary; 3 (9%) spawned in a basin adjacent to their natal tributary, and 18 (51%) spawned in a basin not adjacent to their natal tributary.

Stream contributions to the parasitic population

Analysis of the tag recoveries indicates that there are no significant differences in the contributions of the tributaries that were evaluated during this study to the parasitic population of sea lamprey in Lake Champlain. For both years of the study, a chi-square test indicates that the proportion of tags recovered was not significantly different from the proportion of transformers that were tagged in each tributary (χ^2=0.9286, 3 df for 2001 tag year, χ^2= 0.9256, 2 df for 2002 tag year; Table 4)

Whole-lake population estimate

A Lincoln-Peterson estimator, using a Chapman modification for small sample size, was used to estimate the size of the parasitic population in Lake Champlain during summer 2001 at 269,139 ± 55,610. For summer 2002, the parasitic population estimate was 111,105 ± 23,362. These estimates violate the assumption that there is little or no mortality between the tag and recapture phases; different life stages of lamprey were tagged and recaptured, and mortality may be quite high between the transformer phase and parasitic phase. This problem may result in the estimate

being biased.

Discussion

The number of transformers tagged (2,653 in 2001-02, 1,472 in 2002-03) was higher than projected, and capture rates of the parasitic phases were also higher than anticipated (2,272 total in 2001-02; 2,114 total in 2003-04). However, recapture rates were extremely low for the project in both years, with only 41 tags recovered across all recapture methods, comprising only 1% of the number tagged. These results compare to a tag-recapture study in Lake Huron, in which 8% (42 of 555) of the tagged lamprey were recovered during spawning migrations; however, in that study 67,597 migrating lamprey were captured and examined for tags versus the 4,386 lamprey that were examined in our study (Bergstedt and Seelye 1995). In 2004, less than half the number of tributaries were trapped than in 2003 due to lack of time, manpower, and funding, and yet a comparable number of tags were recovered (15 in 2003; 19 in 2004). Overall trap catches were also higher in 2004 (1,487) than 2003 (981), but this is not due to alterations in trapping methodology or efficiency. Wounding rates on salmonids in 2003 indicated that parasitic lamprey abundance increased from 2002, contradictory to the results from the population estimate noted above. Again, the assumptions for this estimate are numerous, and many are violated; the contradictory evidence from the wounding rates and trap catches against the lower population estimate demonstrates how these violated assumptions can affect the accuracy of the population estimate.

Inter-basin movement

The low proportion of recaptured tagged lamprey suggests either that the lamprey population in Lake Champlain was very large over the study period, as supported by the Lincoln-Peterson estimate for both 2001 and 2002, and/or there was substantial mortality of lamprey between the transformer and spawning migration periods. The major contributors of parasitic lamprey to the lake during the period of the study were Pike/Morpion River, Malletts Creek, Winooski River, Lewis Creek, Poultney River, and the Saranac River. Of these, the latter three were treated during the experimental control program, but have not been treated since. Pike/Morpion River lies in Quebec, and construction of a lamprey barrier is currently under discussion. Malletts Creek contains endangered northern brook lamprey, so chemical treatment cannot occur in this tributary. The Winooski River has historically been considered too large for successful chemical treatment, but is scheduled for TFM treatment in the fall of 2004. Lewis Creek could not be treated in 2001 due to low flows, but was treated in 2002. A lawsuit resulted in a 5-year ban on treatment of the Poultney River, pending research into non-chemical alternatives for control. If Lewis Creek was the major remaining source of parasitic lamprey in Lake Champlain, as is suggested by the high larval population in the stream, then tag returns should theoretically be higher in 2003-4 (and they were, proportionally) after the Lewis Creek source has been removed by TFM treatment. The majority of tag returns in 2004 were from the animals tagged and released in Lewis Creek (13 out of 20, or 65%) after the 2002 fall TFM treatment. This indicates that Lewis Creek was in fact a major contributor of lampreys to the parasitic population, but the fact that the overall tag recoveries in 2004 were still very low indicates that there are still other major lamprey-producing tributaries in the basin that need to be addressed by the management

program. Lamprey wounding data support this conclusion; the number of wounds per 100 lake trout (533-633 mm) have risen steadily since 1998 from over 30 to over 90 in 2003, higher than prior to the initiation of the experimental control program (Lake Champlain Fisheries Technical Committee, unpublished data).

The large number of tagged lamprey recovered from Lewis Creek, Malletts Creek, and Pike River/Morpion Stream was not unexpected, given the large number of lamprey tagged in each of these tributaries. An approximately equal proportion of tags were returned from each of these tributaries, indicating that Lewis Creek may not have a substantially greater contribution to the lake than the other two tributaries. The returns from Saranac River are unexpected, given the low number of lamprey tagged there (23), and may be indicative that the Saranac River may contribute a significant number of parasites.

Our data indicate that not only do lamprey move widely around Lake Champlain, but they also travel relatively freely among the basins. Of the 21 lamprey that moved between basins from their natal to their spawning stream, all but one had to cross through openings in causeways separating basins, and most had to cross through at least two causeways. Presumably the more extensive movements are in part facilitated by hitchhiking on host fish; given that the causeway openings are very shallow (< 5 m), much of the movement we documented most likely occurred in winter while the lake was not temperature stratified. While there is no indication of strong spawning site fidelity, nine lampreys (four from Malletts Creek, four from Lewis Creek, and one from Pike/Morpion) returned to their natal tributary to spawn. However, other individuals from each of these streams were found in alternate streams as spawners.

In-stream population estimates

Achieving population estimates of transformers was more difficult than anticipated; the drought during the fall of 2001 probably limited migrations of transformers while the fyke nets were installed. Without the rainfall that generally occurs in late October through December to raise water levels and increase turbidity, there was little stimulus for migration. Fyke nets had to be removed the week before Christmas in both Lewis Creek and the Poultney River. Access to these two locations became too difficult during the winter months, and it is likely that the transformer migrations occurred over the winter months. Consequently, we used alternative methods to estimate transformer populations in 2002, and compared them with QAS estimates made by USFWS assessment teams.

The independent population estimates all fell within the 80% confidence limits of their respective QAS estimates, with the exception of the plot mark-recapture in the Little Ausable River. This estimate had very tight confidence intervals compared to the other methods, and fell just below the lower limit of the QAS estimate. This estimate was also outside the range of the removal method for that same population. This is most likely because there was a size limit that could be estimated using the coded wire tags – ammocoetes less than 100 mm were not marked with coded wire tags, and even though they were included in the initial capture numbers, they were excluded from the recapture phase. This will result in an estimator that is biased on the low side of the population, and could explain the conflicting confidence intervals of the plot mark-recapture from the removal and QAS methods. In both cases where the plot mark-recapture

estimator was used, this method had the tightest confidence intervals. Not surprisingly, the methods using mark-recapture had the tighter confidence intervals than the removal or QAS. Zippin (1958) found that if all assumptions are valid, the mark-recapture method is generally more precise than the removal method. Zippin's observations are validated by this study, albeit some of the assumptions are possibly violated for the removal method.

Of the three methods (excluding whole-stream mark-recapture), the plot mark-recap had the tightest confidence intervals. The variance in the removal method is probably due to the disturbance factor indicated above, and so due to the variable collection rate among the initial collection passes, the variance of the method is driven upward.. To improve these methods for future studies, increasing the number of plots sampled could improve the variability of both methods by increasing the degrees of freedom for plot variance. For the removal method, an initial pass can be made, and lamprey collected during this pass would not be included in the analysis.

The three independent estimates were not validated by each other in the Mallet's Creek survey of 2002. The removal method and plot mark-recapture were significantly higher than the estimate for the whole-stream mark-recapture. As mentioned above, this could also be due to the low number of plots that were sampled (two, in this case). The plots that were selected may have represented areas of the tributary that had higher densities than the entire tributary itself, causing the two habitat-based methods to overestimate the population.

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Table 1. Number, collection location, and mean length and weight of sea lamprey transformers tagged in the Lake Champlain basin, 2001-2003. Rivers are listed from north to south. "na" indicates sampling was not done at that site.

	Number tagged (electroshocking)	Number tagged (fyke nets)	Number recaptured	Mean length (mm)	Mean weight (g)
2001-2002					
Pike River	569	0	0	152 ± 9	6.0 ± 1.0
Morpion Stream	11	490	25	154 ± 9	5.3 ± 1.0
Malletts Creek	166	33	3	157 ± 10	6.7 ± 1.0
Winooski River	13	0	0	163 ± 11	6.7 ± 1.7
Saranac River	23	0	0	148 ± 11	4.3 ± 1.0
Lewis Creek	1,172	43	1	141 ± 8	4.5 ± 0.8
Poultney River	18	56	0	150 ± 7	5.0 ± 0.7
Putnam Creek	50	0	0	161 ± 9	6.2 ± 0.9
Port Henry Brook	9	0	0	185 ± 13	8.9 ± 1.6
Total for 2001-02	**2,031**	**622**	**29**		
2002-2003					
Pike River	148	na	na	161 ± 9	6.2 ± 0.9
Morpion Stream	na	155	na	159 ± 11	5.9 ± 1.2
Malletts Creek	279	103	21	164 ± 9	6.6 ± 1.0
Lewis Creek	787	na	na	142 ± 9	4.4 ± 0.8
Putnam Creek[1]	92	na	na	151 ± 8	6.0 ± 1.1
Total for 2002-03	**1,306**	**258**	**21**		

[1]all lamprey tagged and released in Putnam Creek in 2002 were presumed to have been killed during the TFM treatment of the creek in fall, 2002

Table 2. Adult sea lamprey collections in streams in the Lake Champlain basin, spring 2003. "na" indicates sampling by that method was not done at that site. Trapping was done with portable assessment traps on all streams except the Great Chazy River, where lamprey were caught in a permanent barrier trap

	2003				2004			
	Collection Method				Collection Method			
Tributary	Trapping	Falls	Nests	# w/tags	Trapping	Falls	Nests	# w/tags
New York								
Ausable River	na	na	33	0	na	na	2	0
Boquet River	na	na	9	0	na	na	0	na
Great Chazy River	373	na	na	6	827	0	na	4
Little Ausable River	12	na	na	0	na	na	na	na
Mill Brook	15	na	na	1	na	na	26	0
Mt. Hope Brook	36	na	na	0	3	na	na	0
Mullen Brook	1	na	na	0	na	na	na	na
Putnam Creek	na	na	30	0	na	na	0	na
Salmon River	60	na	na	0	na	na	na	na
Saranac River	na	na	15	0	na	na	12	0
Beaver Brook	na	na	na	na	137	na	na	5
Quebec								
Morpion Stream	89	na	na	2	na	na	na	na
Pike River	1	na	4	0	na	na	na	na
Vermont								
Allen Brook	0	na	na	0	na	na	na	na
Indian Brook	0	na	na	0	0	na	na	na
LaPlatte River	na	na	na	na	na	na	2	0
Lewis Creek	37	200	66	3	na	52	18	1
Malletts Creek	144	na	na	3	254	na	na	2
Pond Brook	10	na	na	0	14	na	na	0
Poultney River	na	na	37	0	8	na	na	0
Stone Bridge	31	na	na	0	76	na	na	1
Sunderland Brook	7	na	na	0	13	na	na	1
Trout Brook	165	na	na	1	163	na	na	3
Youngman Brook	1	na	na	0	0	na	na	na
Total	982	200	194	16	1,487	52	48	16

Table 3. Recaptures of tagged parasitic phase sea lamprey to date in Lake Champlain. Distance between mark and recapture sites is the shortest distance between the mouth of the natal tributary and the collection point in the lake, or the mouth of the spawning stream.

Tag location	Tag date	Location of recapture	Recapture date	Transit distance (km)
Parasitic phase recoveries				
Morpion	30-Nov-01	Inland Sea (Eagle Mtn)	18-May-02	61
Lewis	26-Sep-01	Burlington Bay	9-Jul-02	29
Lewis	06-Nov-01	Stave Island	25-Jul-02	42
Lewis	27-Sep-01	Burlington Bay	11-Oct-02	29
Lewis	06-Nov-01	Grand Isle Ferry	28-Sep-02	56
Lewis	07-Oct-02	Willsboro Bay	3-Nov-03	31
Migratory/spawning adult recoveries				
Lewis	26-Sep-01	Lewis Creek falls	19-May-03	0
Lewis	26-Sep-01	Lewis Creek falls	19-May-03	0
Lewis	26-Sep-01	Trout Brook PAT	20-May-03	49
Lewis	26-Sep-01	Mill Brook	20-May-03	29
Lewis	26-Sep-01	Great Chazy trap	28-May-03	81
Lewis	22-Oct-01	Great Chazy trap	21-May-03	81
Lewis	22-Oct-01	Great Chazy trap	28-May-03	81
Lewis	25-Oct-01	Great Chazy trap	28-May-03	81
Lewis	29-Oct-01	Lewis Creek falls	19-May-03	0
Lewis	30-Oct-01	Malletts	12-May-03	47
Malletts	12-Sep-01	Malletts	8-May-03	0
Malletts	17-Sep-01	Malletts	12-May-03	0
Malletts	17-Nov-01	Great Chazy trap	9-Jun-03	58
Pike	20-Sep-01	Great Chazy trap	21-May-03	46
Pike	03-Oct-01	Morpion Stream	7-May-03	0
Saranac	15-Nov-01	Morpion Stream	29-May-03	55
Lewis	02-Oct-02	Beaver Brook	21-May-04	18
Lewis	4-Oct-02	Malletts	3-May-04	47
Lewis	11-Oct-02	Beaver Brook	14-May-04	18
Lewis	11-Oct-02	Sunderland	18-May-04	32
Lewis	16-Oct-02	Trout	30-Apr-04	48
Lewis	16-Oct-02	Beaver Brook	3-May-04	18
Lewis	16-Oct-02	Stonebridge	4-May-04	52
Lewis	16-Oct-02	Beaver Brook	10-May-04	18
Lewis	16-Oct-02	Lewis (falls)	12-May-04	0
Lewis	16-Oct-02	Chazy	17-May-04	81
Lewis	16-Oct-02	Chazy	17-May-04	81
Lewis	16-Oct-02	Malletts	21-May-04	47
Malletts	9-Oct-02	Chazy	17-May-04	58
Malletts	25-Oct-02	Malletts	3-May-04	0
Malletts	25-Oct-02	Chazy	17-May-04	58
Malletts	28-Oct-02	Trout	17-May-04	2
Malletts	22-Nov-02	Malletts	5-May-04	0
Malletts	22-Nov-02	Beaver Brook	14-May-04	63
Morpion	22-Nov-02	Trout	19-Apr-04	61

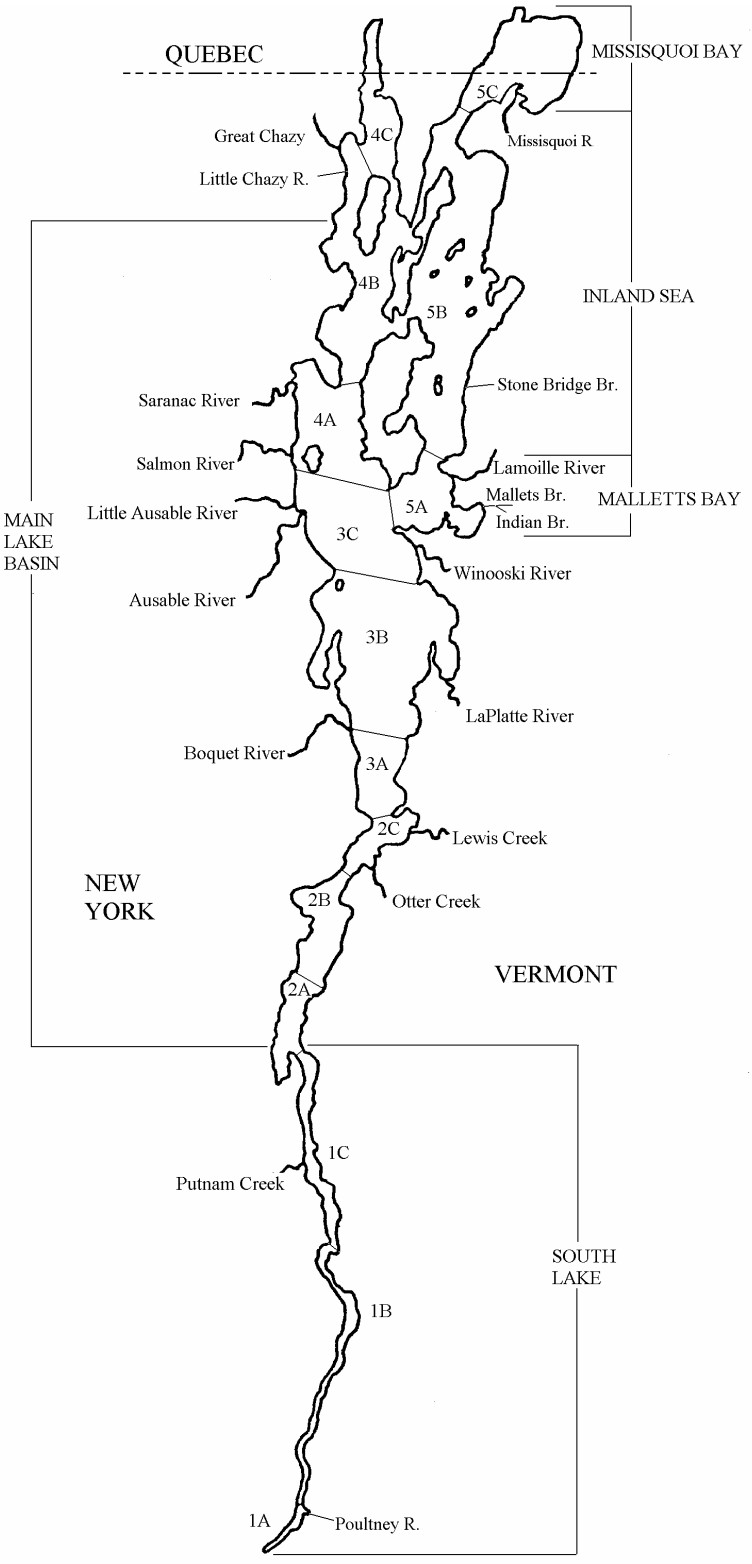
Table 4. Proportion of lamprey tagged in each tributary, compared with the proportion of tagged lamprey recovered from each tributary.

Year, tributary	Tagged	Proportion tagged	# recovered	Proportion recovered
2001				
Malletts	199	8%	3	14%
Lewis	1,215	48%	14	67%
Saranac	23	1%	1	5%
Pike/Morpion	1,070	43%	3	14%
2002				
Malletts	392	26%	6	30%
Lewis	787	53%	13	65%
Pike/Morpion	303	20%	1	5%

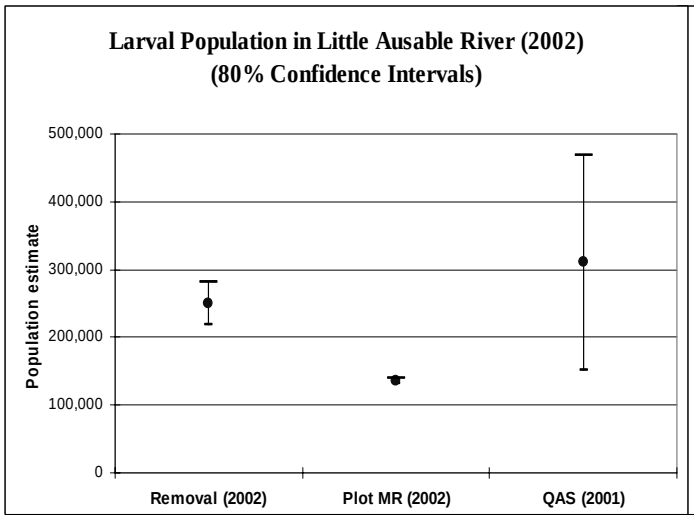
Figure 1. The Lake Champlain drainage basin, showing lake basins and tributaries mentioned in the text.

Figure 2. Modified portable assessment trap for collecting migratory sea lamprey in streams.

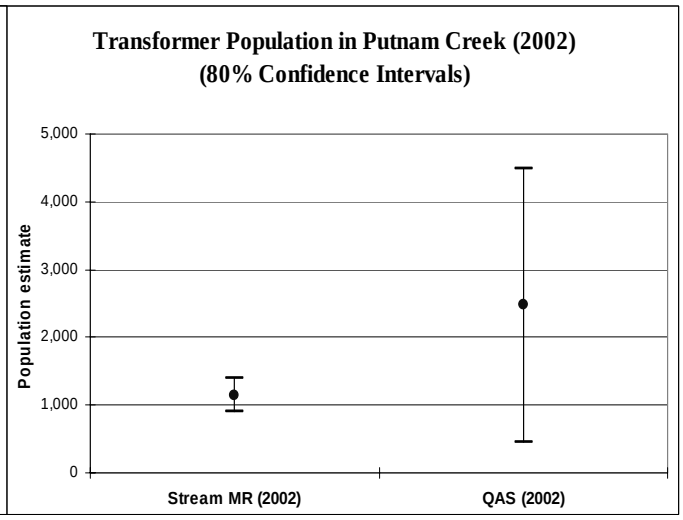
Figure 3. A. Sea lamprey ammocoete population estimates for the Little Ausable River 2002 using removal, plot mark-recapture, and quantitative assessment sampling (QAS) methods.
B. Sea lamprey transformer population estimates for Putnam Creek 2002 using whole-stream mark-recapture (MR) methods and QAS.
C. Sea lamprey transformer population estimates for Malletts Creek 2002 using removal, plot mark-recapture, and MR.
D. Sea lamprey transformer population estimates for Malletts Creek 2001 using MR and QAS.


QUEBEC
MISSISQUOI BAY
5C
Missisquoi R
Great Chazy
4C
Little Chazy R.
4B
5B
INLAND SEA
Stone Bridge Br.
Saranac River
4A
Salmon River
Lamoille River
Mallets Br.
MALLETTS BAY
Indian Br.
5A
Little Ausable River
MAIN
LAKE
BASIN
3C
Winooski River
Ausable River
3B
LaPlatte River
Boquet River
3A
2C
Lewis Creek
NEW
YORK
2B
Otter Creek
VERMONT
2A
1C
Putnam Creek
SOUTH
LAKE
1B
1A
Poultney R.

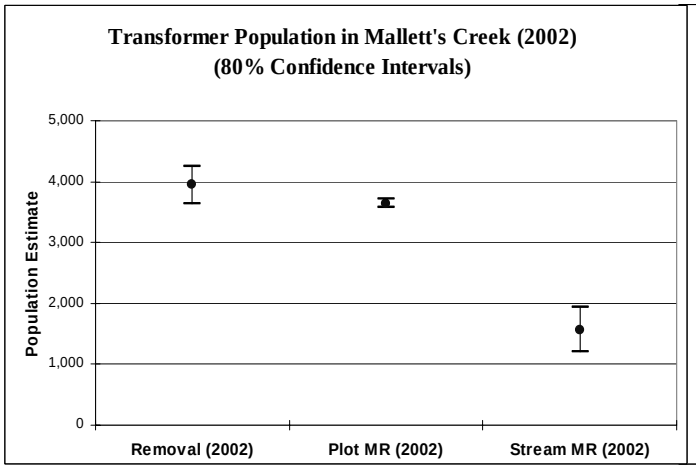
A.


Larval Population in Little Ausable River (2002)
(80% Confidence Intervals)
Population estimate
500,000
400,000
300,000
200,000
100,000
0
Removal (2002)
Plot MR (2002)
QAS (2001)

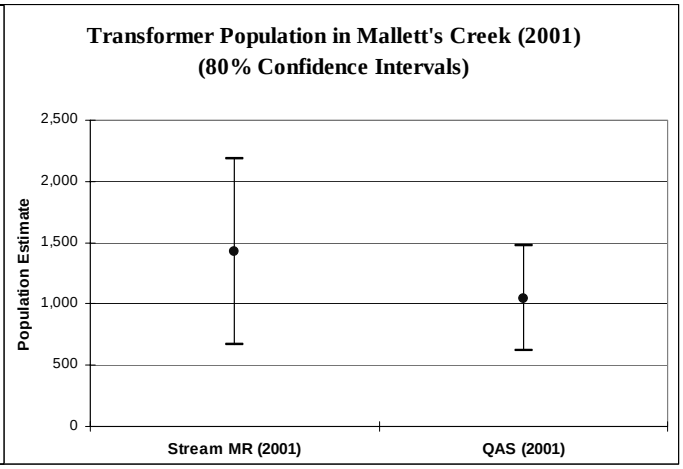
B.


Transformer Population in Putnam Creek (2002)
(80% Confidence Intervals)
Population estimate
5,000
4,000
3,000
2,000
1,000
0
Stream MR (2002)
QAS (2002)

C.


Transformer Population in Mallett's Creek (2002)
(80% Confidence Intervals)
Population Estimate
5,000
4,000
3,000
2,000
1,000
0
Removal (2002)
Plot MR (2002)
Stream MR (2002)

D.


Transformer Population in Mallett's Creek (2001)
(80% Confidence Intervals)
Population Estimate
2,500
2,000
1,500
1,000
500
0
Stream MR (2001)
QAS (2001)