LAKE CHAMPLAIN FISH AND WILDLIFE MANAGEMENT COOPERATIVE

FISHERIES TECHNICAL COMMITTEE

2019 ANNUAL REPORT

Approved at Lake Champlain Fish and Wildlife Management Meeting

July 16, 2020

University of Vermont researchers bottom trawling from the RV Melosira to collect juvenile lake trout (left) and several age classes of wild juvenile lake trout (right) collected in the main lake, Lake Champlain (Photo credit UVM).

Agency Contacts Regarding this Report

William Ardren, USFWS Senior Fish Biologist (802) 662-5302 william_ardren@fws.gov	Rob Fiorentino, NYSDEC Region 5 Fisheries Manager, (518) 897-1291 rob.fiorentino@dec.ny.gov	Margaret Murphy, VTFWD Fisheries Program Manager (802) 786-3864 margaret.murphy@vermont.gov

Executive Summary

Restoration efforts for native salmonids continued to be the primary focus of the Lake Champlain Fisheries Technical Committee (FTC) in 2019. Landlocked Atlantic salmon (salmon) and lake trout were focal species accounting for 73% of 460,631 smolts/yearlings stocked into the lake and tributaries. Highlights from native salmonid management include:

- Eleven of 16 established fisheries indicators met target goals.
- Sampling for juvenile lake trout continued to identify wild lake trout ranging from YOY (young of year) to three years old.
- Sea lamprey wounding rates for salmon and lake trout remained above target levels.
- Salmon returns were strong in all VT rivers in 2019 compared to the low return of 2017 (except Winooski River where the returns were less than 100 fish).
- Condition factor of salmon and lake trout remained high.
- Low thiamine tolerant broodstock at White River National Fish Hatchery were spawned for first time.

There were six lampricide treatments conducted in the Basin during 2019. Trapping efforts at eight locations during the spring spawning run captured 672 adult sea lamprey. Sea lamprey salmon wounding rates decreased to 19.5, in 219, but are still above the target of 15 wounds per 100 fish. However, wounding rates on lake trout increased from 48 in 2018 to 57.4 in 2019; well above the target of 25 wounds per 100 fish. Lampricide treatments are currently scheduled for four tributaries in northern Vermont during the fall of 2020.

Monitoring efforts continued for American eel, muskellunge, bass, walleye, and yellow perch. In 2019, large numbers of dead and dying American eel were observed in Lake Champlain. Efforts to determine the cause of the mortality are ongoing. NYSDEC continued development of a sauger restoration plan. Research efforts in the lake and tributaries included: using acoustic telemetry and sonar methods to monitor lake sturgeon movement patterns; adult salmon movement in the Winooski River using radio telemetry; characterizing evolutionary potential of salmon to respond to thiamine deficiency.

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Introduction

Management of the fishery resources of Lake Champlain is coordinated by the Lake Champlain Fisheries Technical Committee, which is a workgroup of the Lake Champlain Fish and Wildlife Management Cooperative. Members and advisors of the Fisheries Technical Committee includes staff from the Vermont Fish and Wildlife Department (VTFWD), New York State Department of Environmental Conservation (NYSDEC), U.S. Fish and Wildlife Service (USFWS), University of Vermont (UVM), Vermont Cooperative Fish and Wildlife Research Unit (VTCFWRU), Quebec Ministry of Forestry, Wildlife and Parks (MFFP), Lake Champlain Sea Grant, and other universities.

This report briefly summarizes fisheries management and research activities carried out on Lake Champlain and its tributaries during 2019. The names of project leaders are listed after section headings and their affiliation can be found on the FTC Membership list at the end of this document (Appendix 1).

Salmonids

Salmonid Assessment Program for Lake Champlain (Salmonid Working Group)

A workgroup of the Lake Champlain Fisheries Technical Committee was established in 2014 with the goal of maintaining balanced and robust fish populations that provide a fishery for salmonids. The working group had five objectives: (1) Evaluate status of salmonid populations; (2) Evaluate the salmonid fishery; (3) Evaluate salmonid hatchery production; (4) Evaluate fish health status and impact of aquatic nuisance species; and (5) Identify potential management actions.

The working group reviewed relevant fisheries indicators that are part of annual monitoring efforts (Fisheries Technical Committee 2019). A suite of indicators was identified to monitor salmon and lake trout fisheries and restoration of natural populations. The period from 2011 to 2017 was identified as the "desired state" for salmon and lake trout in Lake Champlain. This time period was selected based on the effectiveness of sea lamprey control efforts, stability and quality of the fishery, and evidence of natural reproduction for both species. In an effort to maintain the desired state, target goals were developed for all indicators. Thresholds for target goals were set at 25th and 75th percentile bounds for indicators over the seven-year desired state period. These target goals may change if there are long-term changes to the Lake Champlain fishery but will not be adjusted annually.

In 2019, five of the 16 indicators fell out-of-bounds of the established thresholds (Table 1 and 2). Two indicators – sea lamprey wounding for both salmon and lake trout – were above target thresholds for the third year in a row. Salmon wounding rate declined to 19.5 wounds per 100 fish (wpf) from 29 observed in 2018 but was still above the target level of 15 wpf. The lake trout wounding rate of 57 wpf is still well above the target of 25.

Median total length of lake age 0 salmon was 429 mm (16 inches) and slightly above the upper threshold of 427 mm. Median weight of the top 10 salmon angled in the annual Lake Champlain International fishing derby in 2019 was below the threshold. In 2019, median weight was 1.9 kilograms (kg) (4.4 pounds) and below the lower threshold of 2.8 kg (6.3 pounds).

Finally, total salmonid stocking numbers were below target levels. A total of 460,631 salmonids was stocked: 51,369 (10%) less than the target of 512,000 fish. Salmon stocking numbers declined the most with 49,294 (16.2%) fewer fish being released into Lake Champlain. The Adirondack Hatchery lost fish due to a power outage which resulted in only 12,730 (72% reduction) salmon smolts being stocked in the Saranac River. Numbers of steelhead and brown trout stocked were slightly below target (~1,000 fish each). Lake trout stocking target numbers were met in 2019.

At this time, there are no recommended changes to stocking targets or harvest regulations to Lake Champlain salmonids. However, the FTC is in the process of exploring additional indicators of salmonid status. These include additional sampling to estimate abundance of wild lake trout, evaluating methods to characterize forage fish abundance, exploring alternative measures of sea lamprey impacts on salmonids and options to tag / mark all stocked salmonids. In addition, adaptive management experiments are underway to improve survival of smolt stocked salmon in the lake and increase adult returns to rivers; these studies include evaluating alternative stocking methods and performance of a low thiamine tolerant broodstock.

Table 1. Indicators for annually evaluating the status of landlocked Atlantic salmon, lake trout, and walleye, and fish health in Lake Champlain. Condition factor describes the relative "plumpness" or "fatness" based on fish length and weight. Table 2 further defines indicators and thresholds. Status colors: Green: Good - within desired ranges or threshold targets; Yellow: Caution – outside targets; Red: Problematic – outside targets for three consecutive years.

Species and Indicators	2019 Value	2019 Status	2018 Status	2017 Status
Landlocked Atlantic Salmon				
Pre-stock smolt size percentage	95.2 %	Green	Yellow	Yellow
Median Condition Factor – Lake Age 0	1.17	Green	Green	Yellow
Median Condition Factor – Lake Age 1	0.99	Green	Green	Green
Median Total Length – Lake Age 0	429 mm	Yellow	Green	Green
Median Total Length – Lake Age 1	508 mm	Green	Green	Green
Sea Lamprey Wounding (lake-wide)	19.5	Red	Yellow	Yellow
Median Weight of top 10 salmon in Lake Champlain Inter. Derby	1.9 kg	Yellow	Green	Green
Median Condition Factor salmon in Lake Champlain Inter. Derby	1.06	Green	Green	Green
Lake Trout				
Median Condition Factor - Males	0.86	Green	Green	Green
Sea Lamprey Wounding (Main-lake)	57.4	Red	Yellow	Yellow
Wild Lake Trout - Proportion Unclipped	3.8 %	Green	Green	Green
Median Weight of top 10 lake trout in Lake Champlain Inter. Derby	5.9 kg	Green	Green	Green
Median Condition Factor lake trout in Lake Champlain Inter. Derby	0.99	Green	Green	Green
Salmonid Stocking				
Number of salmonids stocked annually	460,631	Red	Yellow	Yellow
Walleye				
Walleye Median Condition Factor (Males 350 –475 mm)	0.94	Green	Green	Yellow
Fish Health Testing Results	No detections	Green	Yellow	Green

Table 2. Indicators and their thresholds for annually evaluating the state of landlocked Atlantic salmon, lake trout, walleye, and fish health in Lake Champlain. The median is the middle value of all values calculated. Condition factor describes the relative "plumpness" or "fatness" based on fish length and weight.

Species and Indicators	Thresholds or desired ranges	2019 Value	n
Landlocked Atlantic Salmon			
Pre-stock smolt size percentage > 150 mm	≥90 %	95.2 %	2,100
Median Condition Factor – Lake Age 0	0.9 – 1.18	1.17	37
Median Condition Factor – Lake Age 1	0.86 – 1.01	0.99	280
Median Total Length – Lake Age 0	391 – 427 mm	429 mm	38
Median Total Length – Lake Age 1	493 – 561 mm	508 mm	280
Sea Lamprey Wounding Rate (lake-wide)	<15 wounds per 100	19.5	667
Median Weight of top 10 salmon from Lake Champlain International Fishing Derby	2.8 – 3.7 kg	1.9 kg	10
Median Condition Factor from Lake Champlain International Fishing Derby	1.01 – 1.22	1.06	28
Lake Trout			
Median Condition factor - Males	0.84 – 0.94	0.86	293
Sea Lamprey Wounding Rate (main lake)	<25 wounds per 100	57.4	47
Wild Lake Trout - Proportion Unclipped	≥15 %	3.8 %	53
Median weight top 10 Lake Trout from Lake Champlain International Fishing Derby	5.6 – 6.4 kg	5.9 kg	10
Median Condition Factor from Lake Champlain International Fishing Derby	0.92 – 1.08	0.99	143
Salmonid Stocking			
Number of salmonids stocked annually	512,000	460,631	
Landlocked Atlantic salmon	304,000	254,706	
Lake trout	82,000	81,999	
Steelhead trout	58,000	56,991	
Brown trout	68,000	66,935	
Walleye			
Median Condition Factor walleye Males 350.5 – 475 mm	0.90 – 0.98	0.94	74
Health Testing Results	No detection	No detection	

Stocking Summary (Shanahan)

Salmonid stockings in Lake Champlain during 2019 included approximately: 255,000 landlocked Atlantic salmon (smolt equivalents); 57,000 steelhead (smolt equivalents); 82,000 lake trout; and 67,000 brown trout (Table 3). The list includes landlocked Atlantic salmon and steelhead that were stocked in the tributaries to the lake. Also listed in Table 3 are the stocking targets for each species. Stocking numbers are presented as "stocking equivalents." Salmonids are stocked at varying sizes, from recently hatched fry that spend two years in the tributaries before migrating to the lake, to smolts and yearlings that are ready to begin life in the lake at the time of stocking. The numbers stocked are adjusted to stocking (smolt/yearling) equivalents to better represent the effective numbers stocked.

Table 3. Numbers (in smolt equivalents) of salmonids stocked in Lake Champlain during 2019, and stocking targets for the lake.

Species	Main Lake		Malletts Bay/Inland Sea		Total number stocked in 2019
	Target	2019	Target	2019	
Landlocked salmon	227,000	181,692	77,000	73,014	254,706
Lake trout	82,000	81,999	0	0	81,999
Steelhead	53,000	51,491	5,000	5,500	56,991
Brown trout	38,000	36,535	30,000	30,400	66,935
Total	400,000	351,717	112,000	108,914	460,631

Pre-stocking Landlocked Salmon Assessments (Staats)

To undergo the parr to smolt transformation a fish must be greater than or equal to 150 mm total length. In spring of 2019, over 99% of fish exceeded the 150 mm size threshold for Ed Weed hatchery while at least 90% of fish exceeded the size threshold for New York's Adirondack hatchery and at the Eisenhower NFH (Table 4).

Table 4. Pre-stocking assessment of yearling landlocked Atlantic salmon stocked in Lake Champlain. Total number of yearling salmon stocked and the number that reached the viable smolt size (greater than or equal to 150 mm total length) are reported for stocking years from 2012-2019.

Hatchery (agency)	Year	Mean Size (mm)	Numbered Sampled	% Viable Smolts	Total Stocked	Viable Smolts Stocked
Adirondack (NYDEC)	2012	150	400	54.8	45,000	24,638
	2013	163	400	83.0	45,000	37,350
	2014	174	399	90.0	49,260	44,322
	2015	175	300	92.3	45,000	41,550
	2016	180	400	93.8	45,000	42,188
	2017	167	400	85.8	45,000	38,610
	2018	172	400	90.3	45,000	40,635
	2019	**183**	**100**	**94.0**	**12,730**	**11,966**
Ed Weed (VTFWD)	2012	196	999	99.7	155,289	154,823
	2013	191	1,100	99.6	165,459	164,857
	2014	188	999	99.2	146,290	145,119
	2015	181	1,000	95.3	163,827	156,127
	2016	177	1,000	96.4	149,419	144,040
	2017	190	1,100	99.7	160,028	159,548
	2018	191	900	99.7	139,128	138,711
	2019	**181**	**900**	**99.7**	**139,411**	**138,993**
Eisenhower (USFWS)	2012	188	900	96.8	104,706	101,332
	2013	206	1,100	98.8	69,992	69,165
	2014	170	1,000	84.8	76,160	64,584
	2015	163	1,300	82.7	102,430	84,702
	2016	155	1,223	66.6	102,697	68,353
	2017	161	1,800	80.7	113,947	91,955
	2018	153	1,431	67.1	85,510	57,377
	2019	**165**	**1,100**	**91.7**	**69,651**	**63,870**
Overall	2012	185	2,299	92.1	304,995	280,792
	2013	193	2,600	96.8	280,451	271,372
	2014	178	2,398	93.5	271,710	254,024
	2015	171	2,600	90.7	311,257	282,379
	2016	167	2,623	85.7	297,116	254,580
	2017	171	3,300	87.6	318,975	290,113
	2018	168	2,731	81.2	269,638	236,723
	2019	**173**	**2,100**	**95.2**	**221,792**	**214,829**

Fish Passage (Staats)

In 2019 a total of 12 steelhead trout and 58 landlocked Atlantic salmon were trapped at the Winooski One fish passage facility on the Winooski River (VT) in the spring and fall, respectively (Figure 1). Of the salmon lifted in the fall, 31 males and 24 females were processed. Steelhead were released directly above the Winooski dam while salmon were transported above the next two dams and released in the upper Winooski River. In addition to the above, six salmon were lifted in June/July and nine steelhead were lifted in the fall.

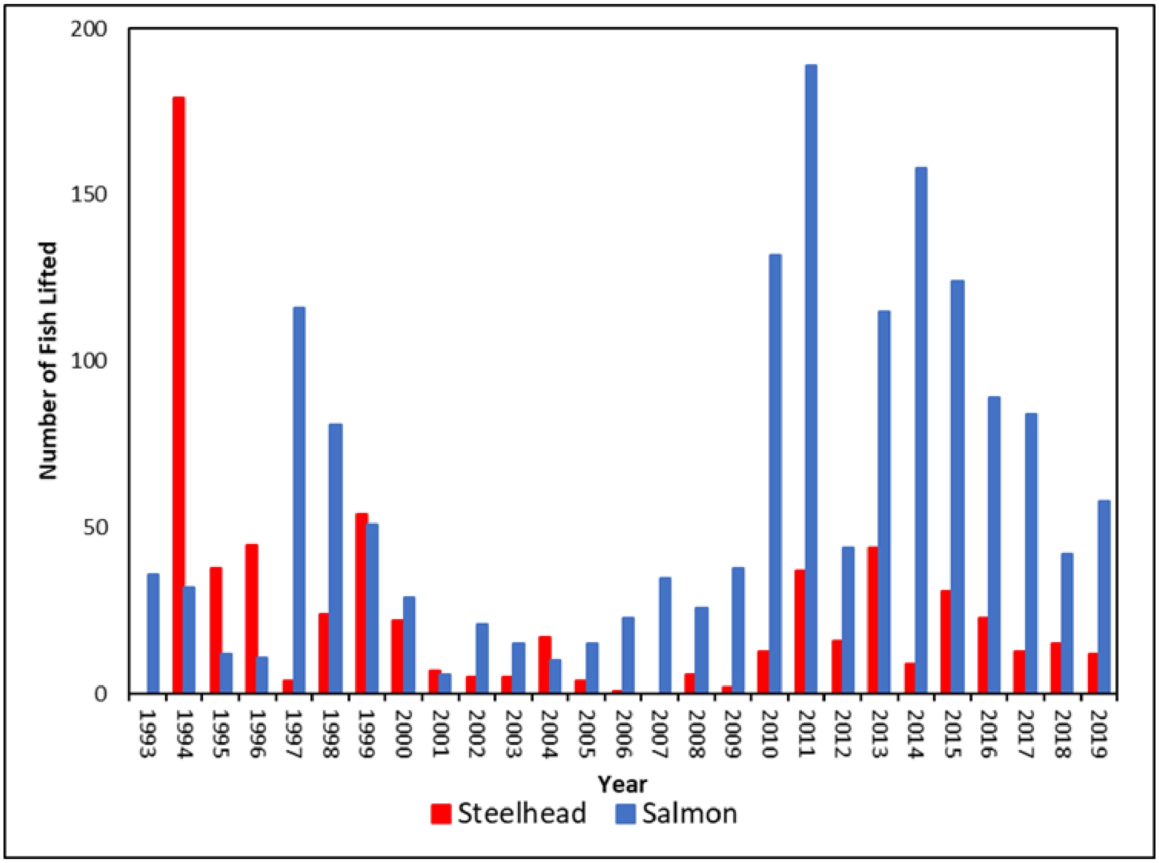

Figure 1. Summary of steelhead trout (spring season) and landlocked Atlantic salmon (fall season) lifted at the Winooski One fish passage facility, 1993 – 2019.

Downstream Passage at Winooski River Essex 19 Dam (Ardren, Staats, Pientka)

The USFWS and VTFWD have been consulting with Green Mountain Power (GMP) and its consultant, Kleinschmidt Associates regarding the application for Low Impact Hydropower Institute (LIHI) Certification for Essex 19 dam on the Winooski River (Figure 2). The USFWS and VTFWD made several recommendations to GMP after initial inspection of the facility on September 23, 2016. Most of the recommendations related to their downstream fish passage facility and the final three issues were resolved in 2019.

- Ensure both gates operate in fully open/fully closed position (or modify the lip of the gate to approximate broad-crested weir geometry)
- Slotted weir impounding plunge pool may require chute/floor to ensure safe plunge
- Modify plunge pool and/or downstream chute to provide safe movement downstream

GMP will need to verify the effectiveness of their modified downstream fish passage system. We recommend pursuing downstream passage effectiveness studies through LIHI first and if that is not successful, using the relicensing process - the project's Federal Energy Regulatory Commission license is due to expire in 2025.

Figure 2. Brett Towler, USFWS – fish passage engineer, and GMP personnel inspect new weir-slot insert that will elevate plunge pool level to reduce possible mortality of downstream-migrating salmonids.

Radio Telemetry of Trap and Trucked Salmon in the Winooski River (Hannon-Moonstone)

During the fall and winter of 2019, the USFWS in cooperation with USGS and VTFWD conducted a study to evaluate migratory behavior of adult salmon trapped at Winooski One dam and trucked upstream above three dams into suitable spawning habitat. Adult landlocked Atlantic salmon were collected from the fish lift at Winooski One dam between October 1 and November 8, 2019. A total of 54 fish were anesthetized using electronarcosis and tagged intraperitoneally with SigmaEight radio tags (Figure 3).

Figure 3. Radio tagging a salmon (left), fixed radio telemetry monitoring station (middle) and mobile tracking (right) used to detect radio tagged landlocked Atlantic salmon in the Winooski River.

Fourteen fixed-station Yagi antennas with SigmaEight automatic data loggers were deployed along the study reach on September 25, 2019 and will operate until spring of 2021. Mobile tracking events were conducted one to four times a week through the entire fall and winter beginning October 1st. Tracking was done using a Lotek telemetry receiver from either a canoe or a combination of in a truck and on foot. All 54 tagged fish were detected after release either by a fixed receiver or during mobile tracking.

Major Finding:

- Twenty-six percent of telemetered salmon (14 of 54) were "fallback" salmon that migrated 24 km downstream past Essex 19 dam after release. These fallback salmon are not able to migrate back upstream to suitable spawning habitat without falling back over two additional dams and being recaptured at the Winooski One dam fish lift.
- Forty-six percent of telemetered salmon (25 of 54) did not migrate out of the river immediately post-spawn and continued to be observed in the Winooski River above Essex #19 Dam as of December 31, 2019. We will continue to monitor to identify when they initiate migration back to Lake Champlain.

Future Work:

- Tag up to 60 adult salmon in fall of 2020.
- Evaluate overwintering survival and outmigration timing.
- Identify critical habitats for spawning and holding pre and post spawning.
- Identify effect of delays due to holding time prior to tagging at Winooski One fish lift.
- Observe downstream passage time at Essex #19, Gorge #18, and Winooski One Dams.

Boquet River Atlantic Salmon Redd, Juvenile, and Habitat Surveys (Withers)

The Willsboro Dam was removed in 2015 opening up over 70 miles of spawning and rearing habitat for landlocked Atlantic salmon. Trapping surveys in 2015 indicated extremely low rates of salmon passage above Willsboro cascades (site of former dam). However, monitoring efforts associated with trapping and trucking salmon over the cascades in 2016 and 2017 indicated some salmon were able to pass upstream over the cascades. Efforts continue to monitor the success of salmon restoration in the Boquet River with the focus on redd surveys, young-of-year snorkel sampling and habitat assessment.

Young-of-year (YOY) snorkel surveys were conducted in the main stem Boquet River and its north branch in June and July 2019. Forty-eight Atlantic salmon YOY were found in the north branch while no YOY were seen in the main stem (Table f, Figure 4). Salmon YOY average length was 42.1 mm (SD = 3.9, n = 46) and a genetic sample was collected.

Table 5. Summary of Boquet River landlocked Atlantic salmon sampling, 2016 – 2019.

Year	River Section	Spring YOY	Fall Redds
2016			
	Main Stem	na	68
	North Branch	na	90
2017			
	Main Stem	0	9
	North Branch	85	32
2018			
	Main Stem	0	164
	North Branch	0	28
2019			
	Main Stem	0	1
	North Branch	48	3

In 2019, portions of the Boquet River and its north branch were surveyed for redds, as an index of adult escapement. Redd surveys have been conducted since 2016 and occur between October and December. Teams of two to three biologists walk each reach multiple times to identifying redds. A total of 192 redds were observed in 2018 which is the largest number observed since surveys started.

Unusually high water levels occurred in late October and early November in 2019. These exceptionally high water levels led to scouring and re-engineering of the river's geomorphology, with substrates being transported downstream in large quantities. High water also inhibited the number of redd surveys conducted. Despite the limited number of surveys performed, four redds were found; however, this redd count was the lowest to date. Low redd counts were likely due to scouring and limited upstream migration of adults given the high water levels.

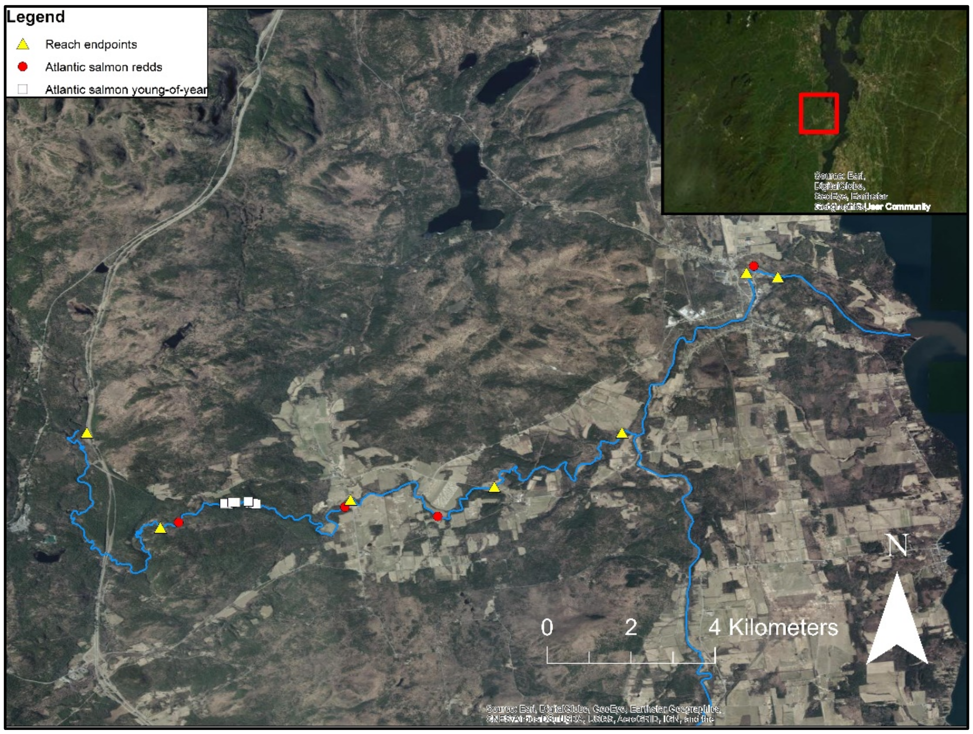

Figure 4. Five reaches of the north branch and mainstem of the Boquet River snorkel surveyed for young-of-year and Atlantic salmon redds in spring and fall 2019, respectively. Yellow triangles denote the start and end points of reaches, white squares denote YOY found, and red dots denote locations where redds were identified.

Spring and Fall Nearshore and Tributary Assessments (Pientka, Smith)

Annual fall boat electrofishing surveys for salmonids were conducted in larger Vermont tributaries and nearshore areas in New York. A fish trap was operated at Hatchery Brook (Ed Weed Fish Culture Station discharge stream) during spring and fall to capture returning salmonids in spawning runs. A trap net was deployed in Hatchery Cove to collect spawning lake trout. These sampling efforts allow for the collection of biological data including total length, weight, sex, and age information as well as lamprey wounding data. Salmonids collected in Vermont tributaries were tagged with serially numbered Floy anchor tags prior to release. The data are utilized in hatchery product and fishery evaluations, and to monitor sea lamprey control progress through time. Numbers of fish reported below do not include same-year recaptures.

The focus of fall nearshore salmonid sampling was on traditional sites in Willsboro and Whallon bays. Sampling took place throughout most of November in 2019. Catches in the Whallon Bay and Willsboro Bay areas consisted of 221 lake trout, 158 salmon, 6 steelhead, and 1 brown trout. Whallon and Willsboro bay salmon catches were on par with recent years. In 2019, a larger portion of the salmon catch was made up of fish larger than 500 mm (Figure 5). These larger older fish were largely missing from the catch in 2018.

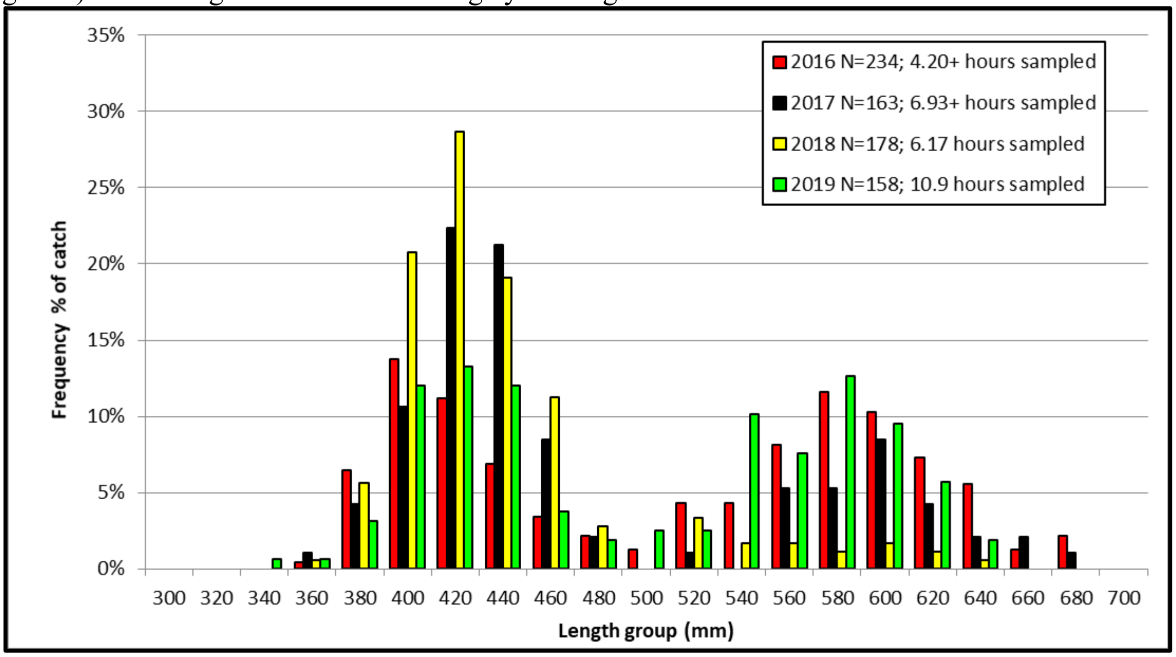

Figure 5. Length frequency distributions of landlocked Atlantic salmon collected from Willsboro and Whallon bays by electrofishing, 2016-2019.

In 2019, the Hatchery Brook trap was operated March 15-May 15, and September 15-November 15. Twenty-two steelhead were captured and processed in Hatchery Brook during the spring season. In the fall, 672 salmon, 23 brown trout and 9 steelhead were captured in the trap and processed.
Electrofishing yielded collections of 135 salmon in seven trips to the Lamoille River, one salmon in one trip to Otter Creek, and 11 salmon in two trips to the Missisquoi River. Numbers of salmon collected in the fall 2019 tributary runs were good for Hatchery Brook and Lamoille River, but multiple high flow events made sampling on Missisquoi and Otter challenging.

A total of 317 (124 males and 193 females) adult salmon were taken from Hatchery Brook for use as broodstock at the Ed Weed Fish Culture Station. Ninety-one of the males, and 27 of the 193 females spawned were lethally sampled for disease testing. One hundred and ninety (97 females and 93 males) were found dead in captivity, and the remainder were released alive in Lake Champlain.

Length frequency distributions of Hatchery Brook and Lamoille River salmon were more typical in 2019, with a peak in the 475 to 525 mm size classes (generally lake age 1) (Figure 6). Age distributions of salmon from these two sites also show a recovery in the lake age 1 cohort in 2019, after a relatively low abundance of lake age 1 fish in 2017 (Figure 7).

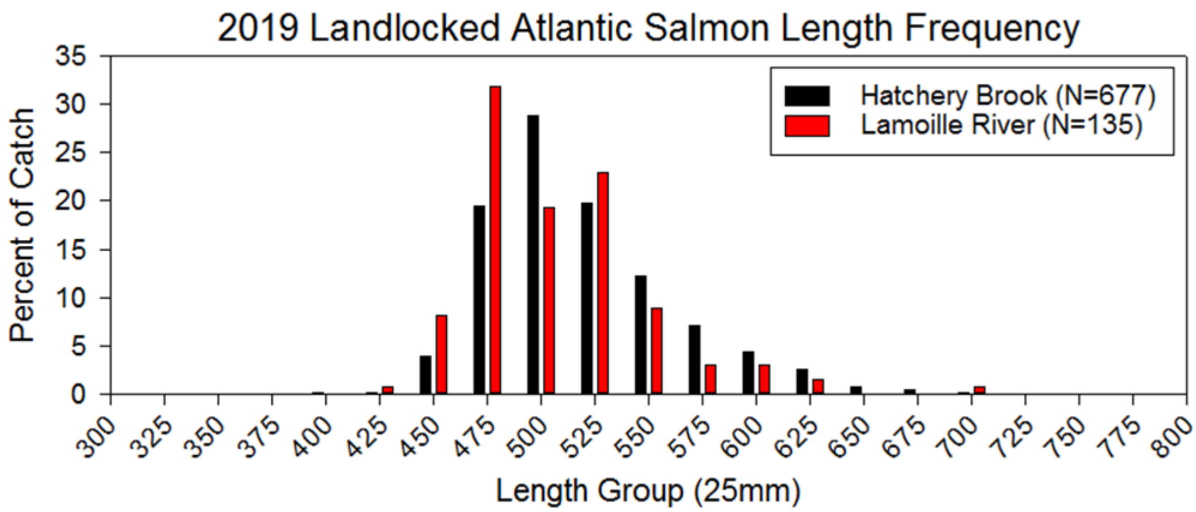

Figure 6. Length frequency distributions of landlocked Atlantic salmon collected from fall spawning runs in Hatchery Brook and Lamoille River in 2019.

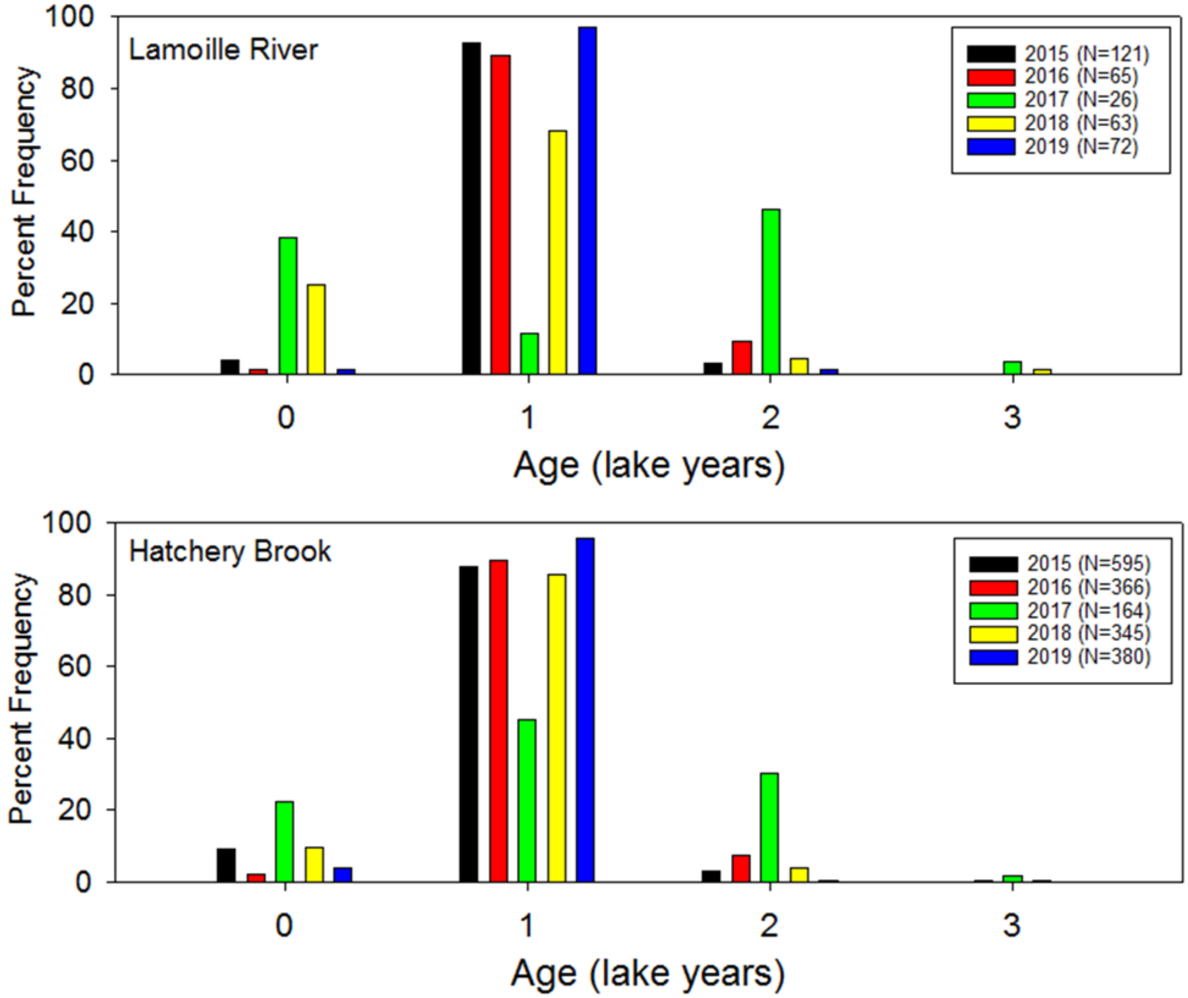

Figure 7. Age distributions (lake years) of landlocked Atlantic salmon from Lamoille River and Hatchery Brook, 2015-2019.

A trap net was deployed in Hatchery Cove for one overnight set in early November to sample the lake trout spawning concentration; it yielded 247 lake trout. Length frequency distributions of male and female lake trout collected by trap net in Hatchery Cove and by electrofishing in Whallon Bay are presented in Figure 8.

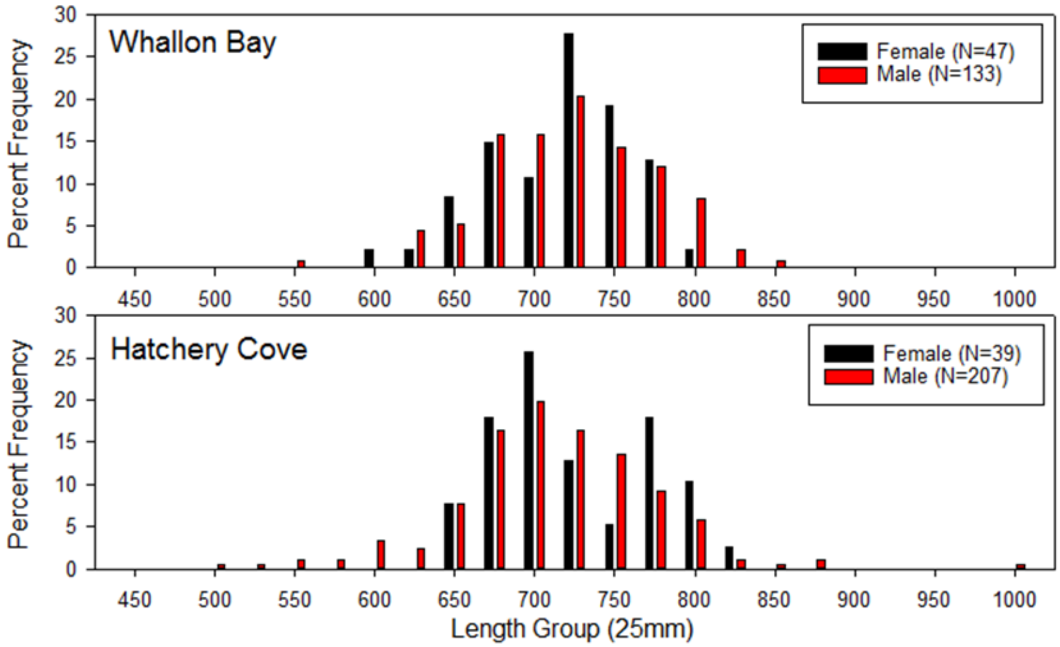

Figure 8. Length frequency distributions of male and female lake trout collected by trap net in Hatchery Cove and by electrofishing in Whallon Bay, November 2019.

Atlantic Salmon Broodstock Development at White River NFH (Ardren, Bouchard, Frost, Boynton)

Two Lake Champlain broodstocks of landlocked Atlantic salmon have been established at White River NFH. Both broodstocks were founded with feral fish from Hatchery Brook collected during the 2016, 2017, and 2018 fall spawning runs. In 2019, these two broodstocks became the primary broodstocks for Eisenhower NFH, serve as backup broodstocks for Ed Weed Fish Culture Station and are potential broodstock sources for Lake Ontario restoration efforts.

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Atlantic salmon in Lake Champlain have critically low levels of thiamine caused by foraging on non- native alewife. Thiamine deficiency complex (TDC) has impacted salmon survival at early life stages and migration performance of adults. We used an applied “Evolutionary Rescue” approach to develop a TDC-tolerant broodstock that a recent study showed had adaptive genetic variation needed to adapt to low thiamine conditions in Lake Champlain. However, the strong selection in the TDC-tolerant broodstock may have also caused for unintended reduction in fitness of other traits and increased levels of inbreeding. Because of these concerns, we also established a max-diversity broodstock founded by surviving families supplemented with thiamine. This max-diversity broodstock is managed to maximize genetic diversity (i.e., large effective population size) but did not undergo selection for tolerance to TDC. A total of 114 unique families foundered these broodstocks, 91% of the families survived with thiamine supplementation and founded the max-diversity broodstock and 43% of the families survived without thiamine supplementation and founded the TDC Tolerant broodstock.

Average fecundity of the 2016-year class females was 3,446 eggs for TDC-tolerant broodstock and 3,425 for max-diversity broodstock. The average eye-up was 69% with a range of 63% - 85% among egg take days. Eyed eggs were transferred from White River NFH to Eisenhower NFH where they will be reared to the smolt stage and stocked into Lake Champlain tributaries. Applied research projects have been started to evaluate the performance of smolts stocked from these two broodstocks over the next 10 years. Performance indicators to be monitored include: return to the fishery, length at age, smolt-adult return, and reproductive success.

Inter-year-class crosses between the 2016 (females) and 2017 (males) were used to establish the 2019 year-class for each broodstock. Number of unique families used to establish the 2019-year class was 46 for the TDC-tolerant broodstock and 50 for the max-diversity broodstock.

Sea Lamprey

Pre-treatment Larval Assessment Sampling (Allaire)

Vermont tributaries including the LaPlatte River, Winooski River, Lamoille River, Stone Bridge Brook, and the Missisquoi River were surveyed in 2019 to determine if a fall 2020 lampricide treatment would be needed. From these surveys, it was determined that lampricide treatments were warranted in the LaPlatte River (below Shelburne Falls), Winooski River, Lamoille River, and the Missisquoi River. Sea lamprey larval density in Stone Bridge Brook (n = 0) did not warrant a 2020 lampricide treatment. Applications for permits to treat those rivers that warrant a treatment will be submitted to the State of Vermont in the spring of 2020.

Post-treatment Larval Assessment Sampling (Allaire)

Post-treatment surveys were conducted in New York tributaries including the Boquet River, Ausable River, Little Ausable River, Salmon River, Saranac River, Rea Brook, Little Chazy River, and Great Chazy River during the summer of 2019 to determine the effectiveness of lampricide treatments conducted in the fall of 2018. Compared to pre-treatment surveys, post-treatment surveys showed that lampricide treatments had been successful (≥ 95%) at reducing sea lamprey densities in the Little Ausable River (96.1%), Salmon River (96.5%), Rea Brook (99.4%), Little Chazy River (100.0%), and slightly less effective in the Great Chazy River (93.7%). Lampricide treatments were less effective than desired in the Ausable River (80.1%), Boquet River (74.4%), and the Saranac River (50.4%). In those rivers that received a less than effective treatment, staff will review treatment data and discuss ways to improve treatment strategies for future treatments.

Other Larval Assessment Surveys (Allaire)

Additional lamprey larval surveys were conducted in Sunderland Brook (VT), Pike River (QC), and Morpion Stream (QC) in 2019.

Lamprey larval surveys are done periodically in Sunderland Brook where trapping is the selected control strategy. With a new and improved adult trap deployed for the first time in Sunderland Brook in the spring of 2019, this survey established baseline data to compare with future surveys to determine the effectiveness of the new adult barrier.

The USFWS began operating an adult barrier in Morpion Stream to remove spawning phase sea lamprey in 2014. Larval surveys have been conducted annually in the Pike River and in Morpion Stream to monitor changes in larval density. With no lamprey control on the Pike River, and permit conditions that only allow us to survey approximately 20% of the river that is accessible to sea lamprey, few conclusions can be made from our Pike River larval surveys. In Morpion Stream, we have seen larval densities drop dramatically since the installation and operation of the new barrier. In 2019, we did see an increase in larval densities from what was observed in 2017 and 2018, but that was likely because we were not able to install the adult barrier in 2018 until May 9th, after the spawning run had begun. Of the total 149 sea lamprey larvae collected in 2019, 88 (59%) were likely 1+ year old larvae (45–75 mm) and from 2018 spawning events. While we may struggle to get the barrier installed prior to the start of the adult spawning migration some years, the barrier has shown good potential for substantially reducing the sea lamprey larval population in Morpion Stream.

Delta Larval Assessment Sampling (Allaire)

Since 2011, deepwater larval surveys have been conducted during the same year as scheduled delta treatments to shorten the time between assessment data and treatments. We believe this increases treatment effectiveness by limiting the amount of time for lamprey larvae to move on the deltas between surveys and treatments. Two delta surveys (Mill Brook (NY) and Hoisington Brook (NY)) were conducted in preparation for possible treatments in the fall of 2019.

Mill Brook Delta: During the 2019 Mill Brook Delta survey no sea lamprey larvae were collected. No Mill Brook Delta treatment was need in the fall of 2019. This compares to one sea lamprey larvae collected during the 2015 survey (not treated) and 30 sea lamprey larvae collected during the 2011 survey (treated).

Hoisington Brook Delta: We collected just one sea lamprey larvae on the Hoisington Brook Delta in 2019. No Hoisington Brook delta treatment was needed. This was the first ever delta survey on the Hoisington Brook Delta.

Detection Sampling (Allaire)

In 2019, staff visited tributaries in the northeastern quadrant of the Lake Champlain Basin that were considered either “negative” for the presence of sea lamprey larvae or in streams where sea lamprey larvae may have previously been found at densities that did not warrant control efforts. No new sea lamprey larval populations were found.

In Otter Creek (VT), we collected 21 sea lamprey larvae during our survey and an additional 34 during biological collections for a toxicity test. This is a substantial increase from the zero sea lamprey larvae collected during the 2015 survey and four sea lamprey larvae collected during a larval survey in 2012. This increase in larval sea lamprey in Otter Creek will be evaluated to determine if future control measures are needed.

Trapping and Barriers (Allaire)

Adult sea lamprey were trapped in eight tributaries to Lake Champlain during the spring of 2019 to prevent or limit reproductive success (Table 6). Baited pots were deployed above trap sites in Malletts Creek (VT) and Trout Brook (VT) to capture sea lamprey that had made it upstream past the downstream weirs or blocking panels. In Trout Brook, we captured 47 adult sea lamprey in pots, all of which were below the blocking panel. In Malletts Creek, we caught 21 adults in pots.

The spawning migration was delayed throughout the Lake Champlain Basin in 2019 by about two weeks. Our largest weekly catch (n=119) did not occur until the first week in June. For most trap sites, we saw a decrease in our trapping efficiency (percent of days that we were successful at blocking all upstream migration). Pond Brook (VT) was the only exception where flows overtopped it on only two out of 83 days. Due to high water levels and the crane not being available, we were not able to install the Morpion Barrier until May 7th. Despite the delayed installation, the spawning run was delayed there as well, and we did not see the number of adults captured reach its peak in Morpion Stream until early June. We caught a total of 177 adult sea lamprey at the Morpion Barrier in 2019 compared to just 40 in 2018, and 30 in 2017. We experienced high flows for much of the trapping season in Hoisington Brook and were only able to completely block upstream lamprey migration for approximately 26.2%

of the trapping season compared to 61.5% of the trapping season in 2018. We saw our adult catch drop from 160 in Hoisington Brook in 2018 to just 34 in 2019. In Trout Brook (VT), we operated the new blocking panel and captured 47 adults in pots compared to just four in 2018.

Table 6. Results of spawning phase sea lamprey trapping in 2019. (*pots only)

Date Trap Set	State/ Province	Stream	Date Trap Removed	Percent Days Trap Operating	5 Year Average (2014 – 2018)	No. of Lamprey Captured (2019)	Percent Change From 5 Year Average
4/04/19	NY	Beaver Brook	7/3/19	97.7	97	34	-64.9
4/03/19	VT	Trout Brook	7/8/19	NA	NA	47*	NA
4/25/19	VT	Malletts Creek	7/2/19	32.4	151	224	+48.3
4/09/19	VT	Pond Brook	7/1/19	97.6	89	80	-10.1
4/11/19	VT	Sunderland Brook	7/1/19	54.3	41	13	-68.3
4/12/19	NY	Mullen Brook	7/3/19	50.0	38	65	+71.1
5/07/19	QC	Morpion Stream	7/1/19	89.1	118	177	+50.0
4/24/19	NY	Hoisington Brook	7/3/19	26.2	NA	32	NA
				Total		**672**	

During the spring of 2019, the USFWS began operating a new removable adult barrier in Sunderland Brook (VT) (Figure 9). This new barrier is similar to a new barrier installed in Pond Brook in 2018 and greatly improves upon the old portable barrier that had been used for many years.

Figure 9. A picture of the new sea lamprey barrier installed in Sunderland Brook in 2019 (left). This new barrier is much more resilient to high flows than the previous barrier (right) and provides more effective control.

Lampricide Control (Smith)

Lampricide treatments were completed on six tributary systems in 2019 (Table 7). The active ingredient and length treated here includes any tributaries treated along with the main stem. Control status of Lake Champlain tributaries is presented in Appendix 2. A treatment history and schedule of future treatments is presented in Appendix 3.

Table 7. Summary of 2019 lampricide applications in tributaries to Lake Champlain.

Stream	Date treated	Discharge (CFS)	TFM (lbs. active ingredient)	Length treated (miles)
Lewis Creek, VT	9/17/2019	18.5	328	5.6
Mt. Hope Brook, NY	9/24/2019	1.2	56	2.1
Poultney River, NY/VT	10/09/2019	118	1,578	12.9
Putnam Creek, NY	10/21/2019	100	812	9.2
Mill Brook, NY	10/29/2019	76	351	0.5
Hoisington Brook, NY	10/30/2019	7.5	71	0.2

Wounding Rates (Pientka, Smith)

The objective of the sea lamprey control program is to achieve and maintain wounding rates at or below 25 wounds per 100 lake trout, 15 wounds per 100 landlocked Atlantic salmon (salmon), and two wounds per 100 walleye.

Sea lamprey wounding rates calculated for 533-633 mm TL lake trout collected in fall 2019 increased to 57.4 wounds per 100 fish (n=47), which remains well above the program objective (Figure 10). However, the 2019 wounding rate estimate for Main Lake salmon in the 432-533 TL interval decreased to 18 wounds per 100 fish (n= 550), (Figure 13). Inland Sea-Malletts Bay (VT) salmon in the same length interval had an estimated 26.4 wounds per 100 fish (n=117) in 2019 (Figure 11).

The wounding rate on Main Lake salmon in 2019 was back down under 20, where it has been most years since 2010, after an observed increase in 2018 (Figure 11). The 2019 wounding rate on Inland Sea salmon was up slightly from 2018, but remains lower than the average rates observed during the experimental program (Table 9). The wounding rate on lake trout in 2019 remains higher than the average rates observed during the experimental program (Table 8).

The sea lamprey wounding rate for walleye (534 - 634 mm TL) collected in spring 2019 from the Missisquoi River was 0 wounds per 100 fish (n=119), which is below the Cooperative's lamprey wounding rate objective for walleye of two wounds per 100 fish.

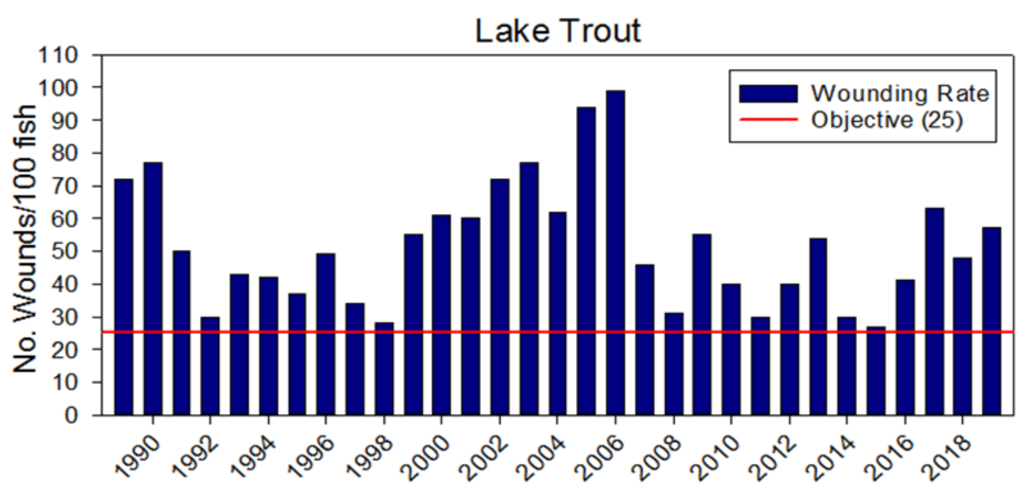

Figure 10. Type A1-A3 sea lamprey wounds (fresh and healing) per 100 lake trout (533-633 mm TL) from fall sampling in the Main Lake basin, 1989-2019. The target wounding rate of 25 wounds per 100 fish is presented for reference (red line).

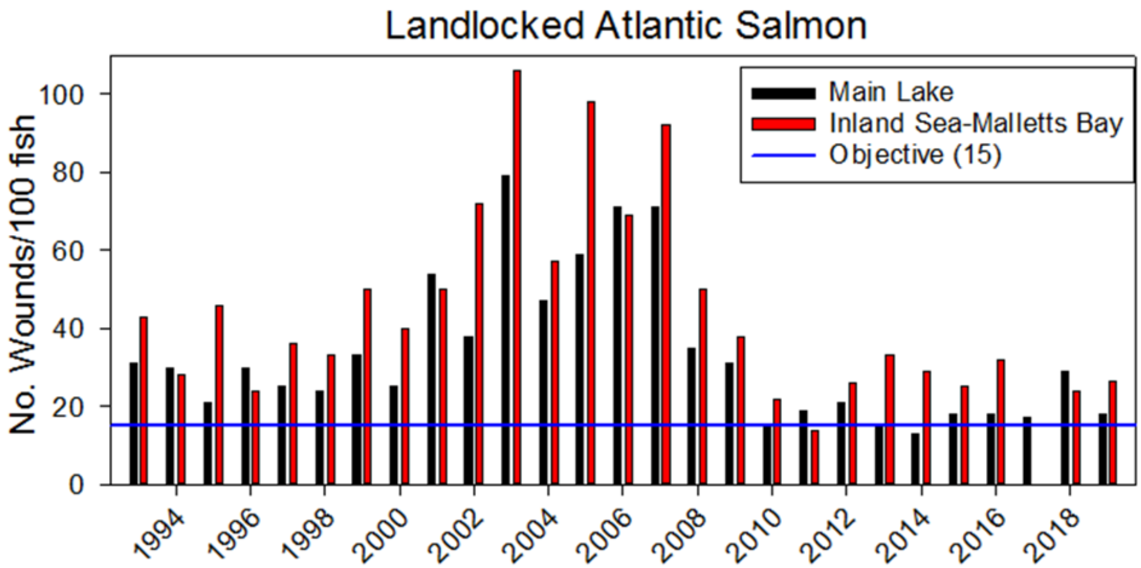

Figure 11. Type A1-A3 sea lamprey wounds (fresh and healing) per 100 salmon (432-533 mm TL) from fall sampling in the Main Lake (black bar) and Inland Sea-Malletts Bay basins (red bar), 1993-2019. The target wounding rate of 15 wounds per 100 fish is also presented for reference (blue line).

Table 8. Sea lamprey wounding rates (A1-A3) on Lake Champlain lake trout with lengths between 533-633 mm (21.0-24.9 inches) and Atlantic salmon with lengths between 432-533 mm (17.0-21.0 inches) during pre-control period (1982-1992), eight-year experimental control period (1993-1998) and 2019.

	Number of type A1-A3 lamprey wounds per 100 fish			
Species and Locations	**Objective**	**Pre-control**	**Experimental control**	**2019**
Lake Trout (Main Lake)	25	55	38	57.4
Atlantic Salmon (Lake-wide)	15	32	31	19.5
Atlantic Salmon (Main Lake)	15	34	27	18
Atlantic Salmon (Malletts Bay-Inland Sea)	15	32	39	26.4

Percidae

Yellow Perch (Pientka)

Experimental gillnets are set overnight at multiple locations in Vermont annually, order to monitor the Lake Champlain fish community. While these nets are not specifically targeting yellow perch, they do provide insight into relative abundance of yellow perch. In 2019, the sampling occurred between July 8th and July 24th.

Yellow perch catch per overnight set (CPUE) in 2019 was similar to recent years for Malletts and Shelburne. Missisquoi and St. Albans were much higher than past sampling (Figure 12). Sampling will continue in 2020.

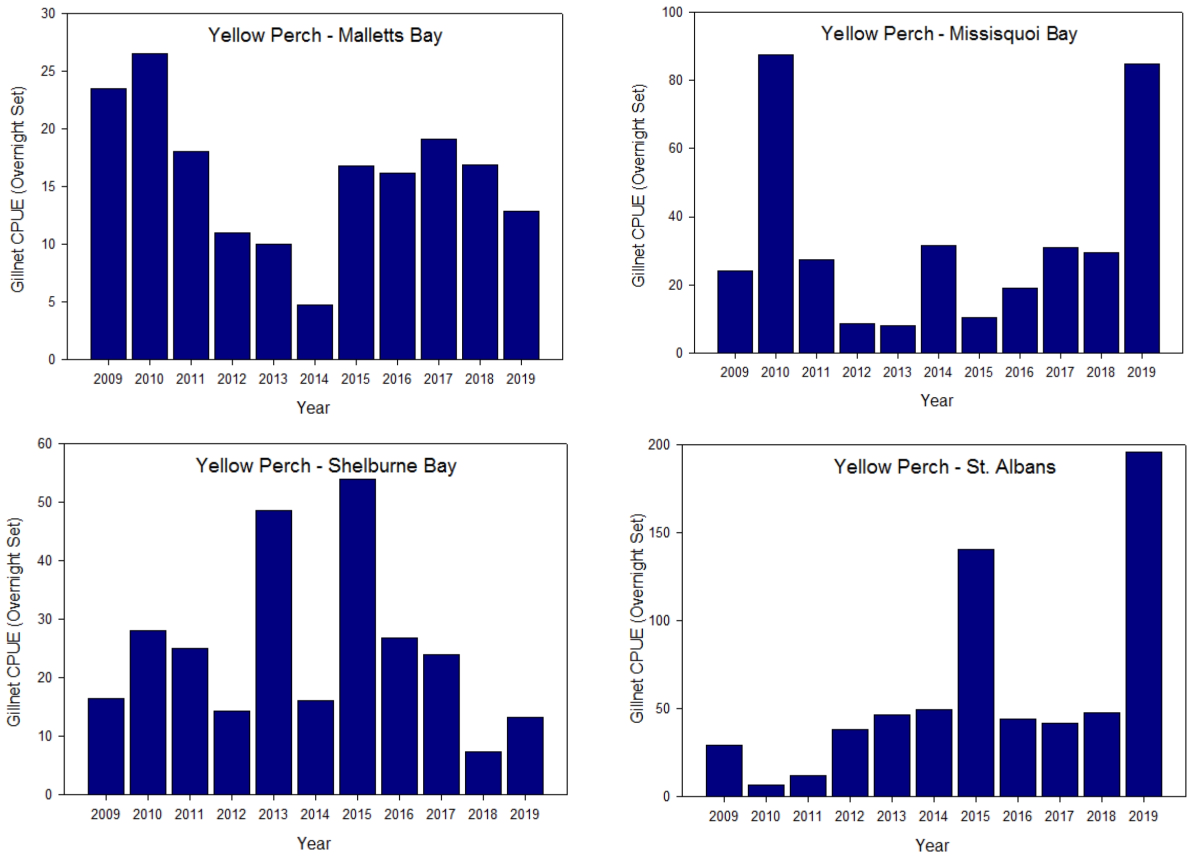

Figure 12. Yellow Perch CPUE for 2009-2019 at four Lake Champlain locations (note different y-axis scale).

Walleye (Pientka, Good)

Walleye management activities in 2019 on Lake Champlain included monitoring adult walleye returning to spawn in the Missisquoi River (VT). The Missisquoi River spawning stock was used for collection of brood stock for the fish culture and stocking program, and evaluation of the contribution of stocked walleye to spawning populations.

Two hundred and eighty-seven walleye (189 males, 98 females) were collected from the Missisquoi River. Twenty-three pairs were spawned resulting in 3.14 million eggs. Eggs were hatched at the Ed Weed Fish Culture Station (FCS) in Vermont. Fingerlings were reared in the intensive culture system located at the Ed Weed FCS and in three ponds managed by the Lake Champlain Walleye Association. All fry and fingerlings were marked with oxytetracycline (OTC) prior to stocking. Fifty age-3 males were collected for evaluation of the contribution of stocked fish to the spawning run in the Missisquoi River.

Sauger (Fiorentino)

NYSDEC is assessing options for sauger restoration in Lake Champlain and has drafted a Lake Champlain Sauger Restoration Plan. The plan has been reviewed by the FTC sauger working group and was presented to the full FTC in July 2019 for final input. A major component of the plan is establishing a sauger hatchery program to restore the species to Lake Champlain with a focus on the South Lake region. The plan suggested using broodstock from the upper Mississippi River or Lake St. Pierre, Canada. The draft plan was sent to Quebec MFFP for their review.

Centrarchids

Largemouth and Smallmouth Bass (Good, Pientka)

Angling for largemouth and smallmouth bass in Lake Champlain continues to be highly popular. The lake is widely considered to be one of the top 5 bass fishing destinations in the country, and it attracts and supports a high level of recreational and tournament-oriented fishing pressure. In 2019, Vermont issued 127 permits for bass tournaments on Lake Champlain, down from 135 the previous year. Of the two major U.S. professional bass fishing tournament series, only Forrest L. Wood (FLW) Outdoors held an event on the lake in 2019. Event results indicate that tournament catches have remained very consistent since the first professional tournament was held on Lake Champlain in 2002 (Figure 13).

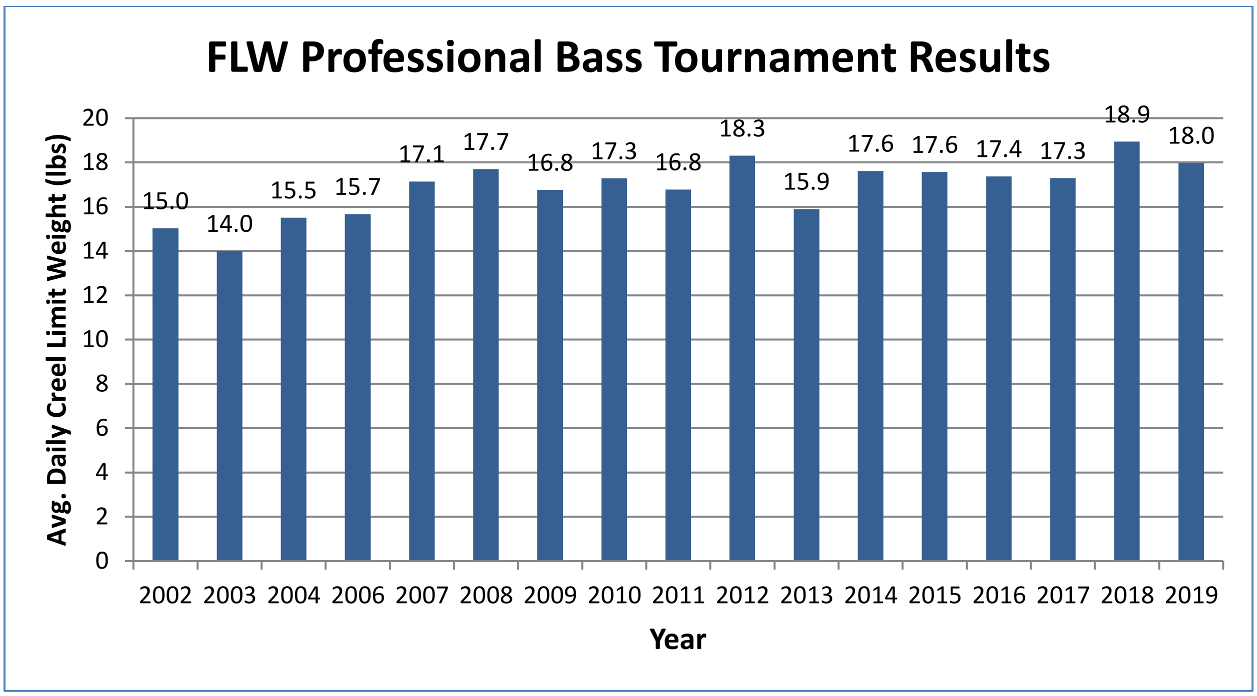

Figure 13. Average daily creel limit weights for the Top 10 anglers each year for FLW Outdoors Professional-level bass tournament series held on Lake Champlain since 2002.

Electrofishing surveys were conducted on Vermont waters of northern Lake Champlain in the spring of 2019. Fourteen transects were sampled at three different sites. A total of 6.6 hours of electrofishing was completed and 147 largemouth bass and 152 smallmouth bass were collected. Largemouth bass ranged in size from 79 to 508 mm total length and smallmouth bass ranged in size from 155 to 521 mm TL.

No bass surveys were conducted on southern Lake Champlain in 2019.

Esocids

Muskellunge (Good, Pientka)

No muskellunge stocking activities were conducted by VTFWD in the Missisquoi River and Missisquoi Bay in 2019 due to the unavailability of surplus fish from NYDEC's Chautauqua Hatchery. Previous year's stocking numbers are provided in Table 9.

Table 9. Muskellunge stocking numbers for Lake Champlain, 2008-2019.

Date	Total Number Received	Total Wt. (kg)	Avg. Length (mm)	Numbers Stocked by Location	
				Lower Missisquoi River & Bay	Above Swanton Dam
8/19/2008	250	2.0	155	250	0
8/19/2009	10,000	79.0	128	10,000	0
2010	0	na	na	0	0
8/18/2011	5,150	43.4	127	5,150	0
8/21/2012	8,800	84.0	136	8,800	0
8/26/2013	7,580	70.4	135	4,580	3,000
8/27/2014	7,000	62.2	133	5,000	2,000
8/25/2015	5,540	38.6	123	3,540	2,000
8/22/2016	6,300	58.1	135	3,800	2,500
8/21/2017	4,340	33.6	127	2,340	2,000
2018	0	na	na	0	0
2019	0	na	na	0	0
TOTAL	**54,960**			**43,460**	**11,500**

In a non-stocking year, fall sampling for juveniles provides an opportunity to document any natural reproduction that may be occurring now that multiple age classes of mature stocked fish are present in the system. Unfortunately, due to poor river conditions and staff limitations, no fall sampling for juvenile muskellunge was conducted in 2019.

However, anecdotal information from angler catches continued to indicate that stocked muskellunge were surviving and growing well, and department sampling activities for other species in the Missisquoi River have resulted in the collection of incidental muskellunge of various size classes, including one yearling that was presumed to be a wild-produced fish from 2018.

In the spring of 2019 during walleye collection activities on the Missisquoi River, department staff collected five muskellunge measuring 328, 865, 882, 930, and 1,020 millimeters in length. The largest fish had a weight of 8,650 grams. The smallest fish at 328 mm TL was the appropriate size to be considered a one-year old, which means it was produced in 2018 – a year where no stocking occurred in the system.

Anguillids

American Eel Mortality (Pientka)

In the late summer of 2019 multiple reports of dead American eels, *Anguilla rostrata* were received around Lake Champlain. The large number of reports prompted VTFWD to establish a report logging system. The system logged each report and collected specific information about the observation such exact location, number of eels observed, size of eels, when they were first observed and any additional details. A total of 77 reports were received between August 11th, 2019 and September 19, 2019. Based the reports, eel mortalities appeared to start in late July and increased through August (Figure 14). Eel mortalities appeared to have declined in early September based on reports. A total of 139 dead eels were reported around Lake Champlain (Figure 15) with a higher concentration of reports in the Inland Sea (or Northeast Arm) area of the lake. When reports contained size information most eels were described to be around 588 mm (24 inches) long.

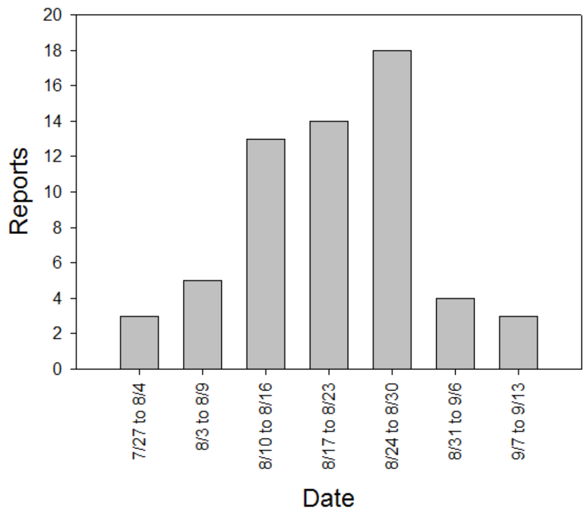

Figure 14. Dead American eel reports by date in Lake Champlain, 2019.

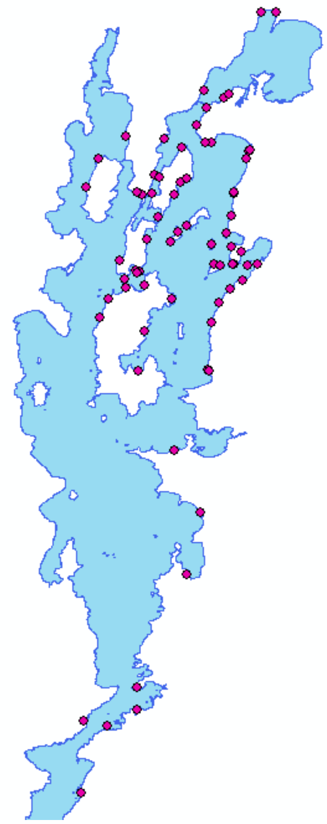

Figure 15. Location of reports (red dots) of American eel mortalities in Lake Champlain in 2019.

In general, the reports described finding one or two dead eels washed up on the shore. One person reported observing nine dead eels. The reports were usually of a dead whole or partial eel, but a few individuals reported seeing live eels swimming at the water surface and then later found them freshly dead on the shore. When possible, freshly dead eels were collected. A total of 11 eels were collected (range 648-800 mm TL). Due to the challenges of fish health diagnostics on recently dead fish a small sub-sample of live eels was also collected. On September 3, 2019 boat electrofishing was conducted in St. Albans Bay to collect live eels for fish health testing. A total of seven individuals were collected ranging in length from 597-781 mm.

All 18 eels collected were examined by VTFWD Fish Health Biologist, and tests were performed. Additional histological samples were also shipped to the University of New Hampshire Veterinary Diagnostic Laboratory for evaluation. While both evaluations identified some minor issues, there was no conclusive evidence of a causative fish pathogen or condition (Jones, 2020).

The heads from all eels examined were frozen and will have otoliths removed for age determination and OTC mark evaluation. From 2005 to 2008, 2.7 million small eels (50-60 mm), marked with OTC, were stocked into the Richelieu River by Quebec MFFP. Examination of the otolith for the OTC mark will be used to determine if these eels were stocked. One study suggested that stocked eels had difficulties in finding their way out of the lake (Westin 2003). Otolith evaluation will be reported once completed.

American Eel Sampling (Staats)

In 1997, an eel ladder was constructed at the Richelieu River dam in Chambly, Quebec and in 2001 a fish ladder and an eel ladder were built at the St. Ours dam on the Richelieu River. These facilities reopened connectivity for eel migration from the St. Lawrence River to Lake Champlain. Québec MFFP, in cooperation with a commercial fishing union and Hydro-Québec, initiated an eel stocking program in 2005 in the Richelieu River to further enhance eel recruitment. In order to monitor the success of these stocking efforts and new passage facilities, Québec asked members of the Fisheries Technical Committee to monitor eel in Lake Champlain.

American eel sampling was conducted in 2019 and the total numbers of eels collected decreased relative to sampling efforts in 2018 (Table 10). Eels collected ranged in size from 314 mm to 782 mm. Mean length remained unchanged at 571 mm (SD = 88, n =124) and mean weight was 373 grams (SD = 184). Except for 2007, the average size of eels collected has increased each year. However, mean length in 2019 was similar to 2018. The smallest eel collected in 2019 was 314 mm. The sampling continues to suggest minimal recruitment of eels is occurring to Lake Champlain.

Table 10. Summary of American eel stocking in the upper Richelieu River and the number of eels caught in Lake Champlain by electrofishing. Catch per unit effort (CPUE) equals number of eels collected per hour sampling.

Year	Number of glass eels stocked	Number of eels collected					
		Keeler Bay	Paradise Bay	Crane Point	Converse Bay	Grand Isle shoreline	CPUE
2005	600,000	na	na	na	na	na	na
2006	1,000,000	na	na	na	na	na	na
2007	425,500	0	0	na	0	1	0.25
2008	746,000	na	na	na	na	na	na
2010	0	1	1	na	25	14	10.25
2012	0	1	2	na	57	21	20.25
2014	0	12	17	na	54	na	27.66
2016	0	18	31	41	58	10	31.60
2017	0	25	13	76	74	16	40.80
2018	0	17	25	15	73	12	28.40
2019	0	19	28	15	60	7	28.80

Acipenseridae

Lake Sturgeon (Murphy, Simard)

The movement of lake sturgeon previously tagged with acoustic transmitters was monitored by stationary acoustic receivers placed throughout Lake Champlain, in spawning tributaries, and on the Winooski River delta. No new sampling or tagging was conducted.

Recreational Fishery Monitoring

Angler Surveys (Pientka, Balk)

No angler surveys were conducted in 2019.

Fish Health (Jones)

Walleye Fish Health Inspection: Adult walleye broodstock were collected from the Missisquoi River and transferred to a bio-secure isolation station at the Ed Weed FCS. Eggs were water-hardened in a 50-ppm iodine solution for 30 minutes and then placed in a quarantine unit until associated fish health inspection laboratory work was completed. On April 29, 2019, 50 gamete contributing adults (25 female/25 male) were lethally sampled and tested by standard cell culture for viral pathogens of concern (IPN, IHN, VHS and OMV). In addition, samples were tested for VHS, Type 4B testing by Quantitative PCR technology. All fish sampled tested negative for viruses of concern and other CPE producing viral agents. Lymphocystis disease virus was presumptively identified on the skin. Muscle tissue was visually examined for the Heterosporis sp. parasite which wasn't observed. One adult was diagnosed with Fibrosarcoma which was previously identified in the Lake Champlain walleye population.

Wild Landlocked Atlantic Salmon Inspection: Sebago strain landlocked Atlantic salmon, originating from Lake Champlain, were captured from the Ed Weed FCS discharge stream and used as an egg source. Eggs were water hardened in iodine at 50-ppm concentration for 30 minutes. Fertilized eggs were held in a bio-secured isolation area until associated fish health inspection laboratory work was completed. From November 5, 2019 through November 19, 2019, a total of 112 salmon were lethally sampled for pathogens of concern (IPN, IHN, VHS, OMV, and BKD) (Table 11). In addition, non-lethal, ovarian fluid samples were collected from 107 females. All fish sampled tested negative for fish pathogens of concern and other CPE producing viral agents including Aquareovirus A which was detected the previous year. The internal Cestode "Diphyllobothrium dendriticium" was documented from the gastrointestinal tract. This parasite has been documented consistently when testing salmon from Lake Champlain.

Vermont Wild Fish Health Testing: Two Lake Champlain locations were sampled in 2019 and samples were forwarded to the USFWS Lamar Fish Health Center to be included in the USFWS's Natural Fish Population Survey. On May 1, 2019, samples were collected from Larabee's Point located in Shoreham, VT. Testing encompassed five fish species for a total of 94 fish sampled; species included: largemouth bass, smallmouth bass, white crappie, pumpkinseed, yellow perch. Pathogens tested for included: VHS, IHN, IPN, LMBV, SVCV, AS, and YR (Table 11). Largemouth Bass Virus (LMBV) was detected in the largemouth bass sample. Common parasites detected include blackspot, redworm, white grub, yellow grub and bass tapeworm.

On May 21, 2019 samples were collected from Dillenbeck Bay located in Alburgh, VT. Testing encompassed three fish species for a total of 97 fish sampled; species included: largemouth bass, pumpkinseed, yellow perch. Pathogens tested for included: VHS, IHN, IPN, LMBV, SVCV, AS, and YR. Largemouth Bass Virus was detected in the largemouth bass sample. Common parasites detected include white grub and yellow grub.

Table 11. Summary of pathogen abbreviations.

Pathogen	Abbreviation	Pathogen	Abbreviation
Infectious Pancreatic Necrosis	IPN	Spring Viremia Carp Virus	SVCV
Infectious Hematopoietic Necrosis	IHN	Furunculosis	AS
Viral Hemorrhagic Septicemia	VHS	Enteric Redmouth Disease	YR
Largemouth Bass Virus	LMBV	Oncorhyncus Masou Virus	OMV

Research

Development of methods to assess lake sturgeon populations in Lake Champlain (Lisa K. Izzo[1], Donna L. Parrish[2,1], Gayle Barbin Zydlewski[3], and J. Ellen Marsden[4], Affiliations: Vermont Coop Unit1, USGS[2], Maine Sea Grant[3], UVM[4].)

In 2019, the Vermont Cooperative Fish & Wildlife Research Unit (VTCFWRU) continued research on movements of juvenile lake sturgeon. Sampling for juvenile lake sturgeon took place from 1 July to 25 October using baited trotlines. A total of 8 new juvenile lake sturgeon received acoustic tags, bringing the total for the study to 29. Of these, 26 were captured in Lake Champlain (25 on the Winooski River delta, and 1 in Burlington Bay) and 3 were captured in the Winooski River. Tagged lake sturgeon are tracked using an array of acoustic receivers deployed in Lake Champlain.

For the third year in a row, a fixed-location dual-frequency identification sonar (DIDSON) was deployed downstream of the lake sturgeon spawning site in the Winooski River to count upstream migrating lake sturgeon. The DIDSON was deployed on 8 May and removed on 19 June 2019. During this period, three major storm events caused a spike in flow levels in the Winooski River that resulted in sedimentation that obscured the view of the DIDSON. For the duration of the season, 241 hours of footage with at least partial visibility were recorded. This footage, along with information from the 2017 and 2018 spawning runs, are being analyzed to estimate abundance of lake sturgeon in the Winooski River during the spawning season. Additionally, in November 2019 we completed another side scan sonar survey on the Winooski River delta. This information will be used to estimate abundance of adult lake sturgeon as they overwinter in this area.

Lake Trout Recruitment (J. Ellen Marsden, Pascal Wilkins, UVM)

The proportion of wild juvenile (Age-0 through Age-3) lake trout (*Salvelinus namaycush*) collected in bottom trawls in the central Main Lake in 2019 was lower (57.4%), for the first time, than the previous year (73.3%). Data from intensive bottom trawling conducted in the central, north, and south Main Lake every 2 to 3 weeks at 30-65 m depths during the ice-free season in 2015-2019 were analyzed to examine differences in distribution of wild and stocked juveniles by depth, and inform design of long-term assessment sampling. Differences in distribution of wild and stocked lake trout were most pronounced during thermal stratification, when wild juveniles were more abundant than stocked juveniles at shallower depths and warmer temperatures and stocked juveniles were more abundant at deeper depths and colder temperatures. Temperature preferences may be a consequence of different early rearing environments; wild lake trout are acclimated to lake temperatures and forage, whereas stocked fish entered the lake with high lipid content and little foraging experience. Unbiased assessment of the proportion of wild lake trout and growth and survival of the entire juvenile lake trout population using bottom trawl sampling should either take place in the pre- and post-stratification seasons when wild and stocked fish are at the same depths, or include the full range of depths and temperatures that wild and stocked fish occupy during the stratified period. Wild (unclipped) lake trout older than Age-3 continue to be captured in trawls, but have not yet appeared in state assessments in fall at Gordon Landing and Whallon Bay.

Lake Champlain food web model (Jason D. Stockwell, J. Ellen Marsden, and Rosalie Bruel, UVM)

Lake Champlain has experienced several potentially important ecological "events" over the last few decades. A number of species have invaded the lake, including zebra mussels (*Dreissena polymorpha*) first detected in 1993, white perch (*Morone americana*) in 1984, alewife (*Alosa pseudoharengus*) in 2003, the spiny water flea (*Bythotrephes longimanus*) in 2014, and the fishhook water flea (*Cergopagis pengoi*). In the last few years lake trout (*Salvelinus namaycush*) natural recruitment has suddenly "turned on" after more than four decades of stocking with no evidence of wild-produced recruits (Marsden et al. 2018). Understanding how changes in the structure of the food web impact the ecosystem as a whole requires an ecosystem-based approach. The data used for models constrain the usefulness and relevance of model outputs, and development of whole-lake food-web models is generally challenged by lack of geographically extensive, long-term data on the suite of abiotic and biotic parameters that are needed to describe aquatic ecosystems. Lake Champlain is an exception, due to long-term datasets (> 25 years) for a broad data set of limnological variables (nutrients, temperature, water chemistry, phytoplankton, and zooplankton). Annual fisheries data (pelagic forage fish surveys, nearshore fish community surveys, lake trout spawner surveys, sea lamprey larval and adult assessments, and stocking rates of Atlantic salmon (*Salmo salar*), lake trout, and walleye (*Sander vitreus*) have also been regularly collected for over two decades. Our objective is to compile these long-term datasets to retrospectively examine the impacts of exotic species invasions in Lake Champlain, and to prospectively test management-relevant hypotheses. For example, if lake trout continue to be stocked at historical rates in the face of substantial, sustained natural recruitment, is the forage fish community likely to collapse? What level of stocking, if any, is sustainable? What will happen to nearshore: offshore and benthic: pelagic carbon cycling if deep-water quagga mussels (*Dreissena bugensis*) invade the lake? Over the past year, the work has focused on extracting from the data some coherent metric among groups. We are analyzing in detail data from the forage fish survey, as the biomass estimate will be key for the rest of the food web (forage fish are at an intermediate trophic level).

Lake Champlain Forage Fish/Carbon Project (Jason D. Stockwell, J. Ellen Marsden, Ariana M. Chiapella, UVM)

Quagga mussels (*Dreissena bugensis*) are a clear and imminent danger to the ecology of Lake Champlain. In the Great Lakes, the invasive quagga mussel has dramatically shifted system production from pelagic to benthic habitats with negative consequences on resource availability for pelagic-dependent trophic levels. Quagga mussels could have the same effects in Lake Champlain when they invade. If quagga mussels induce a shift from pelagic to benthic primary production in the lake, then pelagic-dependent forage fishes such as alewife (*Alosa pseudoharengus*) and rainbow smelt (*Osmerus mordax*), and ultimately lake trout (*Salvelinus namaycush*) and Atlantic salmon (*Salmo salar*), could be negatively impacted. The objective of our project is to understand the carbon (i.e., energy) pathways of Lake Champlain's forage fish community, so that we can anticipate the effect quagga mussels may have on the lake's fishery.

We have sampled the main components of the forage fish food web at two sites in the Main Lake (40 and 100 m) and at 40m in the Northeast arm. At each site we collected samples of basal resources (phytoplankton and detritus) and primary consumers (zooplankton and benthic invertebrates), plus alewife, rainbow smelt, slimy sculpin, and Mysis diluviana. All taxa will be analyzed for stable nitrogen and carbon isotopes to determine trophic position and foraging habitat. We will use these data to delineate the primary basal energy resources that support the forage fish community (and ultimately lake trout) in Lake Champlain. We will identify any vulnerable trophic connections, and the consequent resiliency of the forage fish community to the likely invasion of quagga mussels. In conjunction with the Lake Champlain food web model, this project will inform how certain management and/or stocking decisions may impact the stability of the forage fish community.

Among-family Variation in Survival and Gene Expression Uncovers Adaptive Genetic Variation in a Threatened Fish (Avril M. Harder, Janna R. Willoughby, Mark R. Christie – Purdue University; William R. Ardren – USFWS)

Variation in among-family transcriptional responses to different environmental conditions can help to identify adaptive genetic variation, even prior to a selective event. Coupling differential gene expression with formal survival analyses allows for the disentanglement of treatment effects, required for understanding how individuals plastically respond to environmental stressors, from the adaptive genetic variation responsible for differential survival. We combined these two approaches to investigate responses to an emerging conservation issue, thiamine (vitamin B1) deficiency, in a threatened population of Atlantic salmon. Thiamine is an essential vitamin that is increasingly limited in many ecosystems. In Lake Champlain, Atlantic salmon cannot acquire thiamine in sufficient quantities to support natural reproduction; fertilized eggs must be reared in hatcheries and treated with supplemental thiamine. We evaluated transcriptional responses (via RNA sequencing) to thiamine treatment across families and found 3,616 genes differentially expressed between control (no supplemental thiamine) and treatment individuals. Fewer genes changed expression equally across families (i.e., additively) than exhibited genotype × environment interactions in response to thiamine. Differentially expressed genes were related to known physiological effects of thiamine deficiency, including oxidative stress, cardiovascular irregularities and neurological abnormalities. We also identified 1,446 putatively adaptive genes that were strongly associated with among-family survival in the absence of thiamine treatment, many of which related to neurogenesis and visual perception. Our results highlight the utility of coupling RNA sequencing with formal survival analyses to identify candidate genes that underlie the among-family variation in survival required for an adaptive response to natural selection.

Effect of Dam Removal on Habitat use by Spawning Atlantic Salmon (Nicole Hill, Jessamine Trueman, Ashlee Prévost, Dylan Fraser, James Grant- Concordia University, William Ardren – USFWS)

By impeding migration and degrading habitat downstream, dam construction has caused population declines in many migratory fish populations. As part of the landlocked Atlantic salmon (Salmo salar) restoration program in Lake Champlain, the Willsboro Dam was removed from the Boquet River, NY in 2015 providing an opportunity to study the effects of dam removal on spawning habitat quality and availability. Spawning habitat surveys were conducted downstream of the dam site in 2014, 2016 and 2017, and in historical spawning grounds upstream in 2016 and 2017. The habitat used was characterized by measuring depth, water velocity, and substrate size at each redd. Mean habitat use did not differ between upstream and downstream sites for any variables in 2016 and only differed for depth in 2017. However, the variance in depth and substrate used for spawning were lower at the upstream site in 2016, likely due to an abundance of habitat. In the downstream site, the mean and variance in depth at redds decreased after dam removal as did the variance in substrate size, increasing the habitat suitability of redds. When compared to literature data, habitat used upstream of the former dam was of medium quality in both 2016 and 2017 and improved downstream from low to medium quality in both column velocity and substrate size after dam removal. This study illustrates that positive shifts in the quality of habitat used can occur rapidly following dam removal by allowing access to suitable spawning habitat upstream and improving habitat downstream.

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Appendix

Appendix 1. Members and Advisors of the Lake Champlain Fish and Wildlife Management Cooperative, Fisheries Technical Committee

U.S. Fish and Wildlife Service:
W. Ardren (FTC Chair), B. Young, B.J. Allaire, Essex Junction, VT
N. Staats – Liaison to VTFWD – Essex Junction, VT
S. Smith – Liaison to NYSDEC – Essex Junction, VT
H. Bouchard – North Chittenden, VT

Vermont Fish and Wildlife Department:
B. Pientka, L. Simard - Essex Junction, VT
Murphy, S. Good – Rutland, VT
Kelsey – Grande Isle, VT

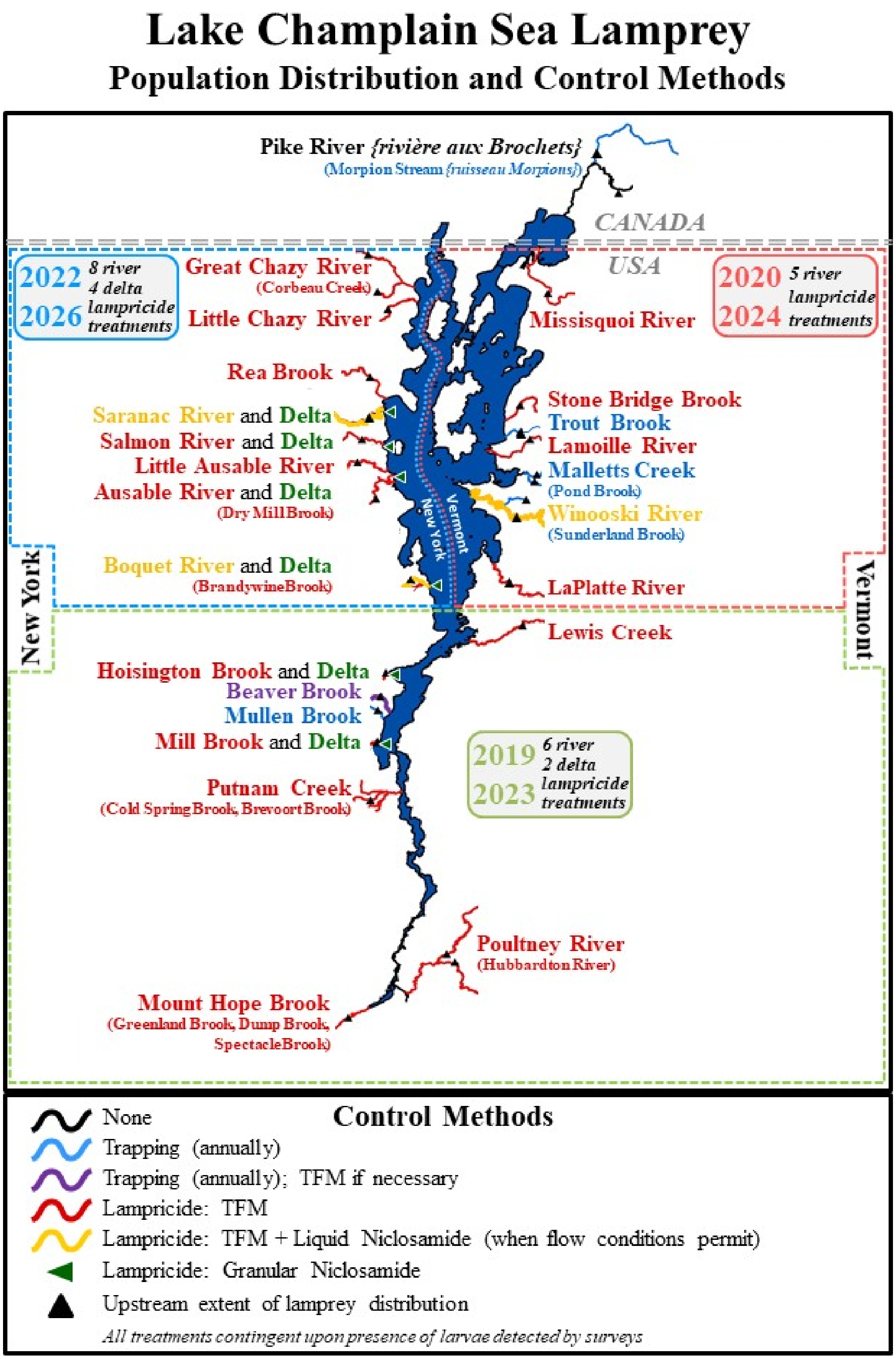
New York State Department of Environmental Conservation:
R. Fiorentino, N. Balk, T. Shanahan – Ray Brook, NY

University of Vermont:
E. Marsden – Burlington, VT

Vermont Cooperative Fish and Wildlife Research Unit (USGS):
D. Parrish – Burlington, VT

Lake Champlain Sea Grant:
M. Malchoff – Plattsburgh, NY

Appendix 2: Map of Lake Champlain tributaries with lamprey populations and the site-specific methods used to control them.



Appendix 3: Schedule of completed and projected Lake Champlain lampricide treatments. The "T" denotes completed TFM-only treatments, "B" denotes completed Granular Bayluscide delta treatments, "C" denotes completed TFM + 1% Niclosamide treatments, and "P" denotes pending treatments. Treatment histories from the experimental control program (1990-2000) and the long-term program from 2001-2009 are available in earlier annual reports. The geographic reorganization plan was completed in 2017 resulting in the temporal and geographical alignment of treatments in the Lake Champlain Basin and a new cycle of treatments in 3 out of every 4 years.

			10	11	12	13	14	15	16	17	18	19	20	21	22	23
New York	WEST	Great Chazy River			T		T				T				P	
		Little Chazy River									T				P	
		Rea Brook									T				P	
		Saranac River				C					C				P	
		Saranac Delta			B		T				B				P	
		Salmon River	T				T				T				P	
		Salmon Delta					B				B				P	
		Little Ausable River	T				T				T				P	
		Ausable Delta Complex		B			B				B				P	
		Ausable River	T				T	T			T				P	
		Boquet River		C			C				C				P	
		Boquet Delta					B								P	
	SOUTH	Hoisington Brook										T				P
		Beaver Brook							T							P
		Mill Brook			T							T				P
		Mill Delta			B											P
		Putnam Creek	T			T			T			T				P
		Mt. Hope Brook			T			T				T				P
		Poultney/Hubbardton rivers		T				T				T				P
Vermont		Lewis Creek	T				T	T				T				P
	EAST	LaPlatte River							T				P			
		Winooski River			T			T					P			
		Stonebridge Brook				T			T							
		Lamoille River				T							P			
		Missisquoi River			T								P			