FINAL REPORT

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LAKE CHAMPLAIN FISH COMMUNITY MONITORING

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PROJECT SUMMARY

Significant changes in Lake Champlain's cold-water community - including substantial natural recruitment of lake trout (*Salvelinus namaycush*) and invasion of alewife (*Alosa pseudoharengus*) - highlighted the need for a long-term survey of the cold-water prey community. Through this project, a new, comprehensive cold-water forage fish bottom trawling survey was designed and implemented in Lake Champlain that can be used to track fluctuations in prey fish populations - including alewife (*Alosa pseudoharengus*), rainbow smelt (*Osmerus mordax*), slimy sculpin (*Cottus cognatus*), and trout-perch (*Percopsis omiscomaycus*). A standardized operating procedure, data analysis scripts, and the foundation of a long-term survey dataset with a standardized database were established to enable managers and researchers to identify trends in the forage base, better understand the drivers of predator population changes, and make informed stocking decisions to maintain the cold-water fish community and fishery.

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1. PROJECT INTRODUCTION

Management of piscivorous sport fishes such as salmonids requires an understanding of the forage available and the number of predators in the system (a predator: prey ratio). Understanding the predator population requires data on fish abundance and population growth, and number stocked (if the population is dependent on stocking). Forage fish data need to include abundance, year class strength (as an indicator of recruitment), length-distribution, and biomass of each species. In Lake Champlain, the primary targets of sport fishing are Atlantic salmon, lake trout, and walleye; the first two have been supported by stocking since 1972, after their extirpation by 1900, and walleye populations are partially supported by stocking (Marsden et al. 2010, Marsden and Langon 2012). Diet studies of these predators indicated that all three species have incorporated alewife into their diets (Simonin et al 2018, Futia et al. 2025).

Several changes have occurred since 1990 in Lake Champlain that may affect the growth and survival of predators. Sea lamprey control began in 1990 and its success at reducing wounding of salmonids could result in higher survival of predators, and thus increased forage demand (Marsden et al. 2003). Alewife were discovered in Missisquoi Bay in 2003; by 2006 they were found throughout Lake Champlain and became part of the diet of cold-water predators (Marsden and Langdon 2012). Two predatory cladoceran zooplankton invaded the lake in 2014 and 2018, potentially changing the zooplankton forage for rainbow smelt and alewife. The first evidence of wild lake trout recruitment was observed in 2015, and by 2025 the population was considered to be recovered (Marsden et al. 2018, Wilkins and Marsden 2021); however, this success means that there are additional predators in the lake in addition to those that have already been stocked. Several studies have shown that wild fish are more effective predators than stocked fish (Futia et al. 2025; Marsden et al. 2022; Savino et al. 1993).

In response to the increasing perception of the importance of understanding predator-prey dynamics, and likely increase in predator abundance after sea lamprey control decreased wounding of salmonids, a forage fish survey was developed by the University of Vermont (UVM) (Kirn and LaBar 1991). The survey was conducted annually in cooperation with the VTFWD from 1990 to 1997 before being adopted entirely by VTFWD and initially used stepped-oblique midwater trawling at night during August (LaBar 1998; Table 1). The survey aimed to examine any changes in rainbow smelt population structure and growth rates. Initially, four locations throughout the lake were sampled, two in the Main Lake (Shelburne Bay and Juniper Island), one in the Inland Sea, and one site in Malletts Bay (Figure 1). A fifth site, Barber Point in the Main Lake, was added to the assessment in 1993 (LaBar 1998). The appearance of alewife in Missisquoi Bay in 2003 stimulated the addition of hydroacoustics to the survey in 2005; this gear produces data on abundance and fish length and can be used to sample long transects and estimate population biomass. In 2008, floating gill nets were added to the forage fish survey to collect young-of-year alewife for age and growth analysis (Staats and Pientka 2009). In 2015, VTFWD discontinued the forage fish assessment due to a perception that the continued population stability of the cold-water predators and their prey did not require management assessment or interventions. That same year, sampling conducted by UVM produced evidence of natural recruitment of lake trout for the first time since stocking began in 1972 (Marsden et al. 2018). Fisheries managers raised concerns about the ability of the forage base to sustain the number of predators in the lake, and the need to re-start a long-term forage fish survey.

Table 1. Timeline of events associated with forage fish surveys in Lake Champlain.

Year	Event
1990	UVM develops a forage fish survey focused on midwater trawling for rainbow smelt
2003	alewife discovered in Missisquoi Bay
2005	hydroacoustic sampling added to survey
2008	floating gillnets added to survey to sample alewife near the surface
2015	VTFWD forage fish survey terminated
	First evidence of lake trout recruitment, 4 wild year classes of juveniles present
2016-2023	no forage fish data collected; intensive sampling for juvenile lake trout by UVM
2019	New UVM forage fish survey study initiated, funded by LCBP
2020	Research halted by COVID
2022	New UVM research vessel arrival delayed
2023	New UVM research vessel arrived in summer, too late for spring sampling
2024	UVM begins new forage fish survey
	VTFWD and UVM repeat midwater and hydroacoustic survey in Main Lake
2025	UVM continues new forage fish survey
	VTFWD and UVM repeat midwater and hydroacoustic survey in Main Lake

The 'restart' of a forage fish survey provided an opportunity to re-examine methods and data needed by managers and redesign the Lake Champlain survey. This study evaluated metrics useful for understanding the forage basin, using decades of similar forage fish surveys conducted by the Great Lakes that have similar fish communities and management objectives. All five Great Lakes use bottom trawling as the main sampling method for coldwater forage fishes, with hydroacoustics also used in lakes Ontario, Michigan, Huron, and Erie. Trawling and gillnets collect biological samples (fish) and yield biodata (individual and bulk lengths, weights, and ages estimated from otoliths), whereas hydroacoustic data are derived from fish echoes on sonar and yield count data and estimates fish sizes, but age data are not available (Table 2). Nets are limited by the size of the net or volume of water sampled; hydroacoustics detect virtually all fish in the water column beneath the boat for the entire distance 'sampled'. An essential difference between the methods is the extrapolation of the sample data: trawling is generally done at index stations and used for comparative abundance (catch-per-unit-effort) over time, while hydroacoustics samples a much larger spatial extent of a lake and 'samples' vastly more fish, allowing whole-lake estimation of fish abundance and biomass per unit area. Data on abundance and biomass per unit area cannot be compared among methods, but lengths and biomass estimates can be compared. We have incorporated the data from the VTFWD/UVM repeated survey to provide an initial comparison of the former methods (midwater trawl and hydroacoustics) with bottom trawling used in this study.

The overarching goal of this project was to design and initiate a prey fish community survey in Lake Champlain that will allow assessment of changes in coldwater prey fish communities (abundance, condition, length/age structure), monitor year class abundance of wild lake trout recruits, and inform management decisions. **Outputs** include (1) meetings with biologists from Vermont and New York to integrate elements of the VTDFW survey (1982-2015) and prey fish surveys conducted in lakes Ontario and Michigan into design of a fish community monitoring survey plan for Lake Champlain, (2) implementation of two years of a forage fish survey based on bottom trawling to evaluate the abundance and condition of alewife, rainbow smelt, slimy sculpin, and trout-perch in 2024 and 2025 relative to years prior to recruitment of wild lake trout, and (3) a forage fish community monitoring plan with a standard operating procedure. **Outcomes** include information to inform a fisheries management decision about which method(s) to use for a new long-term forage fish sampling survey, and presentations to inform the public about the status of harvested fish populations in the lake (rainbow smelt, lake trout).

Table 2. Comparison of sampling methods used in the prior and current forage fish surveys, and data acquired by each method. CPUE = catch per unit effort.

Sampling details	Midwater trawl	Floating gillnet	Hydro-acoustics	Bottom trawl
Sampling period	at night	at night	at night	during daytime
# sampling sites	five	five	1 transect per basin	seven
Sampling effort per site	four 55-min tows	1 net	74 km total	four to nine 10-min tows
Type of data acquired				
Abundance	# fish/CPUE	# fish/CPUE	# sonar echoes	# fish/CPUE
Biomass	biodata	biodata	estimated	biodata
Length distribution	biodata	biodata	estimated	biodata
Age classes	age data	age data	no	age data
Length-at-age	age data	age data	no	age data

2. Tasks Completed

Task 1 - Develop forage fish and lake trout survey protocol

A comprehensive understanding of current and former forage fish assessments being conducted on the Great Lakes and Lake Champlain was acquired through research and meetings with biologists from Vermont and the Great Lakes. This information, in conjunction with meetings with biologists from Vermont Fish and Wildlife Department (VTFWD) and New York State Department of Conservation (NYSDEC) to better determine their desires for a forage fish survey, became the foundation for a bottom trawling standard operating procedure (SOP; Appendix I). The SOP was drafted before the first trawling season, and minor tweaks were made throughout the sampling seasons to account for any procedural changes.

Task 2 - Develop QAPP

Completed 2020.

Task 3 - Implement forage fish and lake trout survey

Bottom trawling was conducted in April-May 2024 and 2025, and in Nov 2024.

Task 4 - Data analysis

Field data were entered into a standardized database, as described below, and metrics that describe the status of the forage base (length-frequency, condition, biomass, and density for each basin) were summarized using R.

Task 5 - Survey evaluation; Quarterly and final reports

The project team (PI Ellen Marsden and graduate student Shelby Scarfo) met regularly with colleagues from the VTFWD and the Lake Champlain Fisheries Technical Committee (FTC) to design and modify components of the forage fish survey to provide data that were useful for the FTC.

Quarterly reports were submitted on schedule each year, and the current document is the final report. Ongoing progress on the project was reported to the Fisheries Technical Committee at their tri-annual meetings. Scientific presentations were made by Shelby Scarfo at the New York American Fisheries Society conference in 2025 and the Lake Champlain State of the Lake meeting in 2025.

1. METHODOLOGY

Task 1 - Develop forage fish and lake trout survey protocol

Bottom trawling transects were identified at sites in each of the basins that support coldwater fish species based on the initial forage fish survey (Kirn and LaBar 1991) and bottom trawl surveys for juvenile lake trout (Marsden et al. 2018). Although similar to the sites used in the original survey, the new sites were identified based on substrate where bottom trawls can be deployed without obstruction —a consideration that did not need to be factored into midwater trawling. In the new survey, tows were conducted along-contour at 10-m depth intervals for a duration of 10 min at depths ranging from 20 to 90 m based on site bathymetry and deepest depth; trawling locations may need to be adjusted each year due to changes in lake depth. Trawling began as soon as the lake was ice-free in late March or early April and before the lake was thermally stratified. Surveys were conducted during the day to target forage fish while they were congregated near the bottom rather than suspended in the water column. Each depth transect at each site was sampled once to produce index data for each year. Sampling was conducted using a 3-in-1 bottom trawl based on the Dealteris design (Dealteris et al. 1989) with an 8 m headrope, 9.8 m footrope with chains attached, and 1.25 mm stretch cod end liner (Appendix II). A CTD (conductivity, temperature, and dissolved oxygen) meter was deployed to collect temperature profiles at the deepest portion of each trawl site to confirm the absence of a thermocline. The net was then deployed into the water with the boat moving forward at approximately 4.0 kts and it was confirmed that the trawl doors were 'flying' properly. The appropriate length of cable was let out to get the trawl to the desired depth (warp:depth ratio of 3:1). The vessel speed was then reduced to approximately 2.7 knots while the trawl was on bottom. Time, depth, and location (latitude:longitude in decimal degrees) was recorded at the beginning and end of each tow, defined as the moment all the cable was let out to the moment when haul-back commenced. While the net was fishing, the wind speed (knots) and direction, vessel speed (knots), the amount of warp deployed (feet, as marked on the trawl cable), and the depth strata being sampled (meters) were recorded on a standard datasheet. After retrieving the trawl, the catch was emptied into totes. First, all infrequent large-bodied fish (American eels (*Anguilla rostrata*), lake whitefish (*Coregonus clupeaformis*), cisco (*Coregonus artedi*), lake trout, suckers (*Catostomus spp.*), sea lamprey (*Petromyzon marinus*), yellow perch (*Perca flavescens*), white perch (*Morone americana*), lake sturgeon (*Acipenser fulvescens*)) were removed and individually measured (TL, in mm) and released alive if possible (except sea lamprey). Additional data were collected from these fish (e.g., tissue samples, fin clip data, lamprey wounds, whole fish samples) as dictated by other ongoing projects. Next, the remaining catch was sorted by species and all remaining fish were individually measured. If there was a large number (more than 600) of individuals of a certain species, the bulk fish protocol was used, as described in the SOP (Appendix 1). Biomass and density of fish per hectare were estimated, regressions between length and weight calculated, and a regression between fresh and frozen lengths (Appendix I) was calculated so that, at need (e.g., under challenging field conditions) fish may be frozen on board and lengths measured later in the lab. Otoliths were extracted from subsets of 100 fish per site and used to estimate ages; age data were used to calculate length-at-age of each species.

Task 3 - Implement forage fish and lake trout survey

Bottom trawling was conducted in April-May 2024 and 2025, and in Nov 2024, following the protocols described above. In summer 2024 and 2025, sampling was also conducted by VTFWD personnel assisted by UVM doctoral student Mia McReynolds using a midwater trawl and hydroacoustics to duplicate the methods used in the original VTFWD state survey. Biological data (length, individual and bulk weight) were collected from fish caught in the trawl. Although no fish were collected during hydroacoustic sampling, the data were used to generate fish density estimates, including count and biomass estimates for each site sampled (Pientka and McReynolds 2025).

In the period while the UVM research vessel was not available (2022-2023), the VTDFW retrofitted their research vessel Doré and worked with UVM to acquire a new but identical Dealteris bottom trawl, and began a survey for juvenile lake trout. These data were important for assessing continued recruitment and growth of wild year classes and thus progress toward a decision to end stocking. In consequence, there was no longer a need for the current forage fish survey to acquire these data, although all lake trout caught were, per standard practice, measured and assessed for fin clips before release.

Task 4 - Data analysis

Field data were entered into a standardized fish collection database in Microsoft Access throughout the sampling period when time allowed. At the end of the trawling season, the data was QAQC'd. R scripts were created to analyze the two years of trawling data and can be used to populate and append future data into figures or tables. Biomass of each focal species was calculated by taking the aggregate weight (in grams) of all individuals sampled within a basin (i.e., individual and bulk weights) and dividing this sum by the number of hectares trawled to obtain a metric of kilograms of each species per hectare. Condition was calculated for alewife and rainbow smelt by year and by basin using Fulton's condition ($K = W/L^3$) and a scaling factor of 10^{-5} to bring the condition value close to 1. The predicted weights of a 130 mm alewife and a 125 mm rainbow smelt were calculated for each year and basin using a log-linearized length-weight regression populated with fish between 110 to 150 mm and 105 to 145 mm for alewife and rainbow smelt, respectively. Condition was then calculated using the lengths of 130 mm for alewife and 125 mm for rainbow smelt and their predicted weights to compare interannual changes and actual lengths within the selected intervals and weights of all individuals within the size ranges for interbasin comparisons.

Condition of each species among basins for each year was compared using a Kruskal-Wallis test, followed by a Dunn's test with a Bonferroni correction to identify interbasin differences for each species and year. A Bonferroni correction was used to reduce the possibility of a type I error when comparing condition among the basins. To calculate fish density, bulk-weight-to-counts were calculated using the equation: bulk count = (bulk weight x average subset count)/average subset weight. The average subset count and weight were calculated for each trawl and species using count and weight data from bucket-weighed fish. Density was calculated by summing the individual catch data plus back-calculated bulk-weight-to-count data, by species, and dividing by the number of hectares trawled for each basin. A length-to-weight equation was created for each species by basin using a log-transformed length-weight regression.

Task 5 - Survey evaluation

Design of a new forage fish survey that will be adopted by VTDFW and NYDEC has been a subject of ongoing conversations with state and federal partners. In parallel with the current project, a doctoral student at the University of Vermont has been working with the VTDFW to analyze the hydroacoustic data from the original survey and evaluate whether hydroacoustics should be incorporated in a future survey. A decision about what method(s) to use for a future long-term forage fish survey, and who will conduct the survey, will be made during discussion with members of the FTC scheduled for late October 2025.

Task 6 - Quarterly reports

Reports were submitted quarterly throughout the project. Updates on the project were reported at tri-annual meetings of the Fisheries Technical Committee. A final report will be presented to the LCBP TAC in fall 2025.

4. Quality Assurance Tasks Completed

A7 – Quality Objectives and Criteria for Measurement Data

Objectives. The project data-quality objective is to collect, analyze, and document data that describe the abundance and population attributes of the forage fish community in Lake Champlain, specifically rainbow smelt, alewife, trout-perch, and slimy sculpin.

The forage fish data collections meet the quality assurance objectives outlined in this section. Data quality was measured in terms of accuracy, precision, and completeness.

Intended use of the data. Data were used to assess the status of forage fish populations in Lake Champlain, specifically the relative abundance (#fish/ha), biomass, year class strength, length-at-age, and condition of rainbow smelt and alewife. Data on slimy sculpin and trout-perch were also collected, but as these species comprise only a minor proportion of the diets of salmonids (but an unknown proportion of the diets of other predators), they were not a focus of most of the data analyses.

Performance and acceptance criteria. Field data sheets (on Rite-in-the-Rain waterproof copy-paper) were fully completed (all sections for data entry filled in, no cells left empty) during each field sampling day. At the end of each field day, all sample sheets (one sample sheet per trawl) were numbered with a unique sequential identifier which was meta-linked to all of the data from that trawl in subsequent electronic files. The Program Manager ensured that data on field sheets are correct (data, correct format for location of each trawl including latitude and longitude, depth, and site name) and legible; subsampling methods were clearly documented, and fish counts and fish measurements were clearly identified by species. If data were missing, illegible, or suspect, the Program Manager queried the field team to ensure the data were corrected; if a correction was not possible (missing data), the data from that sample was not used in further analyses.

Laboratory processing of samples included measurement of length and weight, and involved age estimation of a subsample of fish. After data were entered into the Access database, an R script was used to check length and weight data for outliers, i.e., lengths outside the normal range for the fish species, graphing length-weight data, and length-at-age for all fish to look for outliers. Any data outside the normal bounds for the species were checked against the original data sheets; if the source of the error could not be found the data for that fish were omitted from the database.

A8 – Special Training Requirements/Certifications

No certifications were required for this project. The Project Manager trained field and laboratory personnel in fish identification, measurement (length, weight), counting procedures, and age analysis. The Project Manager trained staff in the Rubenstein Lab and on board the research vessel as investigative sampling proceeded.

A9 – Documentation and Records

All field data were collected on standardized forms that have been in use for over seven years at the Rubenstein Ecosystem Science Laboratory (RESL). Each trawl received a unique, sequential identifying number which links all fish data from the trawl to metadata on the trawl location, duration, depth, personnel, weather, and water temperature in the electronic database. All datasheets were scanned at the end of each field day. The scanned copies are filed on a OneDrive site. Laboratory data sheets are filed the same way; data on each sheet were entered into and compiled in a database that is metalinked to the trawl from which the fish came. Scanned copies of data sheets and the electronic database are stored indefinitely.

The approved QAPP was sent by email to the QAPP distribution list by the Project Officer once approved, as was the amended QAPP once completed for year 2 of sampling.

Project data are archived on the UVM OneDrive site and the UVM FEMC (Forest Ecosystem Monitoring Cooperative) data archive (https://www.uvm.edu/femc/data). The data will be listed as private until the project is completed and any associated manuscripts are published. The data storage in this archive will be permanent.

5. Deliverables Submitted

Task 1 - Develop forage fish and lake trout survey protocol
Survey Standard Operating Procedure was completed, and is appended to this document.

Task 2 - Develop QAPP
QAPP was submitted and approved by LCBP in 2021.

Task 3 - Implement forage fish and lake trout survey
Two years of data were collected at seven locations in three basins of Lake Champlain during this survey (Figure 1). A total of 80 trawls were completed (28 in spring 2024, 20 in fall 2024, and 32 in spring 2025). The raw data were compiled in a database that will be disseminated to VTFWD biologists upon the conclusion of this study.

Task 4 - Data analysis

Biomass of alewife increased substantially in the Inland Sea and Malletts Bay in 2025 and decreased in the North Main Lake relative to 2024; biomass of rainbow smelt changed only in the Central Main lake, with an increase in 2025 (Figure 2). The biomass of the catches was dominated by trout-perch in the north and central Main Lake, and by alewife in the southern Main Lake and Malletts Bay (Figure 3). Rainbow smelt were only a large portion of the biomass in the Main Lake in 2025 and Malletts Bay in 2024. Overall, biomass reflected an abundance of the species targeted by predators, i.e., rainbow smelt and alewife, except in the north Main Lake in 2025. Biomass data cannot be compared with the historical and recent midwater and hydroacoustic survey data because they are calculated in different units (mass/hectare vs. metric tonnes).

Density of each species in 2024-25 (number per hectare trawled, Figure 5) showed the same trends as biomass, and similarly cannot be compared with the prior survey data. The acoustic density estimates indicate a change in proportion in each layer of the lake, with density in the historic range in the epilimnion, much lower in the metalimnion, and higher than the long-term average in the hypolimnion (Figure 6; Pientka and McReynolds 2025).

Condition of alewife dropped in all basins in 2025 compared to 2024, so the increase in biomass was largely due to higher abundance; condition of rainbow smelt was similar in both years (Figure 4). There were no significant differences in condition between any of the basins in 2024. However, alewife condition was significantly higher in 2025 in Malletts Bay than in the Central ($p \le 0.001$) and South

Main Lake ($p \le 0.001$) and the Inland Sea ($p \le 0.001$). In 2024 rainbow smelt condition was significantly higher in the South Main Lake than in the North Main Lake ($p \le 0.05$) and the Inland Sea ($p \le 0.05$).

Length distributions of alewife and smelt indicate the presence of two strong year classes in all basins except smelt in Malletts Bay; year classes of slimy sculpin and trout-perch are difficult to discern from length data due to overlap of size-at-age (Figures 7 and 8). However, age estimates and length-at-age data indicated several year classes were present for each of these species, the same number were present in each basin, and steady annual growth of each species reflected in 2024 data. The project ended before ages could be estimated for a sufficient number of fish collected in 2025. Rainbow smelt average length declined slightly from the 1980s to the 2010s in the Main Lake in the earlier forage fish survey, and neither the repeated survey in 2024 nor the bottom trawling data indicate a change from the overall average in the last eight years of the early survey (Figure 9). The average length of alewife was lower in 2024-2025 in both surveys compared with 2008-2015 (Figure 9).

Trout-perch were larger in the Inland Sea than in the other basins and rare in Malletts Bay, as noted by Lesser et al. (2024). Slimy sculpin were rare in the Inland Sea and absent from Malletts Bay. Distribution data for these species were not obtained in the prior surveys, as midwater trawls and hydroacoustic gear do not sample benthic fishes.

The study also provided tools for a future survey, including fresh-to-frozen length and weight and bulk-weight-to-count conversions. When sampling conditions or large catches overwhelm the ability to do total counts or measure individual lengths and weights of fresh fish, the conversions can be used to calculate the required metrics and estimate the number of fish from bulk weights (Appendix I)).

Figure 1: Map of Lake Champlain showing regions sampled during the trawl survey. Sampling sites are marked with diamonds. Two additional lake basins, the South Lake and Missisquoi Bay (not shown) are shallow and eutrophic and do not support cold-water species, so no sampling was conducted in these basins.

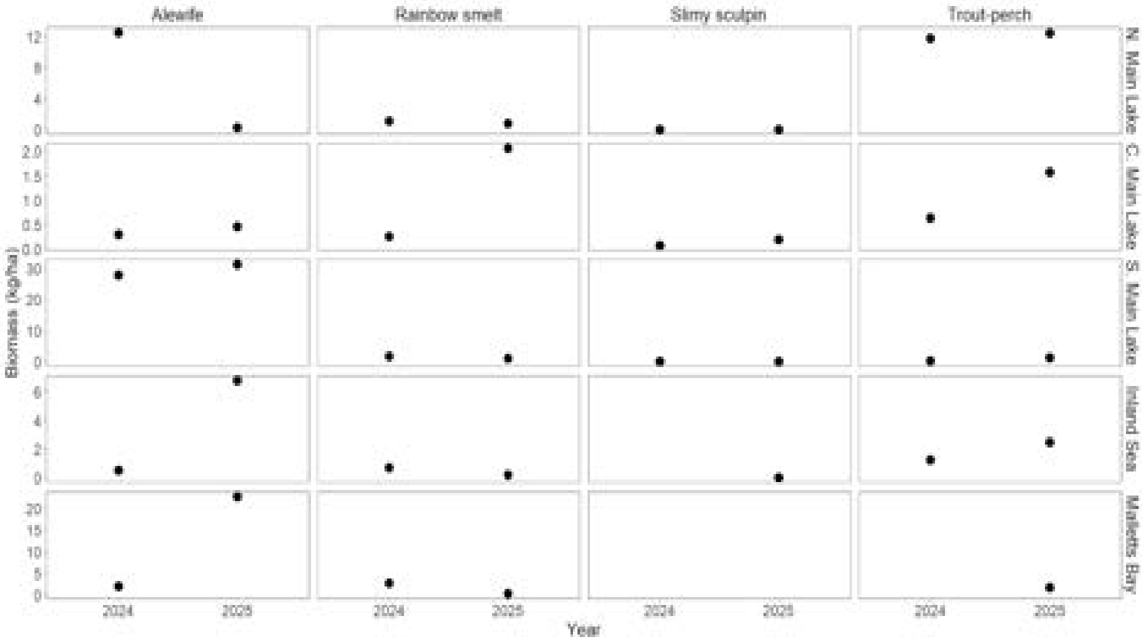

Figure 2. Biomass (kg/ha) of forage fish caught in spring 2024 and 2025 in three basins of Lake Champlain. Slimy sculpins were not collected in Malletts Bay, or in the Inland Sea in 2024, and trout-perch were not collected in Malletts Bay in 2024.

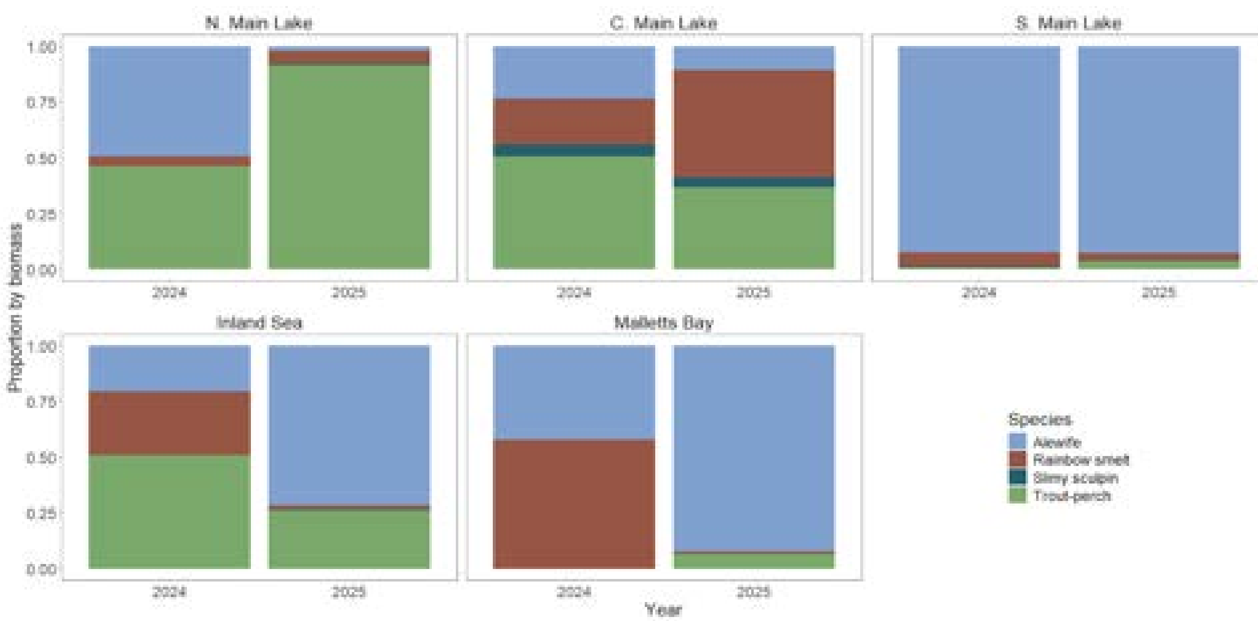

Figure 3. Proportion of catch (by biomass (kg/ha)) for forage fish caught in spring 2024 and 2025 in three basins of Lake Champlain.

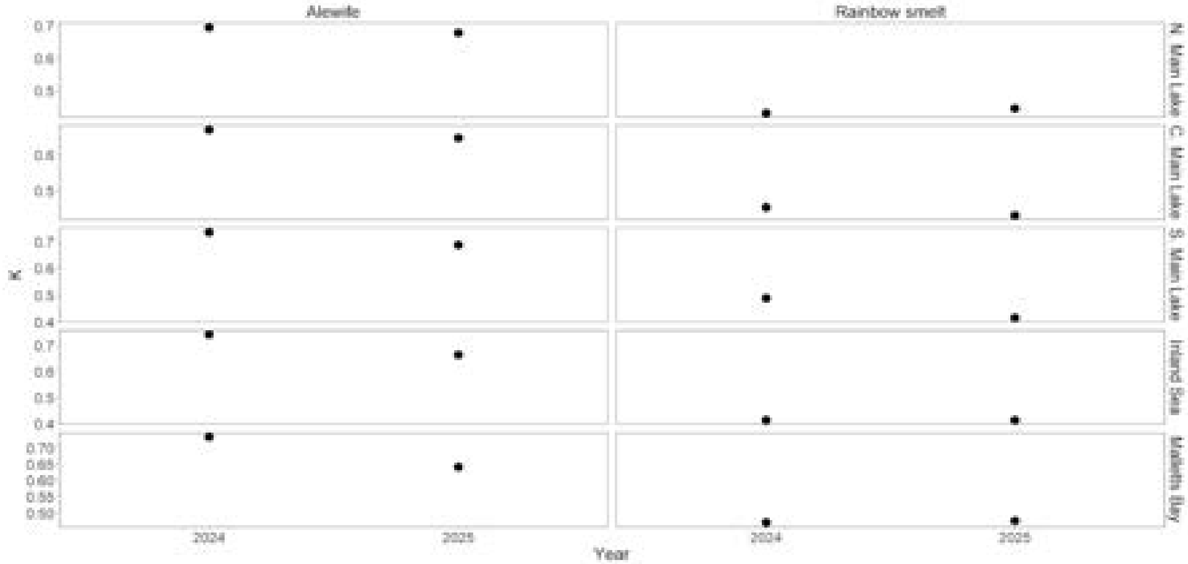

Figure 4. Estimated condition of a 130 mm alewife and 125 mm rainbow smelt from spring 2024 and 2025 in three basins of Lake Champlain used as a standard for comparison among years and basins.

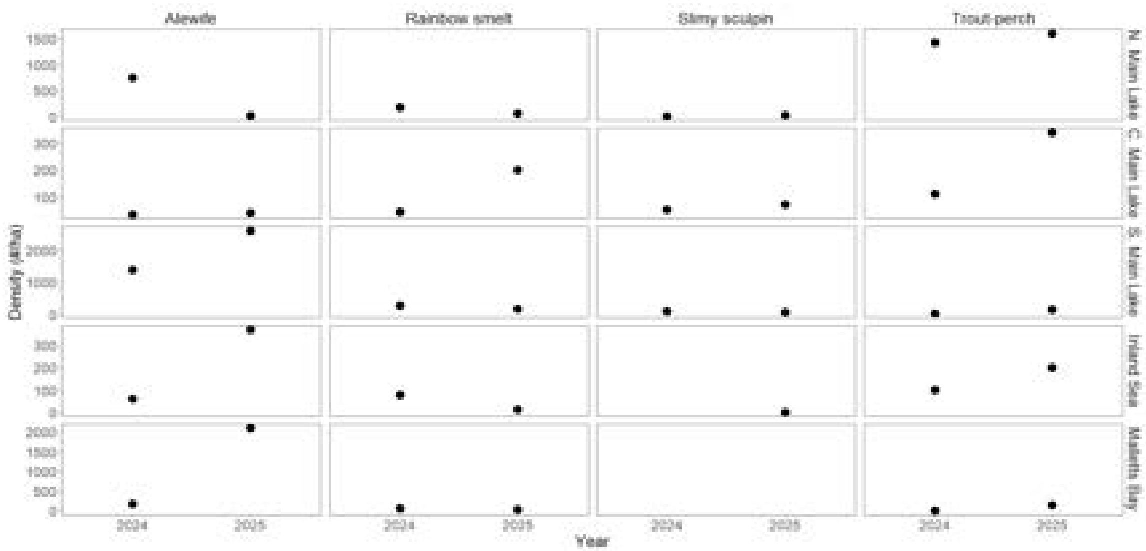

Figure 5. Density (#/ha) of forage fish species caught in spring 2024 and 2024 in three basins of Lake Champlain.

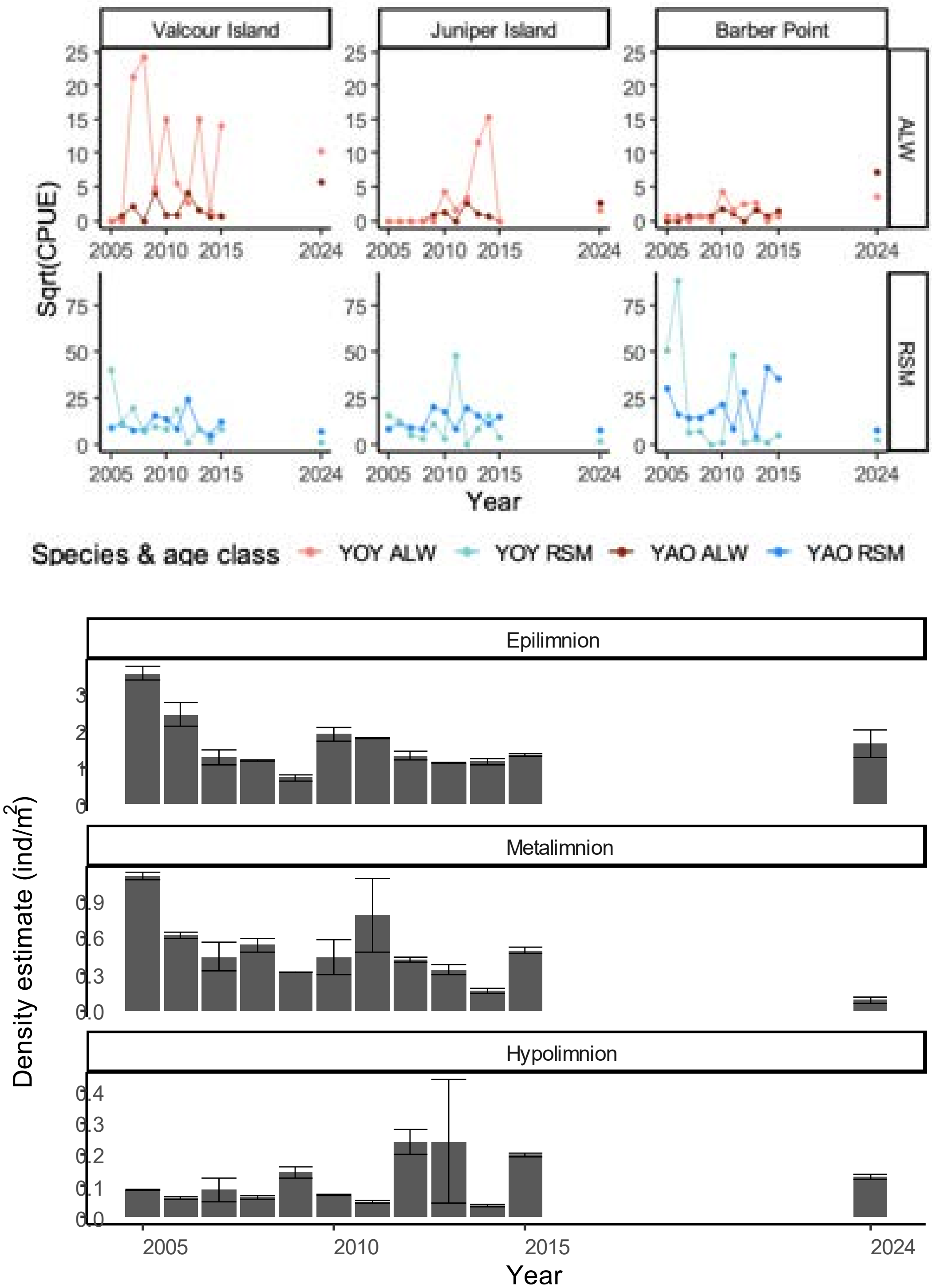

Figure 6. Abundance of rainbow smelt and alewife at three sites in the Main Basin of Lake Champlain, compared between the original forage fish survey after alewife invasion (2005-2015) and the recent survey (2024). Upper panel: catch per unit effort in 55-min midwater trawls; lower panel: acoustic density estimates of abundance of both species from hydroacoustic data at three lake thermal layers. Data and graphics from Pientka and McReynolds (2025).

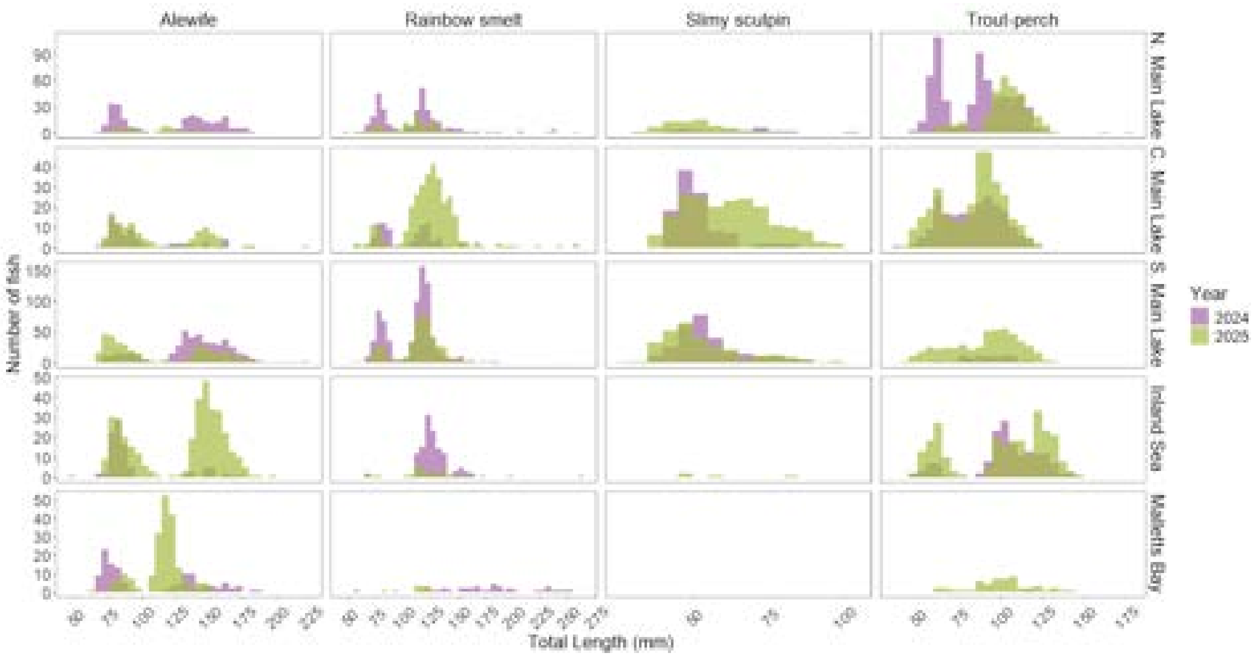

Figure 7. Length distribution of forage fish caught in spring 2024 and 2025 in three basins of Lake Champlain.

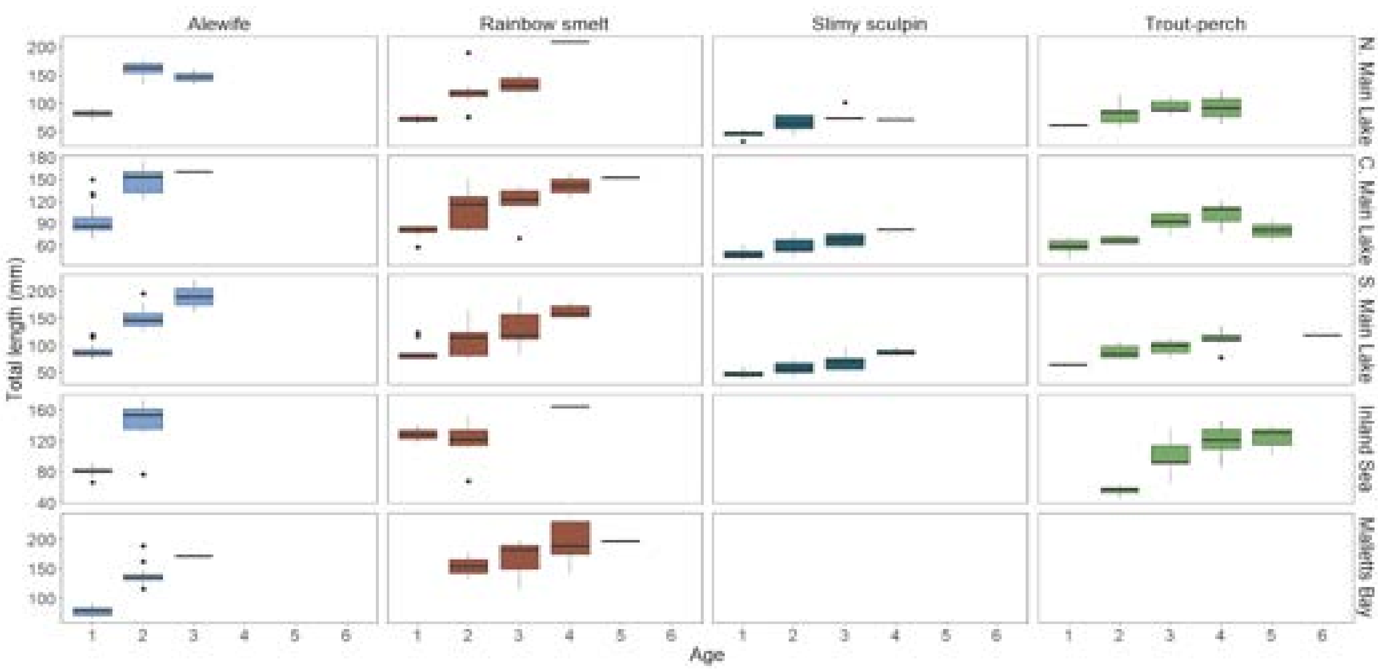

Figure 8: Median length (mm) at age of forage fish caught in spring 2024 in three basins of Lake Champlain.

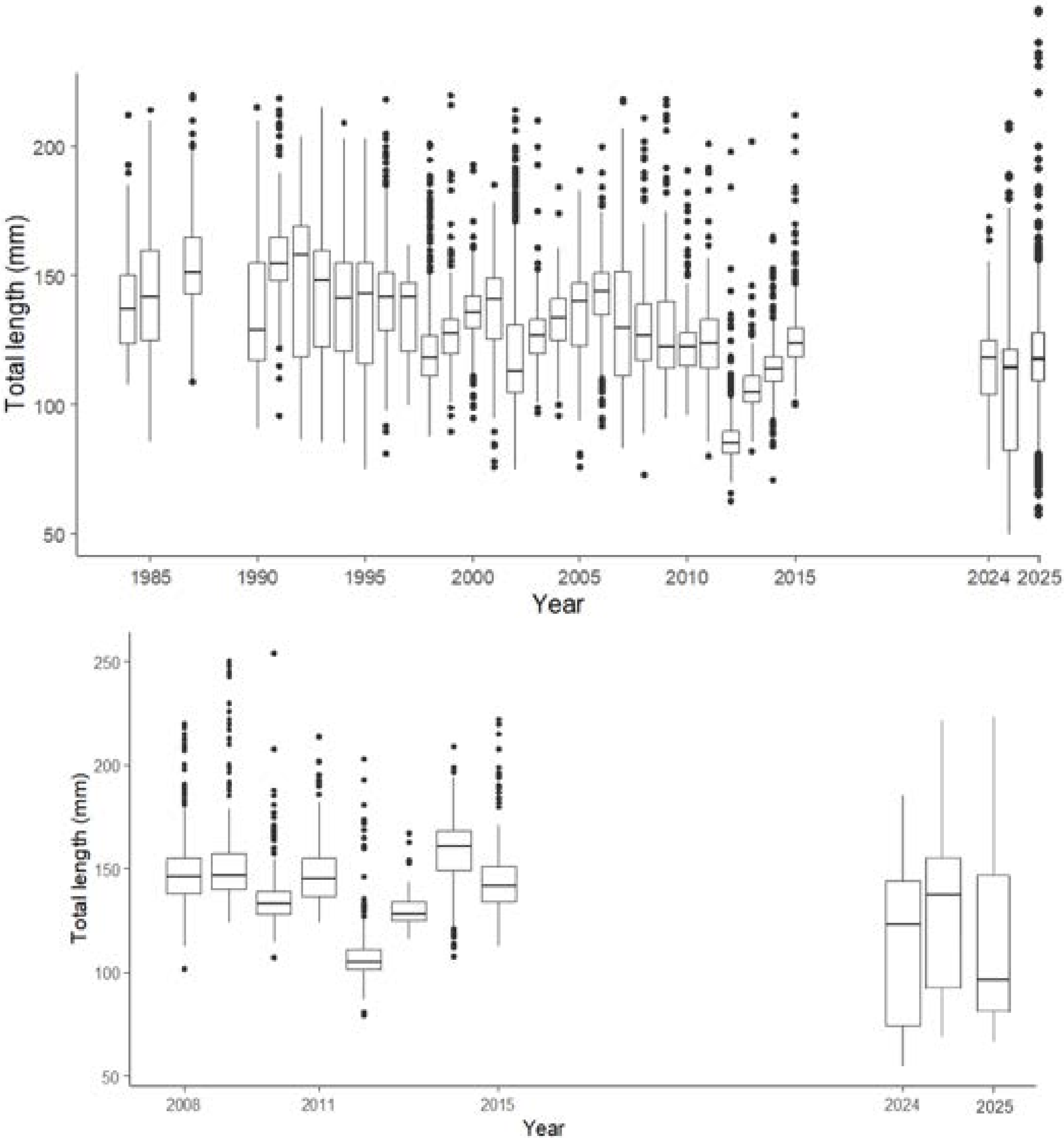

Figure 9. Average total length of rainbow smelt (upper panel) and alewife (lower panel) in the Main Lake basin of Lake Champlain collected using midwater trawls (1990 to 2015 and 2024) and bottom trawls (2024-2025). Data from 1984 to 2015 from Pientka and McReynolds (2018).

Task 5 - Survey evaluation

The project team (PI Ellen Marsden and graduate student Shelby Scarfo) met regularly with colleagues from the VTFWD and the Lake Champlain Fisheries Technical Committee (FTC) to design and modify components of the forage fish survey to provide data that were useful for the FTC.

The two-year sampling period confirmed that spring bottom trawling is an effective method of sampling forage fish throughout the Lake Champlain basins. The data collected during these two sampling years can form the foundation of a long-term forage fish survey to inform stocking and management of coldwater predators throughout the lake. While we recognize that two years of data is not sufficient to identify trends in forage fish various metrics such as biomass, density, or condition, continued monitoring and analysis of these data among the various basins over time will be useful to identify spatial or temporal patterns or shifts in the forage fish populations throughout the lake.

Density was calculated as an index of relative abundance to examine annual changes over time. While trends in density should closely mirror trends in biomass, biomass reflects the actual food available for predators. Length distributions for all four forage fish species were similar between the 2024 and 2025 sampling seasons. Biomass, represented by kilograms per hectare trawled, is arguably the most important metric, as changes in prey biomass reflect the amount of food availability for predators. Substantial changes in biomass may be the result of altered food availability, increased predation, decreased reproduction or recruitment, or even changes in water temperature or habitat availability that may affect distribution.

Changes in condition of prey will be reflected in biomass even if density of prey does not change. Therefore prey biomass is a useful metric to evaluate potential for predator growth. Tracking the condition of forage fish is important for understanding the amount of food available to predators. Low forage fish condition would require predators to increase forage fish consumption, i.e., number of fish consumed, to acquire the same caloric value, but this increased foraging activity has an energetic cost. Condition was only calculated for alewife and rainbow smelt because they are the most common prey items found in predator diets. Condition is largely tied to food availability which can alter with inter- and intra-species competition or changes in the food web. Statistically significant interbasin differences in the condition of both alewife and rainbow smelt in Lake Champlain suggest that there are differences in food availability or competition among the basins. Condition data are not collected by hydroacoustic sampling.

As the presence, or absence, of age classes can reflect the status of reproduction, consistent recruitment, and survival, the presence of a wide range of year classes is encouraging. Length-at-age data can be used to indicate annual growth or to monitor if the populations are being truncated due to increased predation pressure. For example, a reduction in larger, older fish could suggest increased predation pressure, while a reduction in smaller, younger fish would likely indicate reproduction or recruitment issues.

The original and current forage fish surveys used different sampling methods and were conducted at different seasons, so metrics such as biomass, abundance/CPUE, and length distributions cannot be compared between the surveys. However, fish collected by netting methods provide data on individual length and weight from which condition can be calculated; age, number of year classes, year class strength, and length-at-age and can be also compared among fish from different netting methods. Comparison of year classes present indicates that there are no substantial differences in rainbow smelt and alewife age composition between the original and new forage fish surveys. Fish composition is also different among sampling methods: midwater trawling does not collect benthic species (slimy sculpin or trout-perch). These species be useful as indicators of the status of the benthic invertebrate community, and if rainbow smelt and alewife decline, they serve as alternate food resources for piscivores.

Task 6 – Quarterly and final reports
Quarterly reports were written throughout this project to describe the work being accomplished, any challenges faced, and outline the objectives and goals for the coming quarter. A draft final report was submitted on June 30, 2025, pending LCBP/NEIWPCC and TAC review and approval.

6. Project Metrics

Metric	**Final value**
Category of organization	Academic
Undergraduate students supported by this grant	1
Graduate students supported by this grant	1
Audience types engaged (list)	Lake Champlain stakeholders attending SOL Fisheries meeting (43), NY American Fisheries Society attendees (200)

7. Conclusions

Two years of data were collected and analyzed and represent the foundation for the continuation of a forage fish survey in Lake Champlain. Although two years of data is not sufficient to identify trends in forage fish abundance, continued monitoring and analysis of metrics such as abundance and biomass among the various basins throughout Lake Champlain will resolve whether these differences simply represent normal variance among trawls or trends over time. For example, increases in abundance could indicate reduced predation, increased survival, or increased reproductive success. The latter two factors can be a result of multiple ecological influences such as increases in food availability or more favorable spawning conditions. Conversely, decreases in abundance could indicate increased predation or reduced survival and reproductive rates. Long-term increases or decreases in abundance or biomass could also be an indicator of spatial or temporal shifts in the forage fish populations throughout the lake. Long-term monitoring of the length distribution of forage fish species may reveal changes within the fish community. Shifts in length distribution peaks can be a result of fish community changes including increased predation (shift to the left) or issues with reproduction or recruitment (shift to the right).

The forage fish trawling survey was conducted in the spring of 2024 and 2025 was also conducted in the fall of 2024. The objective of the fall sampling was to determine whether any variables in the data were significantly different in the spring versus the fall, including differences in species composition or biomass. Although the fall survey was delayed as long as was feasible, a thermocline was present throughout the entire survey. Below-freezing temperatures and ice conditions by the end of November resulted in the sampling window being cut short before the lake could fully mix. With the presence of a thermocline in the lake, it is unlikely that the fall sampling was representative of the forage fish population. When a thermocline is present, species such as alewife and younger fish will be present in the water column (at or above the thermocline), even during the day. As a result, fall trawling data could not be compared to the spring trawling data in terms of biomass, abundance, or even length distribution. The presence of a thermocline so late into the year and towards the end of the available lake sampling season suggests that fall is not an ideal season to conduct a forage fish bottom trawling survey. Spring generally has a longer window of time between ice coverage and lake stratification than fall trawling, allowing a higher probability of completing the full trawling survey prior to stratification. However, during the spring 2025 sampling, even though the absence of a thermocline was confirmed at the beginning of each sampling day, fish were still seen suspended throughout the water column rather than on the bottom of the lake as expected during this time of year. This anomaly could have resulted in decreased catches and skewed the results of the data analysis. Additionally, dead alewife were present in multiple trawls conducted in the Inland Sea in 2024 and 2025 and Malletts Bay in 2025, indicating that an alewife die-off event occurred over the winter. These die-off events are not uncommon and are well documented in other lakes; however, these events affect catchability of live fish in the trawl and consequently will skew abundance and biomass results and should be documented in a long-term forage fish assessment.

The initial midwater trawling surveys conducted between 1990 and 1997 showed substantial differences among years and among sites (LaBar 1998). However, high variability in annual CPUE varied obscured any trends that may have occurred throughout the survey period. The addition of hydroacoustic data indicated that numbers of rainbow smelt declined over the survey period, with an estimated biomass decrease of more than 50 percent in each area sampled (LaBar 1998). The mean length of all rainbow smelt also declined by 10 mm between 1990 and 1997. LaBar concluded that changes in rainbow smelt populations, such as the overlap of the largest declines in rainbow smelt stocks with areas where predators are most numerous, were likely the result of sea lamprey control efforts which led to increased predator abundance. Data from the trawling surveys before, during, and after the alewife invasion were used to examine the impact of the invasion on the rainbow smelt population in Lake Champlain. Rainbow smelt CPUE declined significantly in Malletts Bay and the Northeast Arm (Inland Sea) after alewife became fully established in 2006-2007 (Bruel et al. 2021).

Continuing a forage fish survey will be crucial for making informed predator stocking decisions and proactively managing Lake Champlain's fisheries. Although any data collected in a forage fish survey can be valuable for increasing the holistic understanding of the fish community, coupling forage information with predator data allows for informed action to be taken when significant changes are seen within the predator or prey populations. Direct action is unlikely to be plausible or effective when attempting to directly increase or decrease forage fish abundance. Although data on predator condition and average length-at-age have been collected for many years, there are limited data on harvest or survival estimates, resulting in unknown predator abundance throughout Lake Champlain. Lake trout survival and abundance have been estimated (Marcy-Quay et al. 2025), stocking of Atlantic salmon needs to be supplemented with adult mortality estimates. With a standardized forage fish survey, the available predator data can be matched with forage biomass to understand the condition of the forage base when there is a thriving or declining predator population. Increasing data on survival, diet preferences, habitat use, abundance, and any bottleneck effects in the predator populations will result in a much more manageable and predictable fishery. Diet data can further our understanding of what prey items are targeted by certain predators and how much of an impact these predators have on the available forage. While recent studies have indicated that lake trout in Lake Champlain primarily consume alewife, with rainbow smelt, slimy sculpin, and trout-perch also present in the diet in substantially different proportions (Futia et al. 2025; Marsden et al. 2022), few diet data have been collected on the other key predators in the lake such as Atlantic salmon, burbot, and walleye (*Sander vitreus*). For example, trout-perch make up a large portion of the forage fish biomass and share spatial similarities with alewife and rainbow smelt, but are rarely seen in the available predator diet data (Lesser et al. 2024; Marsden et al. 2022). Simonin et al. (2018) examined diets of Atlantic salmon, lake trout, and walleye using stable isotopes of likely prey species, but did not include trout-perch. Considering that trout-perch may participate in diel horizontal migration, this species may be more heavily targeted by warm-water predators rather than coldwater predators. Additional data need to be collected to determine the demand other predators such as burbot, non-native salmonids, and cool or warm-water species place on the forage base to determine the best ways to manage predator populations while maintaining the integrity of the forage base. A long-term, standardized forage fish survey will allow managers to anticipate changes in predator condition or abundance at various forage fish biomass levels.

By understanding how predators react to changes in the forage fish community, managers may be able to recognize trends in the forage base, anticipate changes in predator condition, and preemptively take action to avoid major declines in the predator community.

The information acquired during this study, in combination with information from the 2024-2025 midwater trawling/hydroacoustic surveys, will be used to inform a discussion in late October 2025 with the VTFWD, NYDEC, USFWS, and UVM to determine the forage fish survey strategy moving forward – what methods will be used, at what seasons, with what vessel(s), and which agency/ies will lead the survey.

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9. APPENDICES

Appended Documents:

Appendix I - Lake Champlain Forage Fish Bottom Trawling Standard Operating Procedure

Appendix II - Latitude and longitude, in decimal-degrees, of trawling transects used in the 2024-2025 bottom trawling survey of forage fishes in Lake Champlain.

Appendix III - Diagram of Dealteris bottom trawl used in the forage fish surveys in Lake Champlain.

Appendix IV - Cable warp length used for each bottom trawl depth.

Appendix V - Percent change in length and weight after freezing for four forage fish species from Lake Champlain.

Press articles – submitted separately

Adirondack Explorer: From stocking to self-sustaining? The return of Lake Champlain's trout. Link.
Adirondack Explorer: A behind-the-scenes look at the wild revival of Lake Champlain trout. Link.

Scientific presentations – submitted separately

Scarfo, S. 2025. Evolution of forage fish surveys in Lake Champlain. State of the Lake meeting.

Scarfo, S, N Tang, S Sundberg, JE Marsden, 2025. Forage fish bottom trawling in Lake Champlain. NY American Fisheries Society conference.

Photos - Submitted separately

Electronic Data:

The electronic dataset generated in this project is available at https://www.uvm.edu/femc/data ; https://www.uvm.edu/femc/data/archive/project/lake-champlain-forage-fish-bottom-trawling/dataset/lake-champlain-forage-fish-bottom-trawling (also submitted separately)

Appendix I: Lake Champlain Forage Fish Bottom Trawling Standard Operating Procedure

Introduction/Background

This document outlines a standardized operating procedure (SOP) for surveying the cold-water forage fish community of Lake Champlain using bottom trawling. Survey data will inform estimates of the predator-prey ratio in the system to guide predator stocking, specifically lake trout (*Salvelinus namaycush*), Atlantic salmon (*Salmo salar*), and walleye (*Sander vitreus*) throughout the lake. The four species of interest are rainbow smelt (*Osmerus mordax*), alewife (*Alosa pseudoharengus*), slimy sculpin (*Cottus cognatus*), and trout-perch (*Percopsis omiscomaycus*). This survey is a redesign of a forage fish survey that involved multiple survey methods, including nighttime midwater trawling and hydroacoustics, that was started by the Vermont Fish and Wildlife Department (VTFWD) in the mid-1980s and was terminated in 2015. Many biological and survey design changes occurred throughout the time that VTFWD conducted this survey, including the invasion of non-native alewife and the addition of floating gillnets and hydroacoustic surveys (Table 1). The survey and SOP described here simplifies forage fish monitoring by using daytime bottom trawling as the sole sampling method.

Forage fish surveys are conducted to observe and account for any fluctuations in prey biomass when determining the maximum sustainable capacity of predators in a system. Alterations to predator or prey populations, such as overfishing, stocking predators, or invasion of a non-native prey species, can substantially alter trophic relationships and challenge prediction of predator-prey dynamics. When alewife invaded the Great Lakes, major disruptions were seen in the historic prey base and predator populations, leading to adverse effects on lake trout recruitment and factoring in the extirpation of Atlantic salmon in Lake Ontario (Madenjian et al. 2008). In contrast, the arrival of alewife did not produce the same disruptions to Lake Champlain’s ecosystem as it did in the Great Lakes. Analyses of the previous VTFWD trawling survey data showed that native rainbow smelt catch-per-unit-effort (CPUE) declined significantly in Malletts Bay and the Inland Sea after alewife became fully established in 2006-2007 (Bruel et al. 2021). Food-web model projections of rainbow smelt, trout-perch, and slimy sculpin biomass within the Main Lake remained constant pre-, during, and post-alewife invasion (Lesser et al. 2023). However, the model also predicted an increased native predator production with the arrival of alewife, which would increase pressure on the forage base. Wild predator populations would likely self-regulate given the prey availability. However, predators stocked in Lake Champlain (i.e., walleye, Atlantic salmon, rainbow trout (*Oncorhynchus mykiss*), and brown trout (*Salmo trutta*)) do not naturally equilibrate with prey abundance, requiring management intervention to account for prey fluctuations.

Table A1: Timeline of major biological changes and management activities in Lake Champlain related to forage fish.

Year	Biological changes	Management activities
1984		Midwater trawling assessment started in Main Lake, Inland Sea, and Malletts Bay
1990		Established 5 standard trawling stations – 3 in the Main Lake, 1 in the Inland Sea, and 1 in Malletts Bay Beginning of experimental sea lamprey control program
1993	Zebra mussels (*Dreissena polymorpha*) and gizzard shad (*Dorosoma cepedianum*) appeared in Lake Champlain	
1998		End of experimental sea lamprey control program
2003	Alewife found in Missisquoi Bay	
2005		Lake wide hydroacoustic survey started
2006	Alewife found throughout Lake Champlain	
2008	First large-scale alewife die-off in Inland Sea and Main Lake • Inland Sea rainbow smelt trawl CPUE dropped	Floating gillnets added to survey to sample alewife in upper portion of water column
2009	Malletts Bay rainbow smelt trawl CPUE dropped	
2014	Spiny water flea (*Bythotrephes longimanus*) found in Lake Champlain	
2015		Last year of forage fish trawling and acoustic survey
2016		Official letter submitted ending forage fish assessment
2018	Fishhook water flea (*Cercopagis pengoi*) found in Lake Champlain	

Note. Modified from Pientka and Staats 2018; B. Pientka, VTFWD, personal communication.

Lake Champlain forage fish survey design and Standard Operating Procedures

Lake Champlain is a large, narrow lake, situated between New York, Vermont, and Quebec, comprised of five distinct basins separated by islands and causeways (Marsden and Langdon 2012). These basins differ in productivity, size, depth, trophic level, and oxythermal conditions, leading to significant differences in fish communities among the basins (Table 2). Only the Main Lake, Malletts Bay, and the Inland Sea support Lake Champlain's coldwater fishes. Lake trout and landlocked Atlantic salmon make up the majority of the native cold-water predator community; however, other coldwater predators such as burbot (*Lota lota*) are present throughout the lake.

Table A2. Characteristics of the three coldwater species supporting basins of Lake Champlain.

	Basin		
Characteristic	Main Lake	Malletts Bay	Inland Sea
Predator abundance	High	Medium	Medium
Productivity (μg/1 TP)	Low (10-15)	Low (8-12)	High (20-25)
Basin volume (km^3)	Large (21.0)	Small (0.72)	Medium (3.45)
Maximum basin depth (m)	122	32	49
Average basin depth (m)	30.8	13.3	12.8

Modified from Bruel et al. 2021.

Trawl sites

Bottom trawling transects have been identified at sites in each of the coldwater species supporting basins based on previous trawl surveys (Kirn and LaBar 1991; Marsden et al. 2018). Although similar to the trawling locations used in the previous survey, the new sites were identified based on substrate where bottom trawls can be deployed without obstruction —a consideration that did not need to be factored into midwater trawling (Figure A1). Trawling location coordinates may vary annually due to changes in lake depth (Appendix II). In the new survey, tows are conducted along-contour at 10-m depth intervals for a duration of 10 min at depths ranging from 20 to 90 m. Trawling begins as soon as the lake is ice-free in early April or before the lake is thermally stratified. Surveys are conducted during the day to target forage fish while they are congregated near the bottom rather than suspended in the water column. Each depth transect at each site is sampled once to produce index data for each year.

Figure A1: (A) VTFWD original midwater trawling locations. (B) New bottom trawling locations. Site latitude and longitude coordinates are given in Appendix II.

Standard Operations: Trawling

Conduct sampling using a 3-in-1 bottom trawl based on the Dealteris design (Dealteris et al. 1989) with an 8 m headrope, 9.8 m footrope with chains attached, and 1.25 mm stretch cod end liner (Appendix III). Deploy a CTD (conductivity, temperature and depth) meter to collect temperature profiles, at the deepest portion of each trawl site to confirm the absence of a thermocline.

Trawl deployment

Deploy the net into the water with the boat moving forward at approximately 4.0 kts and confirm that the trawl doors are 'flying' properly. Let out the appropriate length of cable to get the trawl to the desired depth (warp:depth ratio of 3:1[1]; Appendix IV). Vessel speed should be approximately 2.7 knots while the trawl is on bottom. Record time, depth, and location (latitude:longitude in decimal degrees) at the beginning and end of each tow, defined as the moment all cable has been let out to the moment when

[1] For ease of calculating the scope, trawl warps are marked in feet. With a scope ratio of 3:1, 10-m depth intervals correspond to a warp length of the depth x 10 (Appendix III). An additional 50 feet of warp may be required at deeper depths (i.e., >70m).

haul-back commences. While the net is fishing, record the wind speed (knots) and direction, vessel speed (knots), the amount of warp deployed (feet; Appendix IV), and the depth strata being sampled (meters) on the standard datasheet (Figure A2).

Sorting catch

After retrieving the trawl, empty the catch into totes. First, remove and individually measure (TL, in mm) all infrequent large-bodied fish (American eels (*Anguilla rostrata*), lake whitefish, cisco (*Coregonus artedi*), lake trout, suckers (*Catostomus spp.*), sea lamprey (*Petromyzon marinus*), yellow perch (*Perca flavescens*), white perch (*Morone americana*), lake sturgeon (*Acipenser fulvescens*), etc.) and release alive if possible (except sea lamprey). Collect additional data from these fish (e.g., tissue samples, fin clip data, lamprey wounds, whole fish samples) as dictated by other ongoing projects. Next, sort the remaining catch by species and individually measure all remaining fish. If there is a large number (more than 600) of individuals of a certain species, use the **bulk fish protocol**:

> First, mix all individuals of a single species together and split the catch in half, and then split one of the halves again, repeating this procedure until each part of the final split contains a random subset of approximately 100 individuals. Individually measure all fish from one of these two subsets. Next, record the weight (grams) of a small bucket (~4 L), place all individually measured fish from the subset into this bucket and record the gross weight after the excess water has been drained out. These buckets can be pre-drilled with small holes to facilitate water drainage. Discard this subset then count the remaining fish into small buckets and weigh each bucket, or until all of the fish or 10 buckets of fish are counted. If there are fish remaining after 10 buckets, weigh the rest of the fish in filled buckets without counting individual fish. Repeat this process for each fish species (rainbow smelt, alewife, and trout-perch). Finally, collect any fish required to complete the calibrations outlined below and discard all remaining fish back into the water. (Note: the process of weighing 10 buckets of counted fish should only be done once for each basin each year, otherwise simply fill and weigh buckets without counting).

Sample and data processing

On a three-year basin rotation (Table 3), or when significant changes in lake ecology warrant, length-weight regressions, bulk weight-to-count conversion, and length-at-age should be re-estimated. Biomass, length frequency, and density should be estimated annually. Under some circumstances, measurements of fresh fish may not be feasible, in which case, fish will be measured after freezing on board. Given that freezing tends to change the length and weight of fish (Ogle 2009), the fresh-to-frozen regression should be used to back calculate fresh lengths and weights.

> **Length-weight regression**: For each of the four species of interest, bag a subset of 100 fish that comprise approximately equal numbers of all size classes of a given species from each basin. Prioritize obtaining 100 fish per species from the first trawl in each basin to ensure the sample is complete if subsequent trawl catches are small. To ensure representation of different sites, collect a random subsample of approximately 100 fish from each site within each basin, aggregated among depths. In the lab, individually measure (length and weight) each fish. Give each fish a unique ID using the three-letter sample abbreviation, the date collected, the trawl number, and an individual sequential number for the trawl (e.g., BOT_20240419_02_001). Create a regression that will be used to approximate weight given the length of an individual fish.

> **Fresh-to-frozen regression**: Using the 100 fish subsets from the length-weight regression, freeze, thaw, and remeasure each individual fish and create fresh-to-frozen length and weight regressions to calculate the impact freezing the fish had on these measurements. This conversion only needs to be done once. The conversion done during this survey is in Appendix V.

Bulk weight to count conversion: create a conversion using the count and weight data collected from instances when the bulk fish protocol was used. Use these data to obtain count estimates for each bucket of fish that was only weighed.

Age-length keys: use the 100 fish subsets from the length-weight regression (and fresh to frozen regression) to create an age-length key. Extract the otoliths (https://www.dfo-mpo.gc.ca/science/species-especes/otoliths/students/removal-prelevement-eng.html) from each fish and place them in vials labeled with the fish's unique ID. When ready to read the otoliths, place them in a petri dish, gently clean them with deionized water, and lightly sand them with a fine-grit sandpaper, if necessary. Examine the prepared otoliths under a microscope and record the estimated age of the fish (ibid.) in an Excel file. Repeat this process with at least one other individual to ensure accuracy and reduce bias. Obtain final age estimates and develop an age-length key using the length data collected on the vessel.

Biomass: sum individual and bulk weights by species and divide by the number of hectares trawled to establish biomass estimates (kg/ha trawled) for each basin. Repeat this process annually.

Length frequency: use fresh fish length data (including converted data from frozen fish) to populate a histogram of the length distribution of a given species within a basin and throughout the whole lake. Repeat this process annually.

Density: Using the individual fish data (and the bulk weight to count conversion, if necessary), sum all individual fish caught and divide by the number of hectares trawled to establish density estimates (number/ha trawled) for each basin. Repeat this process annually.

Table A3: Three-year basin rotation of analyses.

Analysis	Year		
	1	2	3
Length-weight regression	Malletts Bay + Inland Sea	North + Central Main Lake	South Main Lake
Bulk weight-to-count conversion	All basins	All basins	All basins
Age-length key	Malletts Bay + Inland Sea	North + Central Main Lake	South Main Lake
Biomass	All basins	All basins	All basins
Length frequency	All basins	All basins	All basins
Density	All basins	All basins	All basins

Data analysis

Field data should be entered into the standardized fish collection database in Microsoft Access throughout the sampling period as time allows. At the end of the trawling season, these data should be QAQC'd through a series of R scripts. R scripts will be used to populate and append new data to each figure or table. All R scripts required for data processing and analysis are available upon request through a GitHub webpage.

Pg. __ of __ **UVM SAMPLING DATA** Collection Event/Net # ___

Project:		Site:	Crew:	
Collection Event/Net #	Wind speed (kts):	Wind direction:	Surface temp (°C):	
START	Date (yyyy/mm/dd): _ _ _ _/_ _/_ _	Time (24-hr): _ _ : _ _	Depth (m):	
START	Latitude: 44. _ _ _ _ _ _°	Longitude: 73. _ _ _ _ _ _°		
END	Date (yyyy/mm/dd): _ _ _ _/_ _/_ _	Time (24-hr): _ _ : _ _	Depth (m):	
END	Latitude: 44. _ _ _ _ _ _°	Longitude: 73. _ _ _ _ _ _°		
Notes:				

Sampling Gear and Effort: (circle one method and options in parenthesis that apply)

Angling	Method (Jigging / Casting / Trolling / Other:)
Electrofishing	Type (Backpack / Boat) Amps ___ Volts ___ Freq ___ Total seconds ___ Boat only: Vessel Speed (kts) ___
Gillnet	Type (Bottom / Floating) Length (m) ___ Mesh stretch size (in) ___
Net	Type (Fyke, Hoop) Length (m) ___ Mesh stretch size (in) ___
Seine	Length (m) ___ Mesh size (in) ___ Area sampled (m²) ___
Trap	Type (Minnow, Fry, Egg) Number of traps ___
Trawling	Type (Bottom / Midwater) Trawl spec______ Depth strata (m) ___ Warp deployed (ft)___ Vessel speed (kts) ___ Temperature at depth (°C) ___ Good sample (Y / N)
Other	

Notes:

Fish Collection: (check the appropriate box(es) and fill in any additional information that applies)

☐ No fish collected

☐ Fish processed in the field

☐ Fish bagged

Date processed: ____________

Processed: Frozen / Fresh (circle one)

Notes:

Collection permittee: _______________

Pg. ___of ___ **Site:**______________ Date (yyyy/mm/dd): __ __ __ __/__ __/__ __ Collection event/net # ____

GENERAL - INDIVIDUAL FISH

Species	TL (mm)			Species	TL (mm)			Species	TL (mm)		

GENERAL - INDIVIDUAL FISH AGGREGATE/SUBSET

Species:	Species:	Species:
Tare (g):	Tare (g):	Tare (g):
Gross wt (g):	Gross wt (g):	Gross wt (g):
Count:	Count:	Count:

ADDITIONAL/BULK FISH

Species	Count	Tare (g)	G. wt (g)	Notes

Species: alewife = ALW, slimy sculpin = SLS, smelt = RSM, trout-perch = TRP, t. darter = TSD, w. perch = WTP, y. perch = YLP

Record fish in *either* **BULK** or **INDIVIDUAL** fish - do not count the same fish in both categories!

Bulk fish wt should **NOT** include subset fish, this is the weight of all remaining individuals of the given species!

Subset fish is the aggregate weight of fish that were measured individually. This should be done by species!

Ind ID # should reset for each species but be chronological through a given species.

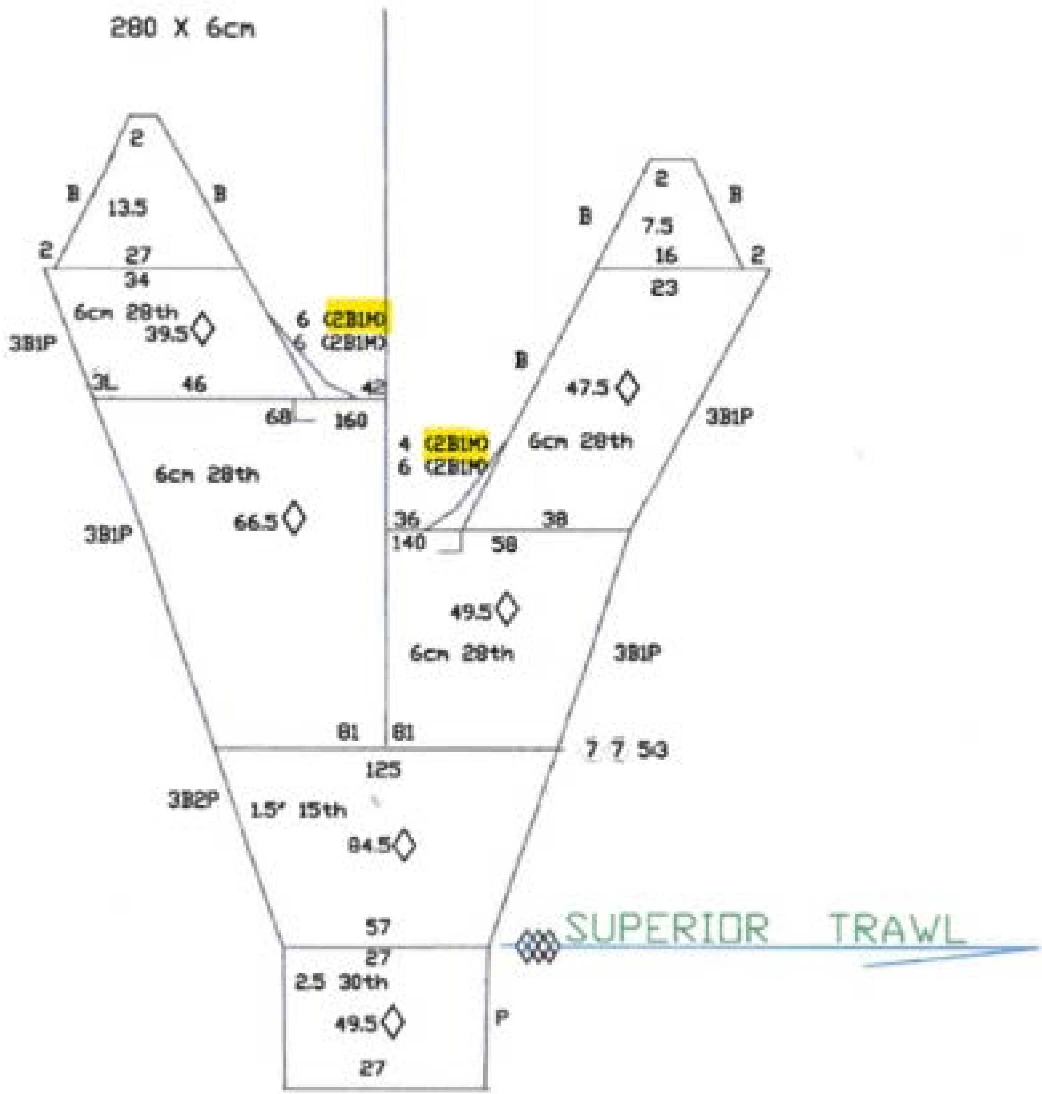
Figure A2. Standard datasheet used to record environmental and fish data while trawling.

Appendix II: Latitude and longitude, in decimal-degrees, of trawling transects used in the 2024-2025 bottom trawling survey of forage fishes in Lake Champlain.

Trawling Depth	Sampling location						
	Rockwell Bay	Burlington Bay	Essex	Barber Point	Malletts Bay	Fish Bladder	Butler Island
20	Start: 44.671712, -73.356662 End: 44.664598, -73.356560	Start: 44.476608, -73.242215 End: 44.471558, -73.236235	Start: 44.329497, -73.342567 End: 44.322502, -73.343213	Start: 44.143285, -73.384605 End: 44.149737, -73.381440	Start: 44.578248, -73.268760 End: 44.584845, -73.264807	Start: 44.658702, -73.221495 End: 44.665497, -73.221610	
30	Start: 44.661675, -73.35745 End: 44.668517, -73.358155	Start: 44.473772, -73.249915 End: 44.468423, -73.244007	Start: 44.326330, -73.340432 End: 44.333123, -73.341983	Start: 44.152050, -73.384692 End: 44.145748, -73.387685	Start: 44.579655, -73.291453 End: 44.585323, -73.284225	Start: 44.685407, -73.221518 End: 44.691915, -73.219393	Start: 44.859612, -73.208642 End: 44.852730, -73.209995
40	Start: 44.660678, -73.360365 End: 44.667528, -73.359833	Start: 44.474448, -73.261057 End: 44.467813, -73.257860	Start: 44.324005, -73.339950 End: 44.330937, -73.340827	Start: 44.146765, -73.390267 End: 44.153160, -73.386365		Start: 44.690472, -73.223672 End: 44.697443, -73.223148	Start: 44.853952, -73.208182 End: 44.861018, -73.206295
50	Start: 44.668242, -73.362817 End: 44.661570, -73.365570	Start: 44.465268, -73.285010 End: 44.472037, -73.285885	Start: 44.324305, -73.338813 End: 44.331203, -73.340082	Start: 44.160048, -73.386617 End: 44.153872, -73.390318		Start: 44.696638, -73.226947 End: 44.703503, -73.226588	
60	Start: 44.657160, -73.371375 End: 44.663483, -73.367423	Start: 44.476022, -73.288420 End: 44.469652, -73.289770	Start: 44.323642, -73.338330 End: 44.330117, -73.337898	Start: 44.159122, -73.401338 End: 44.165855, -73.400808			
70		Start: 44.476808, -73.311515 End: 44.470252, -73.310718	Start: 44.321400, -73.337735 End: 44.327955, -73.33630				
80		Start: 44.726000, -73.309723 End: 44.465892, -73.308133	Start: 44.324902, -73.335393 End: 44.331438, -73.332047				
90		Start: 44.472665, -73.307615 End: 44.465777, -73.305890	Start: 44.326593, -73.333285 End: 44.319905, -73.335387				

*Exact trawling locations may vary depending on water levels

Appendix III: Diagram of Dealteris bottom trawl used in the forage fish surveys in Lake Champlain.



Appendix IV: Cable warp length used for each bottom trawl depth.

Target Depth (meters)	Warp (feet)
20	200
30	300
40	400
50	500
60	600
70	700
80	800*
90	900*

* May require an extra 50 feet of warp

Appendix V. Percent change in length and weight after freezing for four forage fish species from Lake Champlain.

Species	Length equation and R^2	Average length change (±SD)	Weight equation and R^2	Average weight change (±SD)
Alewife	$y = -1.3 + x$; $R^2 = 0.99$	-0.73% ± 2.72	$y = -0.36 + 0.95x$; $R^2 = 1$	-10.45% ± 6.24
Rainbow smelt	$y = 2.3 + 0.96x$; $R^2 = 0.99$	-1.76% ± 2.95	$y = -0.31 + 0.98x$; $R^2 = 1$	-8.32% ± 6.78
Slimy sculpin	$y = 0.76 + 0.96x$; $R^2 = 0.98$	-2.38% ± 3.74	$y = -0.14 + 0.95x$; $R^2 = 0.99$	-14.67% ± 13.32
Trout-perch	$y = 1.4 + 0.96x$; $R^2 = 0.99$	-1.82% ± 2.84	$y = -0.23 + 0.97x$; $R^2 = 1$	-8.07% ± 5.10