Lake Champlain fisheries and ecosystem in the context of the Laurentian Great Lakes: past research, current management issues, and future research priorities

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Abstract

Lake Champlain is a large lake bordered by New York, Vermont, and Quebec. This bi-national, multi-jurisdictional lake shares many management issues and challenges with the much larger bi-national Laurentian Great Lakes, including a history of commercial fisheries, species declines and extirpations, sport fisheries supported by stocking, and invasion of non-native species. The bathymetric complexity of Lake Champlain, which is fragmented into five trophically different basins, makes it an excellent 'test site' for shared research with larger systems of varying trophic states. The size of Lake Champlain makes it very tractable for whole-lake research, including lakewide tracking of fishes with acoustic telemetry. Many research projects have borrowed from Great Lakes expertise, and have likewise contributed to Great Lakes research and management. Valuable contrasts include rapid restoration of a self-sustaining lake trout population in Lake Champlain despite high sea lamprey wounding and an alewife invasion in 2003; decline of naturally-reproducing walleye stocks; a healthy whitefish population and apparent collapse of cisco. Lake Champlain has not yet been invaded by quagga mussels or round goby, so a recently developed whole-lake food web model will be highly informative to predict their potential effects prior to invasion and then test these hypotheses if and when invasions occur. Most commercial fisheries closed in the early 1900s, but the sale of recreationally-angled fishes is legal though undocumented and un-managed. We provide an overview of the biological communities, food webs, management structure, and management history in Lake Champlain, compare and contrast the lake with the Great Lakes, and highlight research priorities to provide a foundation for new research and improve science-based management of fishes in Lake Champlain.

Prologue

Lake Champlain is a narrow glacial lake in the St. Lawrence River basin. At 1,130 km^2, it is dwarfed by the adjacent Laurentian Great Lakes (Figure 1). However, we posit that this size disparity makes Lake Champlain an ideal model system for research and testing hypotheses relevant to the Great Lakes and, more broadly, lake ecosystems facing modern threats. In effect, Lake Champlain can be considered a "trial-sized" system for research on large and great lakes. The ecosystem, fish species composition, and hydrology of Lake Champlain are very similar to the Great Lakes, but work on Lake Champlain is much more tractable due to the lake's smaller size, accessibility, and relatively benign working conditions. The food web is simpler, fewer fish species have been extirpated (four - lake trout *Salvelinus namaycush*, Atlantic salmon *Salmo salar*, muskellunge *Esox masquinongy*, and sauger *Sander canadensis*), and only 51 non-native species - only 25% of those in the Great Lakes. Lake Champlain is fragmented into distinct regions by natural and anthropogenic barriers. The regions vary in trophic state and communities, ranging from shallow, highly productive basins to a deep, moderately productive main basin, and provide a valuable comparison of different trophic levels within a relatively contiguous lake.

Research and management in Lake Champlain and the Great Lakes have and continue to inform efforts in each system. For example, sea lamprey (*Petromyzon marinus*) control in Lake Champlain was informed by decades of experience and methods developed in the Great Lakes, through collaboration with and assistance from Great Lakes control agents (Young et al., 2021). Current research on methods to increase survival of stocked Atlantic salmon is motivated by net pen studies in Lake Ontario. Lake Champlain followed the lead of the Great Lakes Acoustic Telemetry Observation System (GLATOS; glatos.org) to establish the Lake Champlain Acoustic Telemetry Observation System (CATOS). CATOS is currently used to study movements of lake trout, Atlantic salmon, lake sturgeon (*Acipenser fulvescens*), walleye (*Sander vitreus*), and lake whitefish (*Coregonus clupeaformis*) (e.g., Futia et al., 2026, 2025a; Izzo et al., 2022; Pinheiro et al., 2017). Development of a Lake Champlain food web model (Lesser et al., 2023) strongly benefited from Great Lakes examples (Kao et al., 2014; Kitchell et al., 2000; Langseth et al., 2012). Some historically harvested species in the Great Lakes have been virtually ignored in Lake Champlain, including cisco (*Coregonus artedi*) and burbot (*Lota lota*), so developing an understanding of the status and ecology of these species will depend heavily on the body of knowledge available in the Great Lakes (e.g., Stapanian et al., 2008; Stockwell et al., 2009).

Conversely, research on the unexploited populations of harvestable species in Lake Champlain may provide valuable comparisons with stressed Great Lakes stocks. For example, lake whitefish are declining severely in the Great Lakes, likely related to effects of invasive dreissenid mussels (quagga *Dreissena bugensis* and zebra *D. polymorpha* mussels; Cunningham and Dunlop, 2023), whereas in Lake Champlain lake whitefish are thriving despite invasion of zebra mussels in the 1990s (Herbst et al., 2011). In contrast, cisco populations are healthy or recovering in the Great Lakes (Claramunt et al., 2019; Goldsworthy et al., 2025) but appear to have collapsed in Lake Champlain despite the absence of a historical or current fishery and the absence of quagga mussels and round gobies (*Neogobius melanostomus*). Restoration of self-sustaining lake trout populations in the Great Lakes has been underway since the 1960s and progress has been slow; restoration efforts in Lake Champlain began in 1972, recruitment of wild fish began in 2012, and the consistent increase in proportion of wild adults led to termination of stocking in 2025 (Marsden et al., 2018; Wilkins and Marsden, 2021a,b; M. Murphy, Vermont Fish and Wildlife Department, pers. comm.). This recovery, combined with a food web model (Lesser et al., 2023), has stimulated reconsideration of historical assumptions regarding the impact of invasive species (sea lamprey and alewife *Alosa pseudoharengus*) on Great Lakes restoration efforts. Alewife invaded Lake Champlain recently (2003) compared to the Great Lakes (late 1800s), allowing pre- and post-invasion examination of the role of thiamine deficiency in recruitment failure of salmonids (Harder et al. 2018, Ladago et al. 2019). Research on the trophic effects of lakemounts has been facilitated by the ease of working on sites within 15 km of port, relative to Lake Superior seamounts that are 75-150 km from port (Possamai et al., 2024; Rennie et al., 2025).

In the Great Lakes, fishery management and sea lamprey control are facilitated by the Great Lakes Fishery Commission (GLFC), established in 1954, which also funds applied and basic research on topics relevant to management. Two research boards elicit and review proposals focused on sea lamprey biology and suppression and on topics related to fisheries and fish management and conservation. The research boards prompted development of a series of papers that summarize the literature to date in major research themes and identify management priorities and key research questions (Krueger and Marsden, 2007). These papers assist researchers to develop research projects on priority areas for funding by the GLFC and facilitate funding decisions by the boards (e.g., Buchinger et al., 2015; Heck et al., 2014; Ives et al., 2018; Ludsin et al., 2014; McMeans et al., 2016; Miehls et al., 2019; Zimmerman and Krueger, 2009). The current paper serves a similar purpose: we provide an overview of Lake Champlain and the natural and human context of Lake Champlain fisheries, including the geography, habitat, and biodiversity of Lake Champlain, the governance structure in the basin, the history and current demographics of the fishery, and the history and current status of fisheries management with a focus on primary species of management and conservation concern. We list priority areas for research on Lake Champlain identified by managers and by researchers, and research that is also relevant to the Great Lakes. The goal of the paper is to encourage new research on Lake Champlain, particularly in collaboration with Great Lakes needs, and highlight the benefits of cross-system comparisons. To facilitate development of new projects, we also include a summary of existing resources for research - long-term databases, surveys, and infrastructure for field work.

Geography and biological communities in Lake Champlain

Lake Champlain is 20 to 80 times smaller than Lake Ontario and Lake Superior, respectively, the smallest and largest of the Great Lakes. A Great Lake in miniature, it harbors similar fish and invertebrate communities but fewer species, along with comparable but less numerous exotic species, and broadly similar food webs, trophic states, and hydrodynamic characteristics (Chiapella et al., 2023; Lesser et al., 2023; Manley et al., 1999, 2012; Marsden and Hauser, 2009; Myer and Gruendling, 1979; Possamai et al. 2026). The lake is on the border between New York and Vermont, USA, with 56% of the surface area in Vermont, 36% in New York, and 7% in Québec, Canada. Lake Champlain has a maximum depth of 122 m and volume of 26 km^3, making it much smaller than each of the Laurentian Great Lakes and deeper only than Lake Erie (64 m max depth). The lake comprises five basins of differing areas, depths, and trophic states (Main Lake, Missisquoi Bay, Malletts Bay, Northeast Arm, and South Lake; Table 1, Figure 1). The relatively short length (193 km) and maximum width of 19 km, compared to the Great Lakes, makes Lake Champlain highly accessible to sampling multiple sites and habitats within a day.

The most obvious feature of Lake Champlain is its bathymetric complexity; the five basins range from maximum depths of 7 to 122 m, with over 70 islands including small emergent rocky reefs to large islands up to 23 km long, and several lakemounts (Table 1, Figure 1, supplementary materials Figure S1; Possamai et al., 2024). The natural basins formed by islands and sandbars were further isolated by construction of causeways in the 19th and 20th centuries (Marsden and Langdon, 2012). Of the 11 causeways, the largest two separate Malletts Bay from the Northeast Arm (Sandbar, 1.6 km long) and from the Main Lake (Island Line, 5.2 km long). These two causeways have one and two narrow openings, respectively, between 20 and 60 m wide; the openings are very shallow, likely preventing cold- and coolwater species from moving between basins when the lake is thermally stratified. The causeways substantially restrict water flow between basins (Myer and Gruendling, 1979). For example, the Missisquoi Bay causeway, built around 1900, largely closed the bay's connection to the Main Lake and may have contributed to impoundment of nutrients and sediments in the bay and exacerbated frequent cyanobacteria blooms (Lake Champlain Basin Program (LCBP), 2024). An 860-m section of the causeway was removed and replaced with a bridge in 2008 to improve water mixing with the Main Lake and improve water quality, although cyanobacteria blooms and anoxic conditions persist (Isles et al., 2015). The unusual feature of whole-lake fragmentation in Lake Champlain offers a unique platform for comparative studies among different trophic states and predicting effects of disturbances (e.g., invasive species; Chiapella et al., 2023). Examples of the effect of isolation and trophic differences among basins are reflected by population-level differences in growth, abundance, and population trajectories of rainbow smelt (Bruel et al., 2021) and the size structure of trout-perch (*Percopsis omiscomaycus*) populations (Lesser et al., 2024).

The Main Lake is the largest and deepest basin, encompassing 60% (683 km^2) of the surface area and 82% (21 km^3) of the volume (Potash et al., 1969) The Main Lake is characterized by a cold- and cool-water fish community dominated by lake trout, Atlantic salmon, walleye, burbot, slimy sculpin (*Cottus cognatus*), trout-perch, and rainbow smelt. The invasive cool-water species alewife was first detected in 2003 and is now a major component of predator diets and mid-trophic biomass (e.g., Simonin et al. 2018, Lesser et al. 2023, Futia et al. 2025b). The nearshore fish community in the Main Lake comprises cool- and warm-water species including smallmouth bass (*Micropterus dolomieu*) and largemouth bass (*M. nigricans*), yellow perch (*Perca flavescens*), freshwater drum (*Aplodinotus grunniens*), longnose gar (*Lepisosteus osseus*), golden shiner (*Notemigonus chrysoleucus*), and, since the 1980s, non-native white perch (*Morone americana*) and tench (*Tinca tinca*). The invertebrate community in the Main Lake is dominated by *Mysis diluviana* and other typical zooplankton genera (Mihuc et al., 2012). Invasive zebra mussels invaded in 1993 and are abundant at depths < 20 m (Knight et al., 2018).

The second largest basin is the Northeast Arm, locally called the Inland Sea, which is isolated from the Main Lake by large islands and is characterized by similar cool- and warm-water fish species as the Main Lake. Cold-water species include rainbow smelt and Atlantic salmon, with lake trout only present in winter (Futia and Marsden, 2025) as this region is too warm for lake trout during the summer and experiences hypoxic conditions in the hypolimnion (Isles et al., 2017). Rainbow smelt have decreased over recent decades, perhaps related to warming temperatures and increasingly hypoxic conditions confounded by the invasive alewife (Bruel et al., 2021). Nearshore fishes are dominated by percids, centrarchids, and esocids (e.g., Block et al., 2020). *Mysis* are rare in the Northeast Arm, but amphipods are abundant and oligochaetes and chironomids are present in fish diets (Chiapella et al., 2023).

Malletts Bay has an outer bay and smaller inner bay (Figure 1), and is characterized by a similar fish community to the Main Lake and Northeast Arm, minus lake trout during the thermally stratified months (Futia and Marsden 2025). The zooplankton community composition in Malletts Bay is similar to the Main Lake (Stockwell, unpublished data).

The South Lake is an extension of the Main Lake but is riverine in nature and highly productive (eutrophic) compared to the Main Lake. It is a relatively small, shallow region with a fish community dominated by warm- and cool-water centrarchids, moronids, and catostomids (Langdon et al., 2006). The South Lake is susceptible to cyanobacteria blooms (LCBP, 2024). The zooplankton community is similar to other basins, minus the deepwater calanoid copepod *Limnocalanus* (Mihuc et al., 2012).

Missisquoi Bay, at the northeast tip of Lake Champlain, is the shallowest and most eutrophic basin (maximum depth 4 m). The Pike River enters the bay at the north and historically introduced a substantial nutrient load from agriculture and a food processing facility. Missisquoi Bay's fish community primarily comprises warmwater fishes and supported shoreline seining for commercial harvest of lake whitefish in Quebec waters during fall spawning until the population collapsed by the early 2000s (Marsden and Langdon, 2012). Muskellunge (*Esox masquinongy*) and catostomids spawn in the Pike River and its tributary Morpion Creek, and walleye and lake sturgeon spawn in the Missisquoi River at the south side of the bay.

Overview of Lake Champlain in comparison with the Great Lakes

In notable contrast with the Great Lakes basin, which has a watershed to lake area ratio of 1.1:1.0, Lake Champlain's watershed to lake ratio is 18:1 and is largely encompassed by the Adirondack Mountains to the west and the Green Mountains to the east (LCBP, 2025; supplementary materials Figure S2). Consequently, natural and anthropogenic changes to the Lake Champlain watershed can have disproportionately large and rapid effects; the lake is highly responsive both in terms of degradation and restoration. The lake level can rise dramatically during heavy rainfall and periods of snow-melt, with frequent annual variation of 1-2 meters; the extreme lake levels above sea level range from 28.1 m (recorded in 1908) to 31.6 m (in 2011; LCBP, 2025). This variability may account for the diversity in published estimates of the lake area, from 1,124 km^2 (Myer and Gruendling, 1979) to 1,295 km^2 (Wikipedia). The watershed of the lake was largely deforested for periods during the 19th century, leading to significant inputs of eroded soils, phosphorus, and nitrogen from farming. Sediment accumulation rates rose in the Northeast Arm and Malletts Bay from 0.2 - 0.6 kg/m^2 annually in the early 19th century to as high as 1.4 kg/m^2 in the mid- to late-20th century (Levine et al., 2012). These effects highlight the small scale of biophysical linkages in the lake; the lake has a very high edge-to-area ratio, nearshore areas are close to offshore areas, and distances are much smaller than in the Great Lakes, thus linkages among trophic levels, between offshore and nearshore waters, and between the watershed and lake, are 'tighter' than in the Great Lakes. The Main Lake flushes naturally (i.e., without flow controls) through the Richelieu River to the north, with a retention time of three years (compared to 2.9 for Lake Erie, which has the smallest volume of water among the Laurentian Great Lake; the other lakes have retention times of 6 to 191 years; Quinn, 1992). Therefore, recovery efforts may yield success rapidly, except for the legacy deposits of nutrients in lake sediments (Levine et al., 2012).

Relative to the Great Lakes basin, the Lake Champlain basin is sparsely populated (less than 600,000 people in the 2010 census; LCBP, 2026). There are only two metropolitan areas on its shorelines (Burlington, VT and Plattsburgh, NY), with a combined population of approximately 64,500 in 2024; in contrast, the Great Lakes watershed is inhabited by 34 million people, and the 20 largest Great Lakes cities each have between 90,000 and 2.7 million inhabitants. Forestry and agriculture have been the primary land uses in the Lake Champlain basin since the 1800s. Unlike the Great Lakes, very few major industries have been located on the shoreline of Lake Champlain, so pollutant inputs have been dominated by non-point source inputs of phosphorus and nitrogen from farming and urban areas, plus road salt (Celikkol et al., 2021; Isles et al., 2015; Smeltzer et al., 2012). Nutrient inputs, loading, and resulting plankton blooms are most severe in basins with limited water exchange - Missisquoi Bay, St. Albans Bay, and portions of the South Lake (Figure 1). Water quality concerns prompted passing of the Lake Champlain Special Designation Act in 1990, creation of the Lake Champlain Basin Program, and establishment of Lake Champlain Phosphorus Total Maximum Daily Load limits in 2002. The only major historical point-source pollutant inputs apart from municipal water treatment effluent were PCBs from paper pulp dumped Cumberland Bay in the northern lake until 1973 and organic sludge from a paper mill in Ticonderoga, New York, in the South Lake; both sources have been largely remediated since 2000 (LCBP, 2024). As in the Great Lakes, non-point source pollutants include mercury, PFAS, microplastics, pharmaceuticals, and caffeine (Swinton et al. 2019, LCBP, 2024). Fish consumption advisories focus on mercury and PCBs in sport fishes (LCBP, https://www.lcbp.org/our-goals/clean-water/fishable-swimmable-drinkable/fish-advisories/).

Lake Champlain contains 72 native fish species. In contrast to the Great Lakes, rainbow smelt are native to Lake Champlain and only two coregonine species (cisco and lake whitefish) and two sculpin species (mottled sculpin *Cottus bairdi* and slimy sculpin) inhabit the lake (Marsden and Langdon, 2012). Fifteen fish species have been introduced through various vectors including intentional stocking (rainbow trout *Oncorynchus mykiss*, brown trout *Salmo trutta*), unauthorized stocking (largemouth bass, black crappie *Pomoxis nigromaculatus*, white crappie *Pomoxis annularis*, common carp *Cyprinus carpio*, alewife, black bullhead *Ameirus melas*), migration via canals (blueback herring *Alosa aestivalis*, gizzard shad *Dorosoma cepedianum*, sea lamprey, brook silverside *Labidesthes sicculus*, tench) and bait or aquarium releases (rudd *Scardinius erythrophthalmus*, goldfish *Cassius auratus*; Marsden and Hauser 2009). The lake is characterized by a depauperate benthic community in the Main Lake and virtual absence of *Diporiea*

(Knight et al., 2018); *Mysis* are abundant in the Main Lake but rare in the Northeast Arm (Ball et al., 2015; Chiapella et al. 2023), which contains a very high density of amphipods (JDS, pers. obs.). Overall, the biotic community and lake food webs are relatively intact and allow comparison with the devastating effects of invasives in the highly-impacted Great Lakes (Marsden and Langdon, 2012; Mills et al., 1993; Ricciardi, 2006). Although most of the exotic species in Lake Champlain are also present in the Great Lakes, the exceptions provide opportunities for pre-invasion studies and highlight the value of post-invasion studies in the Great Lakes: quagga mussels and round gobies are absent from Lake Champlain, alewife invaded over 80 years later than in the Great Lakes, and tench have been established lake-wide for nearly two decades (Avlijaš et al., 2018; Marsden and Hauser, 2009).

Lake Champlain fisheries history

Unlike the commercial harvests that radically changed the fish communities of the Great Lakes, the period of commercial fisheries in Lake Champlain only lasted from early to mid-1800s to 1917 and was mostly localized (Marsden and Langdon, 2012). Fishing was conducted largely with shoreline seines and focused on lake whitefish, lake trout, walleye, and yellow perch on their spring and fall spawning grounds in the northeastern and southern areas of the lake. Additional commercially harvested species included basses, bullheads, channel catfish (*Ictalurus punctatus*), American eel (*Anguilla rostrata*), northern pike (*Esox lucius*), chain pickerel (*Esox niger*), rock bass (*Ambloplites rupestris*), rainbow smelt, Atlantic salmon, and lake sturgeon, and were fished with trap nets, pound nets, fyke nets, hand lines, set lines, spears, hunting rifles, and grappling irons; trawls were prohibited and gillnetting was considered infeasible in the lake (Marsden and Langdon, 2012). Commercial and/or recreational fisheries for lake sturgeon, American eels, walleye, and lake whitefish were reopened intermittently after 1917 in Quebec and for brief periods in Vermont; American eel commercial fisheries in Vermont were closed in 1967 (Marsden and Langdon, 2012). Atlantic salmon and lake trout were extirpated by the 1830s and 1900, respectively, and lake sturgeon and American eel were depleted; angling harvest for lake sturgeon was closed in 1967 (Marsden and Langdon, 2012). Since closure of the last commercial fisheries, fish harvesting primarily occurs through angling from shore and boats, ice fishing, and a small charter fishery with less than two dozen boats.

An experimental program to monitor the outcomes of sea lamprey control efforts was conducted in 1990-1998. The program focused on wounding of lake trout, Atlantic salmon, and walleye, with ancillary data on lake whitefish and burbot, and was followed by initiation of a long-term sea lamprey control program in 2002 (Fisheries Technical Committee, 1999; Marsden et al., 2003; Young et al., 2021). Assessment and control practices followed those used in the Great Lakes: sea lamprey ammocoetes are monitored by electroshocking in multiple tributaries and six deltas, and spawning adults are assessed using portable assessment traps (Young et al., 2021). The control program uses barriers and traps to block spawning adults, and lampricides are applied to one third of the lamprey-producing tributaries and five deltas every four years; by 2020, a total of 26 streams were treated (Young et al., 2021).

The highly managed species (i.e., interjurisdictional fishes cooperatively managed by the Lake Champlain Fish and Wildlife Management Cooperative; see next section) - Atlantic salmon, lake trout, walleye - have experienced dramatic population declines, or were extirpated, and the first three are or were managed by stocking. In contrast to the Great Lakes, where four Pacific salmon species and one European trout have been stocked since the 1960s, brown trout and rainbow trout are the only non-native species stocked in the lake (< 150,000 overall annually), expressly for the purpose of diversifying fishing opportunities. Brown trout (*Salmo trutta*) support only a small group of anglers, but the interest is considered of value by managers. Few to no data have been collected on diet, distribution, or habitat of either of these two species, and to date there is no evidence that either species has reproduced in the lake or its tributaries.

History of governance and management structure of Lake Champlain

Coordinated lake-wide fisheries management was initiated with the establishment of the Lake Champlain Fish and Wildlife Management Cooperative in 1972, comprising the directors of the Vermont Fish and Wildlife Department (VTFWD), New York Department of Environmental Conservation (NYDEC), and the Northeast Region of the U. S. Fish and Wildlife Service (USFWS) with a working relationship with the Quebec Ministry of the Environment, the Fight Against Climate Change, Wildlife and Parks (Ministére de l/Environnement, de la Lutte contre les Changements Climatiques, del Faune et des Parcs, MELCCFP). The priorities of the cooperative are protection and management of resources of interjurisdictional significance; evaluation of impacts on fisheries resources; development of a comprehensive management plan with input from and implementation by individual agencies; and control of sea lamprey, with USFWS taking the lead role. The cooperative formed the Lake Champlain Fisheries Technical Committee (FTC), comprising the VTFWD, NYDEC, and USFWS, with advisors from outside units, i.e., fisheries faculty at the University of Vermont (UVM), USGS Cooperative Fish and Wildlife Research Unit at UVM (Coop Unit), and the MELCCFP. Discussions and decisions about stocking, assessment, and research are conducted at tri-annual meetings of the FTC and ratified during annual meetings of the Cooperative. The Cooperative is partnered with the Lake Champlain Basin Program and Lake Champlain Sea Grant, which, in the context of fisheries-related work, focus on invasive species prevention, outreach, and funding research.

The first strategic plan for the lake was written in 1977 and focused solely on salmonids, specifically the restoration of fisheries for Atlantic salmon and lake trout (Fisheries Technical Committee, 1977). Stocking to re-establish populations of both species occurred sporadically starting in the 1950 and annual stocking began in 1972, followed by introduction of non-native rainbow trout and steelhead salmon. Efforts to control sea lamprey were initiated as an experimental program in 1990 with the assistance of the Great Lakes Fishery Commission lamprey control agents (Marsden et al., 2003; Young et al., 2021). In the 1990s, the management perspective on use of hatcheries and stocking shifted from supporting recreational fisheries to include their use as tools to support and restore self-sustaining native fish populations. The FTC also began to focus on species of conservation need, specifically American eel and lake sturgeon. This broadening of management effort and focus was reflected in the 2010 Strategic Plan for Lake Champlain Fisheries (Marsden et al., 2010). The 2010 plan outlined priorities for interjurisdictional management, including forage fish monitoring, salmonid population restoration, sea lamprey assessment and control, habitat restoration including fish passage and connectivity, and monitoring of American eel, lake sturgeon, and walleye populations. The 2010 plan also recognized the importance of additional sport fishes including yellow perch, basses, northern pike, muskellunge, sunfishes, and rainbow smelt (Marsden et al., 2010). Subsequent strategic plans in 2020 and 2026 only focus on the species that are managed by the Cooperative , i.e., lake trout, Atlantic salmon, and sea lamprey, plus two species of interjurisdictional conservation concern, American eel and lake sturgeon (Hurst et al., 2020; Lake Champlain Fisheries Technical Committee 2026). Consequently, the focus of cooperative management is on a subset of species targeted by primarily offshore fishers. Additional popular fisheries (e.g., percids, centrarchids, esocids) have fishing regulations established by individual jurisdictions.

The state, provincial, and federal agency teams focused on fisheries in the Lake Champlain basin are small. For example, Vermont and New York combined have only four state biologists who work on Lake Champlain at least part-time, three USFWS biologists conduct the sea lamprey control program and research on Atlantic salmon, and Quebec periodically has one biologist focused part-time on the Quebec waters in Missisquoi Bay. Consequently, as attention to non-salmonid fishes increases, the limits of staff time to conduct surveys on additional species and collect requisite data (age, diets, genetics) is increasingly apparent. However, the few layers of management facilitate rapid communication and nimble decision-making. The small size of the basin and fishing community relative to each of the Great Lakes, and active communication and outreach by the state agencies, enables regular interactions between the agencies and fishers that keeps agency biologists reasonably well informed about attitudes of participating recreational anglers and any dramatic changes in the sportfish communities, either perceived or real. In 2005, a few leaders from the angling community requested better access to up-to-date research and management information, which resulted in development of annual State of the Lake meetings between stakeholders and fisheries managers. These meetings have traditionally been largely attended by a relatively homogeneous group of fishers - older, white, male salmonid and bass anglers - who may not represent the heterogeneity of the fishing population or represent local concerns and priorities within the recreational fishery framework (Nguyen et al., 2025). However, the Lake Champlain Basin Program and Lake Champlain Sea Grant regularly host workshops and partner with local communities to ensure that diverse communities have access to fishing opportunities.

Angler collaborations with biologists and researchers are a valuable resource to understand local fish ecology and enable acquisition of more samples and data than could be obtained by research personnel alone. For example, lake trout and Atlantic salmon have been collected for acoustic telemetry tagging (Futia et al., 2025a, 2025b), sea lamprey were collected as part of a mark-recapture study (Howe et al., 2006), and anglers have supplied hundreds of fin clip samples from Atlantic salmon for genetic studies (Harbicht et al. 2020; Heim et al. in press). These interactions foster strong connections and two-way communication between anglers and researchers and increase angler interest in the status of the lake's fish populations. So far, however, collaborations have been largely with coldwater fishers, reflecting the focus of the majority of research projects and management efforts.

Human Dimensions: current economic value, socio-cultural values, and demographics of the fisheries

Popular fisheries in Lake Champlain include lake trout, Atlantic salmon, and walleye in the offshore area of the lake, and black basses, yellow perch, northern pike, and white perch in the nearshore areas (Center for Rural Studies, 2013; Good, 2017; Pientka, 2020). However, creel surveys have been intermittent and infrequent - they have focused on different basins and seasons (open-water and ice fishing), and data have not been synthesized to piece together a coherent account of changes in angler preferences and harvest numbers (VTFWD Library, 2026; NYDEC Library, 2026). The fishing industry in the Lake Champlain basin is important to the local and regional economy, yet its total economic impacts remain largely undocumented. Lake Champlain fishers directly supported the local economy with an estimated annual spending of at least $200M in 98 fishing-related businesses (i.e., boat and tackle shops) in 2010 (Decerega et al., 2016). The lake is a popular recreational destination that attracts tens of thousands of non-resident fishers annually (Duda et al., 2019) and supports a small group of charter boat operators. The lake also hosts > 100 fishing tournaments annually, ranging from local, small-scale tournaments to multi-million dollar professional circuit tournaments; in 2015, for example, six professional bass tournaments alone contributed over $2M to the regional economy (Henry, 2016). As fishing businesses expand their visibility and tournaments continue to grow, the recreational fishing industry is likely to remain a significant component of the local economy. Anglers may also sell bait fish commercially or to other anglers in the waterbody with a special license, and sell yellow perch, white perch, catfishes, rainbow smelt, freshwater drum, and sunfishes without a permit other than a state fishing license. Vermont residents, including those who do not live near the lake, place economic value on maintaining the quality of the water (Decerega et al., 2016; Lake Champlain Basin Program, 2024), highlighting the value of the lake that goes far beyond the direct benefits of fishing and other water-related activities.

Although Lake Champlain anglers are often perceived as simply fishing for sport and leisure, some groups (hereafter referred to as "provisioning fishers") operate in ways that blur the boundaries between recreational, subsistence, and commercial fishing (Nguyen et al., 2025). Provisioning fishers may derive subsistence and cash benefits from their harvest by selling their catch to local seafood stores, which then sell the fish in local markets or process them for export. The lack of reliable statistics on these small-scale commercial activities and related harvests has hindered managers' ability to assess the contributions and impacts of this fishing sector. Provisioning fishers may engage in fish harvesting (as opposed to catch-and-release) for various other reasons, including connection with the outdoors, food security, nutritional benefits, cultural traditions, or a combination of these factors. Fishing also provides food and cultural ties for Vermont's growing population of New Americans (Stein, 2023), which includes Bosnians, Bhutanese, Vietnamese, Somali Bantu, Burundians, Congolese, and Sudanese (Bose, 2014). A better understanding of this diversity within the angler community is essential for supporting the needs, values, and practices of provisioning fishers within regional fishery management which may not align with the traditional recreational management framework (Nguyen et al., 2025).

Surveys of licensed anglers in Lake Champlain have provided a glimpse into how fishing patterns may differ among angler groups and over time (Good, 2017; Pientka, 2017). Lake Champlain anglers are evenly distributed between self-identified occasional, regular, and avid anglers with various degrees of specialization in preferred target species (Center for Rural Studies, 2013). Avid anglers differ from the rest: not only do they report a greater number of fishing days, but they also invest substantially more in fishing equipment. Non-resident anglers, who account for one third of the estimated number of anglers fishing the lake's open water, may differ from resident anglers - they may be less likely to target salmonids (lake trout, Atlantic salmon) and generally rate the quality of fishing the same or higher than resident anglers (Duda et al., 2019). These studies suggest that Lake Champlain fishers are not a homogeneous group in terms of fishing practices; more information is needed about heterogeneity in fishing patterns and how they relate to anglers' behavior, values, and responses to ecological changes and new management regulations.

Fishing in Lake Champlain is a vital component of the character and identity of the region (e.g., ice shanties for fishing during the long, cold winters). Vermont also has a unique fishing regulation that permits the use of rifles. Rifle-fishing traditionally targeted northern pike and chain pickerel (*Esox niger*) during the spawning seasons, but rifle fishers, similar to bowfishers, also shoot invasive species. New York and Vermont were the only states where the activity was legal and popular until New York banned it in 1969. Although the practice is controversial, rifle fishing remains legal in Vermont for two months in the spring for esocids, bowfin (*Amia occelicauda*), redhorse suckers (*Moxostoma* spp.), gar, bullheads (*Ictalurus* spp.), and carp for those holding a hunting or combination license (Lyons, 1991). Notably, fishing in Lake Champlain is a constitutional right in Vermont. Vermont was the first state to include the right to fish in its constitution, dating back to 1777. As fishers across the United States feel increasing pressure from declining participation and increasing urbanization, 23 states have adopted similar constitutional amendments since the mid-1990s in an effort to ensure that the opportunity to fish will continue.

Research and management decisions have traditionally been and continue to be predominantly guided by western science frameworks (Nguyen et al., 2025), but opportunities are available to meaningfully engage with Indigenous and local knowledge systems. In particular, Lake Champlain has long played a critical role in shaping the history and cultural identity of the local Abenaki (Abenaki: Wôbanakiak) and Mohawk (Mohawk: Kanien'kehá:ka) tribes. However, due to ongoing disputes surrounding the identity of four state-recognized Abenaki tribes of Vermont raised by Canadian First Nations and university scholars (e.g. Benay et al., 2024; Leroux, 2025, 2023; Lish, 2025; Reed et al., 2022), meaningful collaborations with Indigenous Nations must be approached with attention to conflicting sets of criteria for Indigenous identity, including state and self-identification versus considerations of historical continuity and genealogy (Lish, 2025).

Research priorities:

- *Characterize heterogeneity among fisher groups and determine how fishing motivations and patterns vary among diverse fishing groups, including harvest rate, catch rate, behaviors such as consumption or sale of catch, and fishing practices*
- *Determine how to incorporate local and traditional ecological knowledge in management to improve fisheries stewardship*
- *Acquire and compile data from charter fishing harvests and the sale of angler-caught species and bait fishes to evaluate impact on fish populations and local economies. Currently, no regulations are in place to require reporting by charter fishers.*
- *Compile and assess data from annual tournaments to evaluate angler participation, effort, and catch rates*
- *Evaluate the effect of new technologies, such as forward-facing sonar, on fisher success rates, increase in fishers' interest (additional licenses), harvest rates, and local economies.*
- *Evaluate fishers' awareness of existing regulations and the rationale for regulations, and whether they value a risk-averse or risk-tolerant approach to protecting spawning stock and regulating harvest.*

Fish species of management priority

Coldwater fishes

Salmonines - Atlantic salmon, lake trout

The two native salmonine species in Lake Champlain, Atlantic salmon and lake trout, were both extirpated by 1900. Causes for the decline of landlocked Atlantic salmon are obvious - construction of dams on all of the major spawning tributaries to the lake and degradation of spawning habitats by siltation in the 1800s led to disappearance of salmon by 1838 (Marsden and Langdon, 2012). The amount of habitat currently available for Atlantic salmon spawning and suitable for egg incubation is not known. Since 1972, up to 304,000 yearlings or yearling-equivalent fingerling Atlantic salmon have been stocked annually and support a valuable lake- and river-based fishery (Figure 2). However, evidence of spawning has been limited to the presence of redds and, by 2016-2017, capture of alevins in the Boquet River in New York and Winooski River in Vermont (Prévost et al., 2020), and the capture of the first smolt in the Winooski River and fry in the Saranac River in 2024.

The primary challenges for Atlantic salmon restoration are aquatic connectivity, TDC, and habitat degradation in rivers. Egg thiamine monitoring indicates critically low levels in 42-76% of salmon evaluated annually since alewife were introduced (Ladago et al. 2019; Heim et al. in press). This monitoring has been conducted at only one spawning tributary, so spatial variation in TDC among fish foraging in different basins and returning to different river systems requires further study. TDC may also be related to low passage performance of female Atlantic salmon in rivers (Harbicht et al. 2018; Heim et al. 2026; Heim et al. *accepted*). Despite widespread TDC, some offspring survival may be associated with inheritable genetic variation (Harder et al. 2020) and has motivated evaluation of 'assisted evolution' (i.e., intentionally increasing potential adaptive genes via captive breeding) to produce hatchery fish with higher reproductive success in the wild (Heim et al. *in press*). Applied research efforts have focused on identifying approaches that maximize post-stocking survival, including assessment of broodstock selection (e.g., feral vs. domestic, Chipman 2018), hatchery water sources, and stocking timing (Harbicht et al. 2020), fry stocking strategies (clumped vs. dispersed, Brunsdon et al. 2017), stocking locations of smolts (Heim et al. 2025), the impacts of hydroelectric dams on fish passage (Nyqvist et al. 2017; Heim et al. *accepted*), and net-pen rearing (Balk 2022a). Seasonal movements and habitat use of salmon in the lake remain unstudied

The extirpation of lake trout from Lake Champlain by 1900 is still a mystery. In the Great Lakes, overfishing and sea lamprey predation are considered the primary causes of extirpation, and thiamine deficiency complex due to consumption of invasive alewife may be impeding restoration (Harder et al., 2018). In Lake Champlain, the limited commercial fishery in the 1800s seems unlikely to have caused a population collapse (Marsden and Langdon, 2012). Stocking began in 1972, initially using a diversity of strains but focused since 1995 on the Seneca Lake strain and the Lake Champlain strain, progeny of broodstock based on feral lake trout. Natural recruitment began with the 2012 year class, and the population was considered to be restored by 2025, despite the arrival of alewife and high sea lamprey wounding rates relative to the Great Lakes. The presence of multiple, well-studied nearshore lake trout spawning sites in Lake Champlain has made intensive studies of thiamine deficiency complex possible (Futia et al., in review). Lake trout thiamine deficiency is not as severe as in most of the Great Lakes (Ladago et al., 2020) and was not impeding restoration in Lake Champlain. Thiamine content in lake trout eggs can increase through overwinter absorption from ambient sources, and early consumption of thiamine-rich zooplankton may mitigate effects of thiamine deficiency in free embryos (Ladago et al., 2016).

Lake trout spawn at multiple natural and constructed sites lakewide, with very high egg and free embryo densities at some sites (Marsden et al., 2005; Ladago et al., 2016). The first evidence of recruitment was observed in 2015 with three year-classes of unclipped age-1 to age-3 juveniles captured in bottom trawls (Marsden et al., 2018). Evidence of strong year classes of adults in summer gillnet assessment led to reduction and then cessation of stocking in 2025 (Figure 2). The reasons for the sudden recruitment and restoration may be related to consumption of lipid-rich alewife (Lesser et al., 2023). The Seneca strain has higher survival than the Champlain strain (a hybrid mixture of multiple strains stocked in the early years of the restoration program; Marcy-Quay et al., 2025). A small percent (20%) of adults contribute to successful reproduction, and the resulting population is relatively small but has high survival. Acoustic telemetry studies have demonstrated that wild fish do not return to the primary site where spawning populations have been assessed since 1990, and where abundance of spawners is unusually high (Futia et al., 2025a).

Research priorities:

- *Assess the spatial, seasonal, and ontogenetic variation in the diets of Atlantic salmon and relationship between diet and egg thiamine content*
- *Evaluate the predator demand and prey supply for lake trout and Atlantic salmon*
- *Assess the natural reproduction potential of Atlantic salmon in Lake Champlain if habitat were to become available above dams on both major and minor river systems. Determine how much and where spawning habitat is currently available and accessible to/used by spawning salmon*
- *Assess the natural and fishing mortality of lake trout and Atlantic salmon*
- *Assess the post-release mortality of angler-caught lake trout and Atlantic salmon in relation to lake stratification. Is mortality different between wild and stocked lake trout?*
- *Determine how different stocking strategies (life stage, time of year, stocking location) affect survival and contributions of Atlantic salmon to spawning populations*
- *Determine whether Atlantic salmon show tolerance for low thiamine, and whether this trait can be used in hatchery production and stocking*
- *Determine whether thiamine deficiency in lake trout eggs affects ability of free embryos to forage on zooplankton*
- *Measure effect of early feeding by lake trout free embryos to provide sufficient thiamine to overcome thiamine deficiency*
- *Assess how rapidly wild lake trout will diversify genetically and behaviorally from stocked fish*
- *Determine whether adult Atlantic salmon exhibit fidelity to their stocked or natal river or basin, and whether the lake population is a mixed stock of fish from different tributaries or stocking locations*

- *Investigate the cause of poor spawning migration performance and high post-spawning mortality of female salmon relative to males*
- *Expand egg-thiamine monitoring in tributaries to investigate spatial variation in the prevalence of TDC*
- *Construct a life cycle model for Atlantic salmon in Lake Champlain*

Coregonines - lake whitefish and cisco
Lake whitefish were commercially fished in the late 1800s with an average annual yield of 18,537 kg and a peak catch of 31,751 kg in 1912 (Herbst et al., 2011). However, populations were still stable in the early 1930s (Van Oosten and Deason, 1939). In the 2010s, over a century since exploitation ended, the population still demonstrated strong growth, condition, age distribution, and year class strength (Herbst et al., 2011). Recently, lake whitefish have been observed in autumn in the Missisquoi, Lamoille and Winooski rivers, suggesting river-spawning populations may be present (B. Pientka, VTFWD pers. comm.). However, commercial fishing data for lake whitefish in Canadian waters of Missisquoi Bay show a clear decline to apparent population extinction between 1890 and 2005 (Marsden and Langdon, 2012; Hurst et al., 2020). The causes of the decline are as likely to be due to severe eutrophication of the shallow bay as to overharvest. Although lake whitefish were virtually unknown to anglers before 2000, they were 'discovered' in the 2010s and have been added to the Vermont Master Angler Program which recognizes anglers who catch one or more fish that exceed the minimum qualifying length for each species. Currently, no regulations on lake whitefish fishing are in effect. Lake Champlain offers an opportunity to compare the current status of adult stock size and recruitment to lakes Michigan and Huron where whitefish populations have collapsed.

Cisco was not a target of historical commercial fisheries, and has not been a focus of assessment or management, so virtually nothing is known about their historical or current abundance or population dynamics. Midwater trawling at depths over 30 m in the late 1970s caught as many as 100 cisco per 10-min trawl (VTFWD, unpublished data), but the midwater trawl forage fish survey in the Main Lake from 1999 to 2015 caught a maximum of 11.2 cisco per 55-min trawl as bycatch and by 2013 no more cisco were found in the survey (Figure 3). Larval densities were very high (> 2,500/1,000 m^3) in 2010 throughout the near and offshore areas of the lake (Herbst et al., 2011; larvae reported as lake whitefish but later genetically identified as cisco), but neuston net sampling in waters < 1.5 m in 2020 and 2021 found few larvae (Marsden, unpublished data). Alewife prey on cisco larvae (George, 2019) and alewife predation is considered to be an important factor limiting cisco recruitment in the Great Lakes (Brown et al., 2024). The absence of a large 'offshore' zone in Lake Champlain may increase the spatial overlap between alewife and cisco and produce a different dynamic than in the Great Lakes. Thus, the status of cisco in the lake remains an open question.

Research priorities:
- *Assess the angling harvest of lake whitefish and whether it can be sustained by the current population*
- *Evaluate lake whitefish larval survival and recruitment in Lake Champlain, where quagga mussels are absent, to evaluate hypotheses about factors that are causing the collapse of lake whitefish in lakes Michigan and Huron*
- *Evaluate the contribution of river spawning to lake whitefish populations in Lake Champlain*
- *Identify current spawning locations and evaluate degradation of historical spawning locations for lake whitefish*
- *Determine whether lake whitefish that spawn in rivers are genetically different populations from those in the lake.*
- *Evaluate the recent and current status of cisco in Lake Champlain. Determine whether alewife could be a contributing factor in their decline*

Rainbow smelt
Rainbow smelt are native to Lake Champlain, unlike in the Great Lakes, and spawn in the lake rather than tributaries. They were a popular target for ice fishing in areas of the Main Lake and South Lake (e.g., Anderson 1978, Chipman 1997), far exceeding the catch of other species, and may be harvested without a limit. However, in a recent winter creel survey on the New York shoreline, rainbow smelt were not even mentioned as a target species (Balk 2022b). Historically, rainbow smelt comprised two 'races', or morphotypes - normal (average TL 150 mm) and giant (average TL 239 mm, up to 356 mm; Greene et al., 1930). However, the proportion of the population classified as giants has declined steadily since the 1930s and are rarely found in the Main Lake, though still present in Malletts Bay and the Northeast Arm (Draugelis et al., 2025). Age and diet data suggest that rainbow smelt in the Northeast Arm have higher piscivory, grow faster, and live longer than in the Main Lake, likely due to the paucity of summer predators in the smaller basins (Draugelis et al., 2025). The invasion of alewife in 2003 caused a decline in rainbow smelt populations in the Northeast Arm, but populations remained stable in the Main Lake where the presence of *Mysis* provides better forage and deep water allowed rainbow smelt to spatially segregate from alewife by depth (Bruel et al., 2021; Lesser et al., 2023).

Other deep, coldwater species
Mottled sculpin are rare in Lake Champlain, and slimy sculpin are, curiously, found in shallow (< 1 m) as well as deep water. Deepwater sculpin (*Myoxocephalus thompsonii*) are absent. Slimy sculpin are abundant in bottom trawl surveys, but reach smaller sizes than in the Great Lakes (average total length 60 mm, maximum 100 mm, Forbes et al., in review).

Burbot are present in the Main Lake, Northeast Arm, and Malletts Bay, but are virtually unstudied. They were not commercially harvested, likely because fishers did not fish in deep water with gillnets or trawls; thus the populations can serve as an interesting contrast with the exploited Great Lakes burbot (Stapanian et al., 2008). Burbot were caught as bycatch in deepwater gillnets during the experimental sea lamprey control program from 1990 to 1998, and sea lamprey wounding was recorded (Fisheries Technical Committee, 1999). Recent studies have suggested that burbot in tributaries may be genetically isolated from populations in the lake (unpublished data).

Trout-perch numerically compose a substantial proportion of bottom trawl catches in Lake Champlain, and represent as much as a third of daytime bottom trawl catches (Scarfo, 2026). The species is highly understudied in large lakes, and their role in the food web is a mystery because they are rarely seen in stomachs of co-occurring deepwater predators. Diet analyses of trout-perch in Lake Champlain indicate they conduct diel horizontal migrations and may acquire most of their prey in nearshore areas at night while avoiding predators during the day in deeper water (Lesser et al., 2024).

Research priorities:
- *Evaluate the status of burbot populations in Lake Champlain and compare this commercially unexploited population with those in the Great Lakes.*
- *Determine where burbot spawn in Lake Champlain, and whether river-spawning populations are distinct from the lake populations.*
- *Examine the resiliency of burbot in the lake in response to climate change.*
- *Identify what niches slimy sculpin occupy in Lake Champlain in comparison with the Great Lakes, which also have deepwater sculpins*
- *Identify predators of trout-perch to inform food-web models, likely linking deepwater food webs with nearshore species.*
- *Evaluate the ice-fishery for rainbow smelt to determine whether loss of harvest focus is due to angler disinterest or changes in availability of the fish.*

Cool and warmwater species

The relative paucity of text on cool and warmwater species other than percids, compared to the coldwater species, reflects the limited resources and capacity of the agencies, as noted earlier, and the limited information available from published research and surveys.

Percids

Yellow perch provides a popular recreational fishery which has largely been assessed in the Northeast Arm (e.g., Chipman, 2017, 2016) and ice fisheries (e.g., Balk, 2022b). Although basses and Atlantic salmon are popular species targeted by anglers in the non-winter seasons, the catch and harvest of yellow perch generally exceeds the catch of any of these species by 1.5 orders of magnitude (Chipman 2019). Introduction of white perch in 1984 in the South Lake prompted concerns about competition for food and predation by white perch on yellow perch eggs (Hawes and Parrish, 2003; Mason and Brandt, 1996). In the 1990s, slow growth of yellow perch led anglers and management agencies to suspect yellow perch were stunted. An exponential increase in the double-crested cormorant (*Phalacrocorax auritus*) population in the 1990s raised concerns about increased yellow perch mortality; cormorant diets shifted to incorporate alewife after 2008 (Debruyne et al., 2012; Marsden et al., 2010), but follow-up studies on the impacts on yellow perch have not been conducted.

Walleye populations in Lake Champlain appear to be supported entirely by river spawning. Walleye were commercially fished in US waters until the early 1900s, and in Quebec waters until 1971. Walleye support a major coolwater recreational fishery, but they have been steadily declining since the 1960s (Marsden and Langdon, 2012; Pientka, 2022). The decline prompted authorized stocking by the Lake Champlain Walleye Association, but by the mid 2000s concerns about potential introduction of Viral Hemorrhagic Septicemia led to transfer of stocking to VTDEC and development of hatchery culture for walleye at the Ed Weed Fish Culture Station in Vermont, using walleye from Vermont rivers as broodstock (Johnson et al., 2021). One to nine million post-larvae have been stocked annually since 1996. By the 2020s, stocked walleye composed the majority of the population, suggesting that wild recruitment has declined (Good, 2023; Figure 4). Relative abundance estimates are only available for spawning populations in Missisquoi Bay, from five-year seining surveys (Marsden and Langdon, 2012).

Centrarchids, esocids, bowfin, freshwater drum, gar, catostomids

Largemouth bass were introduced to Lake Champlain by stocking and likely also entered the lake via the Champlain Canal pre-1900 (Marsden and Hauser, 2009). Largemouth and smallmouth bass are highly popular open-water sport fishing targets and are the focus of regional and international tournaments and national recognition as a bass fishery (Center for Rural Studies 2013). The resulting displacement of catch-and-released individuals has raised concerns about crowding, mortality, changes in local predator density, and mixing of genetically differentiated subpopulations (Maynard et al., 2017). Northern pike and muskellunge are highly popular among fairly small populations of anglers, including ice fishers that target northern pike. Muskellunge are rare; a population in the Missisquoi River was extirpated by a chemical spill in 1979 and was restored by fish stocked in New York waters. Current regulations restrict fishing for muskellunge to catch-and-release. Sauger are considered to be extirpated; the last record of a sauger caught in the lake was from an electrofishing survey in the mid-2000s (USFWS unpublished data). Other species, including bowfin , longnose gar carp , freshwater drum , and redhorse suckers (*Moxostoma* spp.), also attract small numbers of dedicated anglers and may be fished legally with hand-held spears, spear guns, bows, crossbows, and rifles.

Research priorities:

- *Identify factors involved in the decline of walleye in Lake Champlain, including potential for competitive exclusion by stocked fish. Assess the current population demographics (abundance, growth, survival, stock structure) and factors that may be limiting recruitment*
- *Assess the relative importance of alewife, rainbow smelt, and other species in the diet of walleye*

- *Assess the impact of recreational harvest, and particularly tournaments, on abundance, movements, and population structure of largemouth and smallmouth bass and other cool- and warmwater fishes*
- *Assess the importance of the warmwater fishery and tournaments to the local economies in Lake Champlain*
- *Assess the status (distribution, abundance, demographics) of stocked muskellunge populations*
- *Evaluate factors that may limit re-establishment of a self-sustaining population of sauger*
- *Assess the capacity of cool- and warmwater species to support sustainable harvest and sale under current regulations in Vermont, and evaluate economic and social benefits.*

Species of conservation concern

Lake sturgeon

Lake sturgeon populations were depleted in the Lake Champlain basin due to commercial and recreational harvest in the late 1800s and early 1900s and damming of spawning tributaries. Commercial fishing declined through the early 1900s and harvest was closed in 1967; lake sturgeon were listed as endangered in 1972 by Vermont and are threatened in New York.. Managers were hesitant to use stocking to promote restoration in the absence of information about population abundance and number of rivers used by lake sturgeon to spawn. Instead, assessment of lake sturgeon populations began in 2003, and by 2010 adults and/or eggs had been found in the Winooski, Lamoille, and Missisquoi rivers; age-0 lake sturgeon were sampled in the Winooski and Lamoille rivers in 2004-2005 (McKenzie 2008). Juvenile home ranges are seasonally larger than those of adults, but juveniles, unlike adults, do not move across causeways (Futtia et al., 2026; Izzo et al., 2022).

American eel

American eels access Lake Champlain from the Atlantic Ocean via the Richelieu River to the north; the Richelieu River enters the St. Lawrence River approximately 70 km north of Montreal. Construction of two dams on the Richelieu River in the 1960s, and intensive harvest on the river reduced passage of juveniles into the lake. Eel passages were constructed at the St. Ours dam in 2001 and at the Chambly dam in the late 1990s, subsequently upgraded in 2002. Approximately 2.7 million glass eels were stocked into the river and Missisquoi Bay between 2000 and 2005. Stocking ended due to concerns about introduction of the parasite *Anguillicoloides crassus* but is anticipated to resume in 2026. Dams in many tributaries of the lake appear to impede passage to upstream habitat and feeding areas, although American eels have been observed upstream of dams in the Saranac and Poultney rivers. The overall impact of dams on growth and survival, the success of downstream passage in the Richelieu River, and the contributions of stocked eels to the Canadian fishery and the Atlantic spawning population are unknown (Stuart et al., 2025).

Research priorities:

- *Determine the population size of lake sturgeon in Lake Champlain*
- *Identify which rivers are used for spawning by lake sturgeon, which rivers produce recruits, and determine whether spawners use more than one river between or among years*
- *Evaluate genetic differences among lake sturgeon spawning rivers and among lake basins*
- *Determine the impact of barriers and habitat alterations on American eel migration and subsequent survival and growth in Lake Champlain tributaries*
- *Evaluate success of American eel outmigration from Lake Champlain to the Atlantic Ocean, given the presence of barriers in the Richelieu River*

Non-native and nuisance species

Lake Champlain has similar vectors for invasion of non-native species as the Great Lakes - canals that connect the lake to the Hudson and St. Lawrence rivers, unauthorized fish introductions and intentional stocking, bait bucket discards, and recreational boat transfers (Marsden and Hauser, 2009). Lake Champlain has virtually no commercial shipping other than a few ferries and tug-boats brought in through the canals, so the absence of this vector may account for the relatively small number of non-native species - 25% of those in the Great Lakes (https://www.glerl.noaa.gov/glansis/). In addition, the presence of a relatively intact food web, with fewer extirpated species and lower fishing pressure, may resist or reduce the effects of invasive species observed in the Great Lakes (e.g., round goby, quagga mussels, alewife; Chiapella et al., 2023; Lesser et al., 2023).

Alewife were first discovered in Lake Champlain in 2003 but were found throughout the lake by 2007. A substantial mortality event occurred in the southern Main Lake in 2008 (Marsden and Hauser, 2009) and smaller die-offs occur in most years in the Northeast Arm, but not to the extreme seen in the Great Lakes in the 1950s. Alewife comprise an important part of salmonine diets in Lake Champlain (Futia et al., 2025b; Marsden et al., 2022), and their contribution to walleye and other predator diets appears to be high but needs to be quantified. Consumption of alewife has led to thiamine deficiency in lake trout and Atlantic salmonid as noted earlier (Ladago et al., 2020). The importance of alewife as a mid-trophic-level food web link is discussed under food webs. Alewife are perceived as a potential cause of salmonid mortality and a major impediment to restoration of lake trout as a consequence of thiamine deficiency complex (TDC) induced by consuming alewife that contain thiaminase (Harder et al., 2018). However, in Lake Champlain lake trout recruitment began *after* alewife invaded and egg thiamine levels declined.

Zebra mussels were first found in Lake Champlain in 1993 in the South Lake, and spread rapidly northward in the Main Lake. Invasion and population expansion in the isolated basins (Malletts Bay, Northeast Arm, and Missisquoi Bay) was much slower, likely due to limited water exchange with the Main Lake. Populations in the isolated basins are still less dense than in the Main Lake, possibly due to low calcium (Marsden et al., 2013). As in the Great Lakes, zebra mussels have negatively affected native unionid mussels and provided substrate nutrients for benthic macroinvertebrates (Beekey et al., 2004; Hallac and Marsden, 2000). Quagga mussels have not yet entered the lake, so Lake Champlain offers a valuable comparison to the Great Lakes of the effects of a single dreissenid invasion. An intensive survey of rocky habitats was conducted in the mid-1990s to document the benthic communities before dreissenid effects occurred; however, this study has not yet been followed up (Fiske and Levey, 1996).

Other non-native species have received little or no direct attention in Lake Champlain. Tench were first sighted in the lake in 2002 (Marsden and Hauser, 2009) but remained largely unnoticed for ten years except for occasional angler sightings in the Northeast Arm. However, an extensive survey in the mid-2010s showed that tench were present throughout the lake (Avlijaš et al., 2018). Brook silverside were first sighted in the lake in 1998 (Marsden et al., 2000) and are seen periodically in dense schools, but no studies have examined their roles in the lake food web and their population status is unknown. Similarly, rudd (*Scardinius erythrophthalmus*), discovered in the lake in 1991 and likely introduced as bait, are entirely unstudied (Marsden and Hauser 2009). White perch invaded in 1984 and have become widespread throughout the lake as a popular sport fish; although they are largely benthivorous, they shift to consuming *Daphnia* when *Daphnia* populations are high (Couture and Watzin, 2008; Hawes and Parrish, 2003). The addition of these and other planktivorous species, including blueback herring, gizzard shad, and two spiny waterflea species, has likely altered the zooplankton community (see below).

While the potential endemicity of sea lamprey in Lake Champlain has been debated extensively elsewhere, summarized by Young et al. (2021), the origin of this species in Lake Champlain is still uncertain. Sea lamprey are suppressed in Lake Champlain because they are considered a nuisance to fisheries and fish populations, including the threatened lake sturgeon. Sea lamprey wounding has been very high, peaking at 99 wounds per 100 lake trout; the target for wounding was set at 25 A1 to A3 wounds per 100 lake trout between 533 and 633 mm total length, and was finally achieved in 2022 and again in 2025 (Figure 5). The target for wounding of Atlantic salmon, which had peaked over 90 wounds per 100 salmon between 432 and 533 mm TL, was set at 15 wounds per 100 fish; wounding dropped below the target after 2021 (Young et al., 2021; https://www.fws.gov/project/sea-lamprey-control-lake-champlain-basin). Lake sturgeon also experience higher wounding than any of the Great Lakes, with 61.5% of sturgeon having wounds in 1998-2003; the highest percentage in the Great Lakes was 40% (Pratt et al., 2021). In the South Lake, wounding of northern pike has exceeded 40 wounds per 100 pike in some years (Good, 2019). This high wounding may partly be a consequence of a large number of lamprey-producing streams draining into a relatively small lake, in comparison with the Great Lakes; Lake Ontario, for example, has 66 lamprey-producing streams contributing to an area 56 times larger than Lake Champlain, which has 26 lamprey-producing streams. Efforts are underway to establish an adult sea lamprey abundance index to be used in combination with wounding rates to assess the control programs effectiveness.

Sea lamprey control in Lake Champlain is led by the USFWS, with cooperation by VTFWD and NYDEC. In contrast to the multi-state and multi-agency coordination in the Great Lakes, all operations and data collection, including wounding data, are conducted by the three fisheries agencies lake-wide and centralized in a single office in Essex, VT. As in the Great Lakes, control focuses on lampricide applications in streams and deltas and stream barriers with traps (Young et al., 2021). Several streams known to support sea lamprey have not been treated with lampricide, and trapping adults is used as the control strategy: Malletts Creek in Vermont contains endangered northern brook lamprey (*Ichthyomyzon fossor*), Youngman Brook in Vermont and Mullen Brook in New York contain American brook lamprey. The Pike/Morpion River system in Quebec is untreated because provincial agencies did not approve of introduction of pesticides (Young et al., 2021). The high density of spawners and larval lamprey from the Pike/Morpion River system stimulated innovation of a modular screen barrier that can be seasonally deployed (Young et al., 2021), and access to never-treated streams has enabled research on contrasts between growth of larvae in treated and untreated populations (Zerrenner et al. 2006). Research using microchemical analysis to identify tributaries that contributed the highest number of parasites to the lake (Howe et al., 2013; Lochet et al., 2013) revealed that lamprey statoliths, unlike teleost otoliths, are restructured during metamorphosis from the larval to juvenile stages (Lochet et al., 2014). The high abundance of sea lamprey ammocoetes in tributaries facilitated research on transformer outmigration and diel movements to investigate the potential to control sea lamprey at this life stage (Miehls et al., 2019). The USFWS maintains an extensive database of larval assessment and adult trapping records from 1990 to the present.

Research priorities:

- *Evaluate the effect of recent non-native and invasive species (spiny water flea, fishhook flea, brook silverside, tench) on fish populations and community dynamics of Lake Champlain*
- *Evaluate the potential and realized (if invasion occurs) effects of quagga mussels, round gobies, grass carp, and other invasive species on the food web of each basin in Lake Champlain*
- *Determine the extent to which zebra mussels have affected spawning habitat and larval food availability for coregonines in Lake Champlain, in comparison to the combined effects of zebra and quagga mussels on lake whitefish in the Great Lakes*
- *Evaluate the potential for suppression of established non-native species*
- *Assess the potential for additional assessment and control methods to improve sea lamprey control*
- *Assess the dispersal and fate of juvenile and adult sea lamprey to determine which tributaries contribute disproportionately more parasitic adults to the overall population*

Energy dynamics and food webs

Food web research on Lake Champlain prior to 2010 primarily focused on deepwater, offshore fishes, specifically the diets of offshore coldwater species lake trout and rainbow smelt (Kirn and Labar, 1996; Labar, 1993; Stetter et al., 2007; Stritzel Thomson et al., 2011) and walleye (Overman and Parrish, 2001). The earliest, descriptive diet studies on a large range of species were conducted by Rimsky-Korsakoff (1930), along with a focused study on rainbow smelt diets (Greene et al., 1930). Lake whitefish diets were characterized by Van Oosten and Deason (1939), followed up in 2011-12 by Herbst et al. (2013). The only other diet studies prior to 2010 examined invasive white perch and other species that consumed invasive zebra mussels (Couture and Watzin, 2008; Watzin et al., 2008).

Much of the food web research after 2010 has been in response to the alewife invasion in the mid-2000s and the paradoxical onset of wild lake trout recruitment starting in 2012 (Lesser et al., 2023). Isotope studies suggested alewife were incorporated into lake trout, walleye, and Atlantic salmon diets by early summer 2011 (Simonin et al., 2018), although consumption likely occurred soon after alewife establishment. Age-0 to age-3 lake trout consumed *Mysis* and switched to a diet of both rainbow smelt and alewife by the mid-2010s, but any diet differences between stocked and wild fish at these ages likely did not account for the sudden onset of wild recruitment (Marsden et al., 2022). Similarly, adult lake trout diet composition did not vary substantially between stocked and wild fish, although wild fish consumed more prey and had fewer empty stomachs than stocked fish (Futia et al., 2025b). Food web modeling suggested alewife could have filled an empty niche in the food web, providing a more direct energy pathway between primary producers and lake trout and serving as a trophic boost to jumpstart lake trout recruitment (Lesser et al., 2023).

The arrival of alewife and the restoration of lake trout in Lake Champlain provide opportunities to test trophic cascade theory. Alewife are strongly size-selective zooplanktivores and were expected to alter the zooplankton community to dominance by smaller-bodied zooplankton (Brooks and Dodson 1965). Changes in the zooplankton community composition up until 2010 at five sites in the Lake Champlain Long-Term Monitoring Program (LTMP) supported this expectation (Mihuc et al., 2012). Lake trout primarily consume alewife, and with the surge of wild recruits starting in 2012, predation pressure on alewife has likely increased greatly over the last decade. Such predation pressure could result in a trophic cascade that releases zooplankton from predation and results in an increase in abundance of larger-bodied zooplankton and/or increase in average zooplankton body size. However, this type of response by zooplankton is expected to only occur in the Main Lake because lake trout are excluded from the other four basins during spring to autumn, when oxythermal conditions prevent lake trout from occupying those basins (Bruel et al. 2021). The invasion of spiny water flea (*Bythotrephes longimanus*) and fishhook flea (*Cercopagus pengoi*) in 2014 and 2018 appears to have altered the vertical distribution of plankton (Arwine et al. 2025) and may have additional effects on the lower food web.

The negative impacts of quagga mussels on the Great Lakes (Karatayev et al., 2015; Nalepa et al., 2009) and their proximity to invade Lake Champlain has prompted concern over disruption of energy pathways to mid-trophic level fishes (rainbow smelt and alewife) on which Lake Champlain predator fishes rely. The primary carbon sources that fuel rainbow smelt and alewife in the Main Lake is the deep chlorophyll layer - this layer may be reduced by quagga mussels (Chiapella et al., 2023; Possamai et al., 2026) but *Mysis* could play an important role in offsetting such impacts because of their omnivory and ability to use both pelagic and benthic resources (Stockwell et al., 2020; Chiapella et al., 2023). The configuration of the food web in the Northeast Arm may be less susceptible to quagga mussels than the Main Lake (Possamai et al., 2026).

The Northeast Arm does not contain suitable habitat for coldwater piscivores such as lake trout for much of the year, so variation in environmental conditions across Lake Champlain could result in variable food web impacts by invasive species (Bruel et al., 2021; Chiapella et al., 2023). For example, with its poor oxygen conditions, warm habitat, and high productivity, the Northeast Arm could be much more susceptible to a round goby invasion compared to the Main Lake where lake trout, as round goby predators, are abundant (Possamai et al., 2026). On a similar theme, movement of trout-perch appears to be an important vector for transferring energy from nearshore to offshore habitats (Lesser et al., 2024), and thus may provide a food web connection that could be disrupted by invasive quagga mussels or round goby. Additionally, trout-perch size and biomass differences between basins layer additional complexity to energy transfer across habitats, as many processes are size-dependent (e.g., consumption rates, nutrient recycling). Differences in physical habitat (e.g., seiche periodicity), productivity, or size-selective predation can each, or together, influence demographics which in turn influence habitat coupling. Such feedback could translate into varying resilience of populations and food webs to disturbances such as invasive species.

The examples above illustrate how the gradient of environmental conditions, morphometries, and food webs across the basins of Lake Champlain provide unique opportunities to compare and contrast how such conditions may buffer or exacerbate responses to management actions and natural and anthropogenic stressors and disturbances. The parallel configurations of Lake Champlain's basins with the Great Lakes provide added comparisons of such processes across the range of food webs and environmental conditions in the Great Lakes. For example, Missisquoi Bay and South Lake are shallow, highly productive basins akin to western Lake Erie, Saginaw Bay, and Bay of Quinte, the Northeast Arm could be considered as an analogue to central Lake Erie, and the Main Lake is a doppelganger to lakes Michigan and Ontario prior to quagga mussel invasion. The comparatively small size of Lake Champlain, and its basins compared to the Great Lakes provides opportunity to forecast potential impacts of soon-to-arrive invasive species, based on the Great Lakes experience, and also enable testing of mechanisms that may drive the response or resilience of Lake Champlain to such disturbances. Likewise, responses to land-use changes and fisheries management interventions are rapid, compared to the Great Lakes, due to the influence of the large watershed and rapid flushing of the lake.

Research priorities

- *Quantify the consumption demand of offshore predators, including lake trout, Atlantic salmon, walleye, burbot, and cormorants, relative to prey supply in Lake Champlain*
- *Quantify the consumption demand of nearshore predators, including percids, esocids, centrarchids, moronids, catostomids, bowfin, freshwater drum, and cormorants, relative to prey supply in Lake Champlain*
- *Evaluate the cross-habitat connections that lead to trophic transfer between nearshore and offshore food webs among the basins*
- *Evaluate the effect of non-native species (alewife, predatory cladocerans, zebra mussels, tench, rudd, brook silversides) on predator demand and prey supply*
- *Test the hypothesis that lake trout induced a trophic cascade in the Main Lake through suppression of alewife, releasing the zooplankton community from size-selective predation, in contrast to other basins where lake trout predation on alewife is absent.*
- *Evaluate how regional gradients of environmental conditions in Lake Champlain influence the impact of invasive species on food webs and fisheries*
- *Evaluate the adaptive capacity of* Mysis *to impart resilience to the Lake Champlain food web in the face of invasive ecosystem engineers*
- *Evaluate effects of spiny and fishhook water fleas on zooplankton dynamics*

Habitat and physical dynamics

Lake Champlain is ideally suited for study of fish movement because of its fragmented and diverse habitats, and its relative size compared to larger and smaller lakes. Habitat fragmentation by causeways does not appear to have led to strong population subdivision of fish populations (slimy sculpin, rainbow smelt, lake whitefish, Euclide et al., 2020, 2019, 2018), but the causeways do appear to impact movements of fish between basins (lake trout, walleye, and sturgeon, Futia et al., 2026; sea lamprey, Howe et al., 2006). The questions of whether causeways present obstacles that delay migrations between feeding and spawning areas (e.g., walleye), trap fish other than lake trout (Futia et al., 2026) in basins where oxythermal conditions are seasonally stressful, or otherwise impact movements, remain unanswered.

Lake Champlain contains several isolated reefs surrounded by deeper waters that provide opportunities to test whether such “lakemounts” serve as analogs to oceanic seamounts, whereby enhanced production at the base of the food web, through physical-biological interactions at these sites, propagate up the food web to lead to increased productivity/attraction of higher trophic levels, increased diversity, and conservation potential (Possamai et al., 2024). Initial studies on Lake Champlain suggest these offshore habitats in the middle of open pelagic habitat have similar characteristics (diversity, density, and biomass) as nearshore environments in terms of benthic invertebrates, phytoplankton, zooplankton, and fish compared to open water habitats (Possamai et al., in review.). Such studies can inform similar (parallel) questions in the Great Lakes where isolated lakemounts provide habitats for diverse ecomorphotypes of lake trout (Rennie et al. 2025).

In addition to isolation of lake basins by islands and causeways, dams represent another major source of habitat fragmentation between lake and rivers, and within riverine habitats. An estimated 1,200 dams are present in the Lake Champlain basin (Vermont Natural Resources Council, https://vnrc.org/vnrc-tnc-and-us-fish-wildlife-to-prioritize-dams-for-removal-in-the-lake-champlain-basin/), including large dams on all major tributaries. Several dam relicensing and removal projects are underway. Atlantic salmon are the focal species for many dam removal projects, but improving and restoring passage for additional native species is also of interest, including lake sturgeon, American eel, catostomids.

The Main Lake of Lake Champlain has a regular 4-day internal seiche during the stratified season, with shorter oscillations of the thermocline in Shelburne Bay, a long bay several kilometers south of Burlington, Vermont (Manley et al., 2012; Saylor et al., 1999). A similar seiche likely occurs in Willsboro Bay on the New York side (Figure 2). These seiches have facilitated studies on the interaction of upwellings with seamounts (Possamai et al., 2024, Possamai et al. in review.) and provide opportunities to study fish movements, particularly larval stages, in relation to thermal shifts (e.g., Höök et al. 2006). A > 200-yr annual record of whether and when the lake freezes completely in winter is available, and shows a shift from nine years in ten fully frozen, to currently twice each decade, with the average date of closure shifting from late January to early March (Lake Champlain Committee, https://www.lakechamplaincommittee.org/storage-folder/news-articles/200-years-of-lake-champlain-ice-data-climate-change-in-action).

Research priorities:

- *Evaluate the effect of habitat fragmentation by causeways on the movement among basins by fish species other than lake trout, walleye, and lake sturgeon*
- *Evaluate the contribution of lakemounts to the overall productivity and fish recruitment in Lake Champlain. Identify and describe as-yet unstudied lakemounts in the lake.*
- *Evaluate the importance of lakemounts to fishes of different thermal guilds in terms of seasonal use as foraging or spawning areas*
- *Evaluate the potential negative effects of dam removal on sea lamprey control efforts*
- *Determine how dam removal will benefit native species and habitat connectivity, and which species are most likely to benefit*
- *Determine the effect of seiche-induced oscillations on larval fish advection and recruitment*
- *Describe the effect of ice cover, or the absence of ice, on fish population dynamics (e.g., salmonid embryo survival)*
- *Evaluate the potential for wetlands to support fish reproduction and fish recruitment to Lake Champlain*

Research and management resources - surveys, long-term databases, and infrastructure
In contrast with the Great Lakes, Lake Champlain has had fewer and shorter long-term studies or assessments on its fish and fisheries, or analysis of long-term trends in either commercial or recreational harvest. Commercial fishery harvest data in the late 1800s and early 1900s were recorded in US Fish

Commission and Vermont Fish Commission annual reports, but these data have not been compiled, unlike the extensive databases available for the Great Lakes that span over 15 decades (Baldwin et al., 2009). VTFWD survey reports are a source of such data, typically reported on an annual basis, and are available (VTFWD Library 2026). NYDEC provides a less comprehensive library of reports for Lake Champlain fisheries in New York waters (NYDEC Library 2026) .

Single-species Lake Champlain surveys that have been conducted consistently over time are limited to a few fish species - walleye, lake trout, and salmon (VTFWD Library 2026). Forage fish surveys using some combination of trawls, gill nets, and acoustics began decades ago (Kirn and Labar, 1991; Pientka and Staats, 2018), but were terminated in 2015. Revival of forage fish surveys is currently underway. Creel surveys were and continue to be conducted sporadically in time and space, and are focused on a disparate range of species with few consistent studies (e.g., Balk, 2023; Gilbert, 2000). Overall, inconsistency in the fisheries, species, basins, and sites targeted by surveys over time make interpretation of patterns difficult. A substantial portion of the Lake Champlain fisheries and fish data are compiled in a database held by the VTFWD and accessible upon request; an effort similar to that of the Great Lakes (Baldwin et al., 2009) is needed to complete this database, index and summarize the data, and make them available to support the research priorities outlined herein (Table 3; Appendix 1). For the future, a long-term vision for surveys is required to maximize the return on investment for information to better understand fisheries and their relationship to the ecosystem.

Unlike fish and fisheries data, limnological data from Lake Champlain have been collected more or less consistently since the 1990s, at a lakewide scale, and are widely available (website to be provided once harmonized data set is published). The Lake Champlain Long Term Monitoring Program collects samples on zooplankton, phytoplankton, and an assortment of physical (e.g., temperature, Secchi depth) and chemical (e.g., nutrients, ions) variables at 15 stations across the five basins every two weeks from spring to autumn (Mihuc et al., 2012; Smeltzer et al., 2012; Appendix 1). Caution should be exercised when using phytoplankton and rotifer data from the LTMP because they are collected using relatively large mesh sizes (63- and 153-µm mesh nets, respectively). The LTMP data set provides a strong basis for supporting research priorities including the effects of environmental conditions and their gradients on food web dynamics.

Forty-three rivers are monitored with stream gages maintained by the USGS, representing approximately 80% of the lakes' tributaries. These monitoring stations, in addition to five lake-level gauges, provide valuable data on frequency of flooding events. Increased discharge and addition of impervious urban landscapes has likely exacerbated sediment and road salt discharge into Lake Champlain. Effects of changes in flooding on wetland areas and nearshore species have not been widely studied.

High-frequency, real-time data on water temperature and weather variables are provided by monitoring buoys deployed throughout the ice-free season in the Main Lake, Northeast Arm, and Malletts Bay. The buoys and data are managed by SUNY Plattsburgh and Lake Champlain Basin Program (e.g., https://lcri99.github.io/) and real-time data are available at https://data.lcbp.org/. Additionally, the small size of Lake Champlain facilitates relatively fine-scale lakewide acoustic tracking of fish movements in a bathymetrically complex, fragmented system (Futia et al., 2026). CATOS currently comprises 113 acoustic receivers deployed throughout the lake, largely north of Crown Point (Figure 2), and in some of the major tributaries. The receiver coverage is one receiver per 9.5 km^2, compared to the Great Lakes array with approximately 4,000 receivers and a coverage up to one receiver per 35-120 km^2 in the densest arrays (lakes Ontario and Huron). The CATOS receiver array is managed collaboratively by the USGS Cooperative Fish and Wildlife Research Unit, the University of Vermont, and VTFWD. Similar to GLATOS, new studies pay for tags and, as needed, additional receivers and assistance with data downloads, and work with CATOS to discuss receiver locations.

Research priorities

- *Compile and publish historical fish surveys and harvest data for long-term perspective on fisheries resources and potential harvest, similar to Baldwin et al. (2009)*
- *Collaborate with GLATOS to use Lake Champlain for whole-lake fish movement studies, and migration of fishes via canals to other systems (e.g., St. Lawrence and Hudson rivers)*

Epilogue

Researchers and managers in Lake Champlain and the Great Lakes have much to offer each other, and the contrasts are as valuable as the similarities. We have highlighted research priorities that address particular issues in Lake Champlain, some of which are likely to benefit, or benefit from, collaborative work with Great Lakes scientists and managers. To inform potential collaborations among existing and new researchers in Lake Champlain, we have included an overview of surveys and available long-term data resources. The research priorities here include a mix of old and new - long-standing priorities of management interest (e.g., Atlantic salmon restoration), emerging issues in fisheries management (e.g., provisioning fisheries), and community and ecosystem dynamics (e.g., resilience to invasive species across ecological gradients). Collectively, we hope such a diverse research portfolio will propel Lake Champlain fisheries research forward to the ecosystem-based management approach adopted in the Great Lakes (Budnik et al., 2024; GLFC, 2007; Ludsin et al., 2014).

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List of tables and figures

Table 1. Regions of Lake Champlain with their physical attributes (Potash et al., 1969).

Basin	Area (km^2)	Volume (10^9 km^3)	Avg. depth	Max. depth	Trophic state
Main Lake	683	21.0	30.8	122	Mesotrophic
South Lake	57	0.14	2.5	14	Eutrophic
Missisquoi Bay	78	0.22	2.9	4	Eutrophic
Northeast Arm	269	3.45	12.8	49	Eutrophic
Malletts Bay	54	0.72	13.2	32	Meso-oligotrophic
Whole lake	1,130	25.8	19.5	122	

Table 2. Fish species of management, fisheries, and conservation importance, and non-native fishes, in Lake Champlain, with dates of commercial fishery closure for species that were the target of commercial fisheries, and status as species of concern or non-native (in boldface). Species of primary interest to the recreational fishery, and thus part of the Vermont Master Angler program, are indicated. Species that were the focus of management surveys and/or research are indicated, with the date of the most recent species management plans.
* indicates 'cullfish', or species harvested in fall or spring commercial fisheries that targeted lake trout and lake whitefish.
**Atlantic salmon were not seen in the lake after 1838, and lake trout were not seen after 1900.
Regulations on catch: L = length limit; C = creel limit; S = seasonal restrictions; NF = no fishing permitted; CR = catch-and-release

Family	Common Name (*Latin Name*)	Master angler list and catch limits	Commercial fishery closed	Status	Targeted surveys and research	Management plan date
Acipenseridae	Lake sturgeon (*Acipenser fulvescens*)	NF	1967	VT-E, NY-T	Population evaluation, telemetry, genetics	2016
Amiidae	Bowfin (*Amia occelicauda,* formerly *calva*)	x SC				
Anguillidae	American eel (*Anguilla rostrata*)	x	2002	VT-SC	Diet	2025
Atherinidae	**Brook silverside (*Labidesthes sicculus*)**			non-native		
Catostomidae	Quillback (*Carpoides cyprinus*)			VT-SC		
	Longnose sucker (*Catostomus catostomus*)	x				
	White sucker (*Catostomus commersonii*)	x				
	Greater redhorse (*Moxostoma valenciennesi*)	x SC		VT-SC		
Centrarchidae	**White crappie (*Pomoxis annularis*)**	x LC		non-native	Community surveys	
	Black crappie (*Pomoxis nigromaculatus*)	x LC		non-native	Community surveys	
	Rock bass (*Ambloplites rupestris*)	x	1912*		Community surveys	
	Smallmouth bass (*Micropterus dolomieu*)	x SLC			Community surveys	2017 VT
	Largemouth bass (*Micropterus nigricans*)	x SLC	1912*	non-native	Community surveys	2017 VT
	Bluegill (*Lepomis macrochirus*)	x	1912*	non-native	Community surveys	
	Pumpkinseed (*Lepomis gibbosus*)	x			Community surveys	
Clupeidae	**Blueback herring (*Alosa aestivalis*)**			non-native		
	Alewife (*Alosa pseudoharengus*)			non-native	Forage fish surveys	
	Gizzard shad (*Dorosoma cepedianum*)			non-native		
Cottidae	Mottled sculpin (*Cottus bairdi*)					
	Slimy sculpin (*Cottus cognatus*)				Forage fish surveys	
Cyprinidae	**Common carp (*Cyprinus carpio*)**	x		non-native		
	Rudd (*Scardinius erythrophthalmus*)			non-native		

	Golden shiner (*Notemigonus crysoleucas*)					
	Tench (*Tinca tinca*)			non-native		
	Fallfish (*Semotilus corporalis*)	x				
Esocidae	Muskellunge (*Esox masquinongy*)	x CR		VT-SC		
	Northern pike (*Esox lucius*)	x SLC	1912*			
	Chain pickerel (*Exox niger*)	x C	1912*			
Gadidae	Burbot (*Lota lota*)	x				
Hiodontidae	Mooneye (*Hiodon tergisus*)			NY-T		
Ictaluridae	Channel catfish (*Ictalurus punctatus*)	x	1912*			
	Stonecat (*Noturus flavus*)			VT-E		
	Bullhead (*Ictalurus* spp.)	x	1912*			
Lepisosteidae	Longnose gar (*Lepisosteus osseus)*	x SC				
Moronidae	**White perch (*Morone americana*)**	x		non-native	Community surveys	
Osmeridae	Rainbow smelt (*Osmerus mordax*)	x	1912*		Forage fish surveys	
Percidae	Sauger (*Sander canadense*)			extirpated		
	Walleye (*Sander vitreus*)	x SLC	1912, 1971		Assessed since 1950s	1998
	Yellow perch (*Perca flavescens*)	x	1912*			1991
Percopsidae	Trout-perch (*Percopsis omiscomaycus*)				Forage fish surveys	
Petromyzontidae	Northern brook lamprey (*Ichthyomyzon fossor*)			VT-E, C-SC		
	Silver lamprey (*Ichthyomyzon unicuspis)*			VT-SC		
	American brook lamprey (*Lampetra appendix*)			VT-T		
	Sea lamprey (*Petromyzon marinus*)			non-native	Larval surveys, adult trapping	2001
Salmonidae	**Brown trout (*Salmo trutta*)**	x LC		non-native		
	Atlantic salmon (*Salmo salar*)	x LC	1835**	extirpated, stocked	Annual spawning surveys	1977, 2026
	Rainbow trout (*Oncorynchus mykiss*)	x LC		non-native		
	Lake trout (*Salvelinus namaycush*)	x LC	1912**	extirpated, restored	Juvenile, adult, spawning surveys	1977, 2026
	Cisco (*Coregonus artedi*)	x				
	Lake whitefish (*Coregonus clupeaformis*)	x	1912		Population dynamics, diets; acoustic telemetry	
Sciaenidae	Freshwater drum (*Aplodinotus grunniens*)	x	na			

Table 3. Long-term surveys and databases on Lake Champlain.

Survey type	Agency	Timespan	Focal species/life stages	Method(s)	Areas surveyed
Sea lamprey assessment	USFWS	1992-current	ammocoetes (larvae) migratory adults	electroshocking trapping	26 tributaries 8 tributaries
Forage fish assessment	VTFWD	1982-2015, 2024-2025	rainbow smelt alewife after 2005	midwater trawl, hydroacoustics	Main Lake, Northeast Arm, Malletts Bay
Forage fish assessment	UVM	2024-2025	smelt, alewife, sculpin, trout-perch	bottom trawl	Main Lake, Northeast Arm, Malletts Bay
Long-term monitoring project	LCPB	1992 - current	plankton, water chemistry, zebra mussel veligers	156-µm plankton net, multi-probe sonde	15 lake sites 22 tributaries
Fish community monitoring	VTFWD	2010 - current	nearshore fish spp., esp. white perch, yellow perch	gillnets	all basins
Lake trout juvenile survey	UVM	2015-2025	lake trout	bottom trawl	north, central, south Main Lake
Lake trout adult survey	VTFWD	2021-current	lake trout	gillnets	central Main Lake
Salmonid fall assessment	VTFWD	1994 - 2008 2009 - current 1992 - current 2010 - current	lake trout, Atlantic salmon lake trout, Atlantic salmon lake trout, Atlantic salmon lake trout, Atlantic salmon	electroshocking trapnet electroshocking electroshocking	Gordon Landing Gordon Landing Whallon Bay Willsboro Bay
Walleye survey	VTFWD	1950s - current	walleye	electroshocking	Lewis Cr., Otter Cr., Poultney R. Lamoille R., Winooski R., Missisquoi R.
Walleye survey	VTFWD	1960 - current every 5 yrs	walleye	2 x 183-m seine	Missisquoi Bay

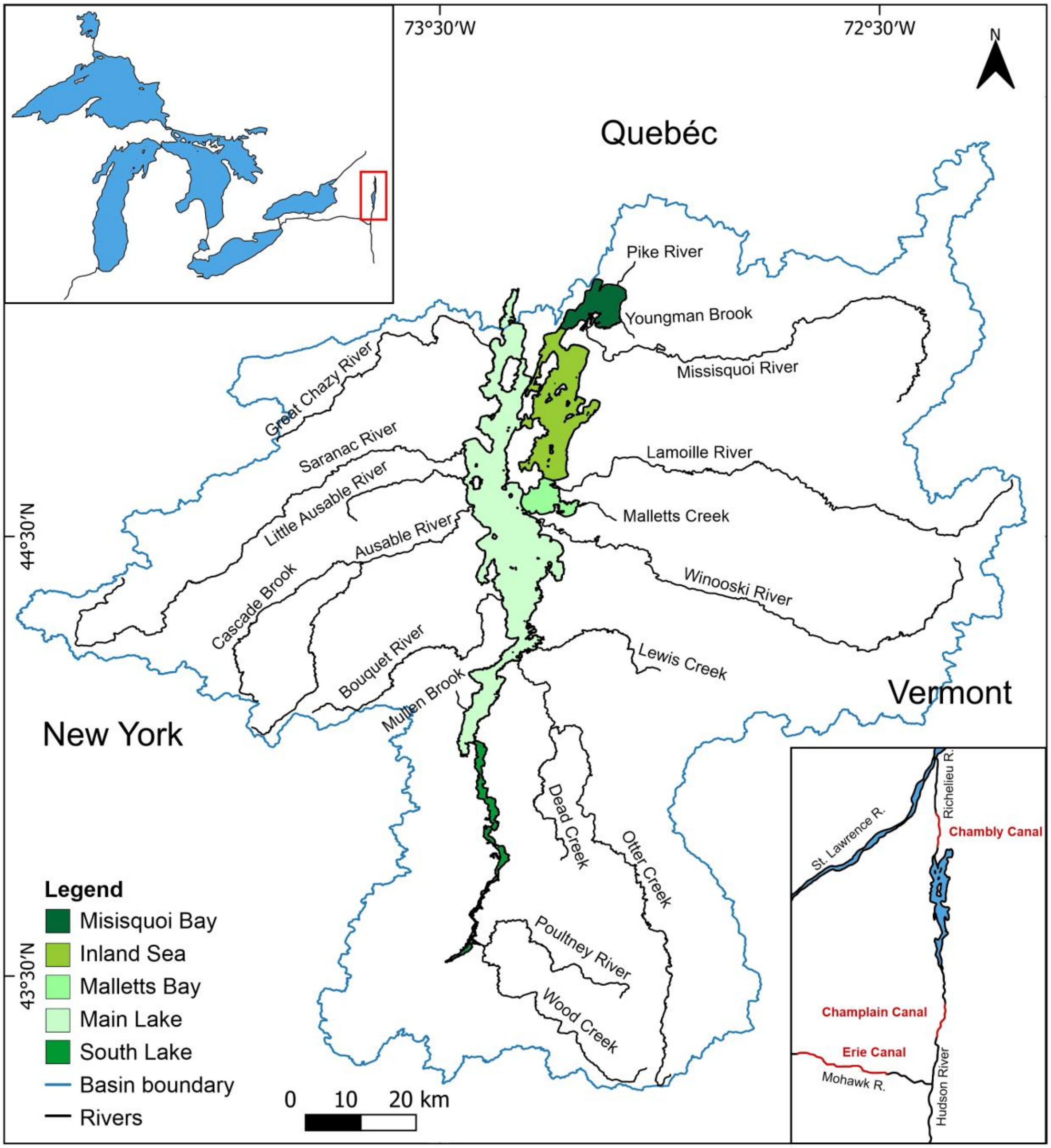

Figure 1. Lake Champlain in the context of the Great Lakes (upper inset), showing the drainage basin, five major basins, and major tributaries, with additional smaller tributaries mentioned in the text. Lower inset shows artificial (canal) linkages with the Hudson and Mohawk rivers, and the Chambly Canal that bypasses rapids on the Richelieu River. Flow is south to north. Map data are from Northern Cartographic.

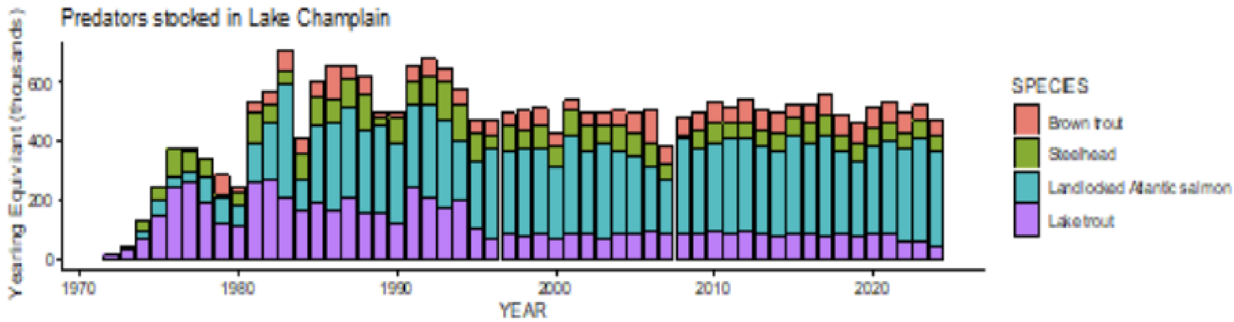

Figure 2. Timeline of numbers of salmonid species stocked in Lake Champlain. Numbers of fish stocked at expressed in terms of yearling equivalents. (draft figure)

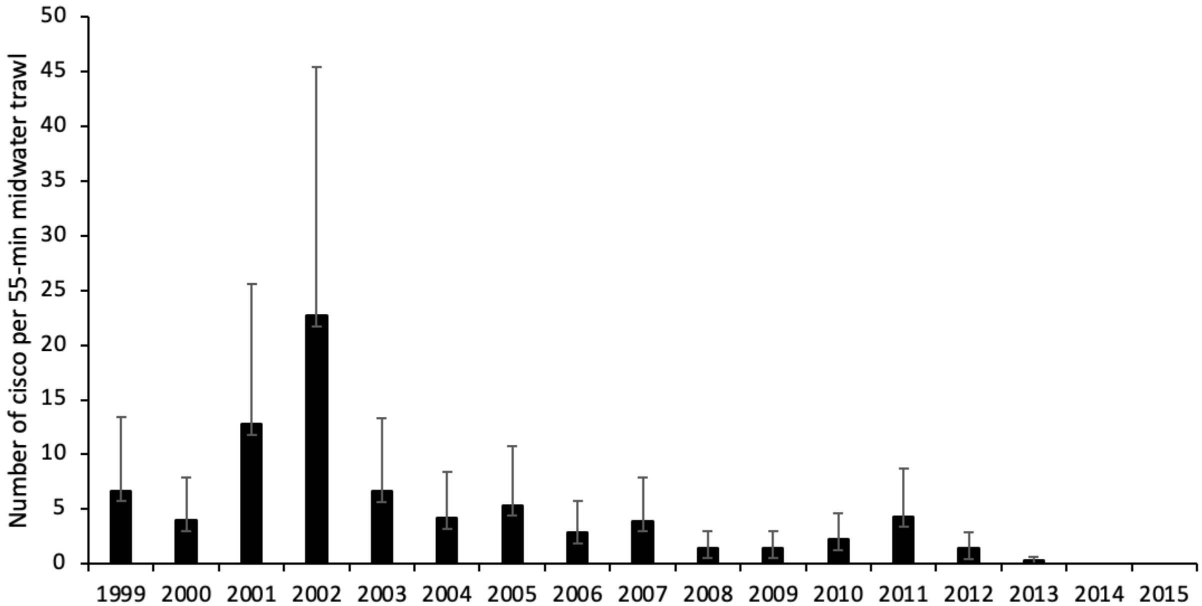

Fig. 3. Mean CPUE (± SD) of cisco (fish per 55-min midwater trawl) during forage fish surveys conducted at three sites in the Main Basin of Lake Champlain from 1999 to 2015. By-catch data (including cisco) were not collected prior to 1999; the survey ended in 2015. No cisco were found in the repeated survey in 2024 and 2025. B. Pientka, VTFWD, unpublished data.

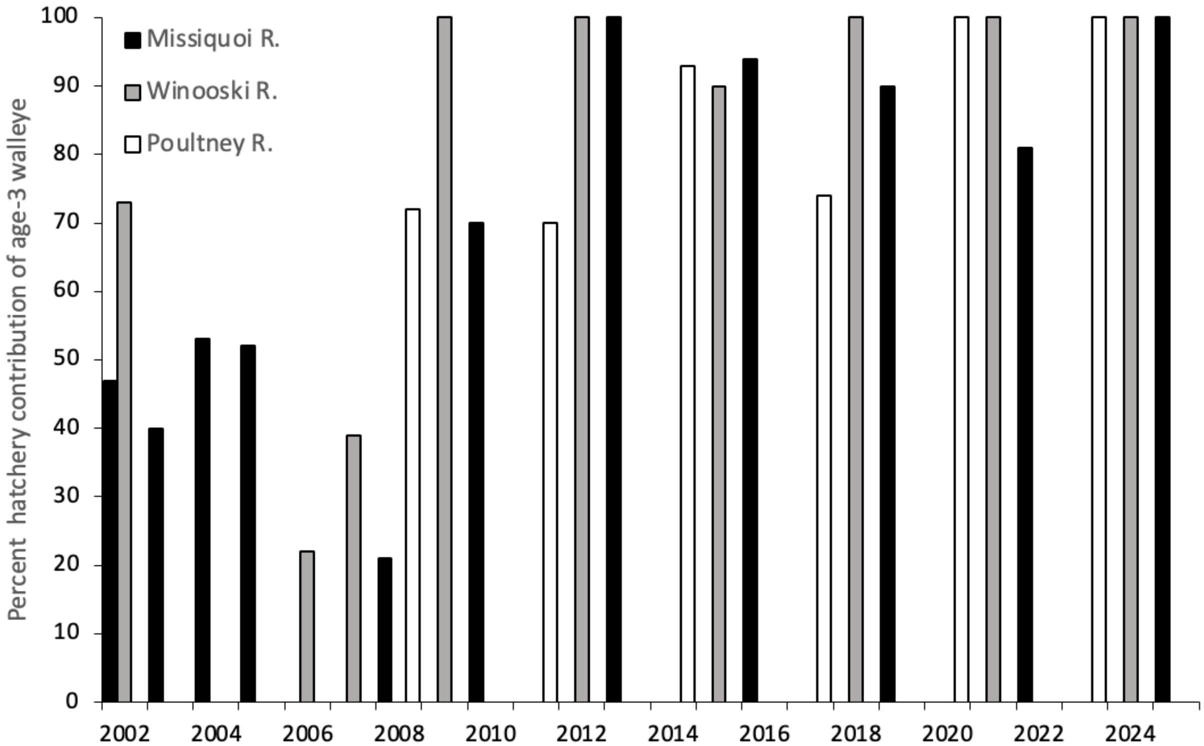

Figure 4. Percent of age-3 male walleye sampled in three Lake Champlain tributaries since 2002 that were stocked. Fish origins were identified by examining otoliths for an OTC mark from 30 fish sampled each year on a 3-year cycle since 2008. Data source: B. Pientka, VTDFW.

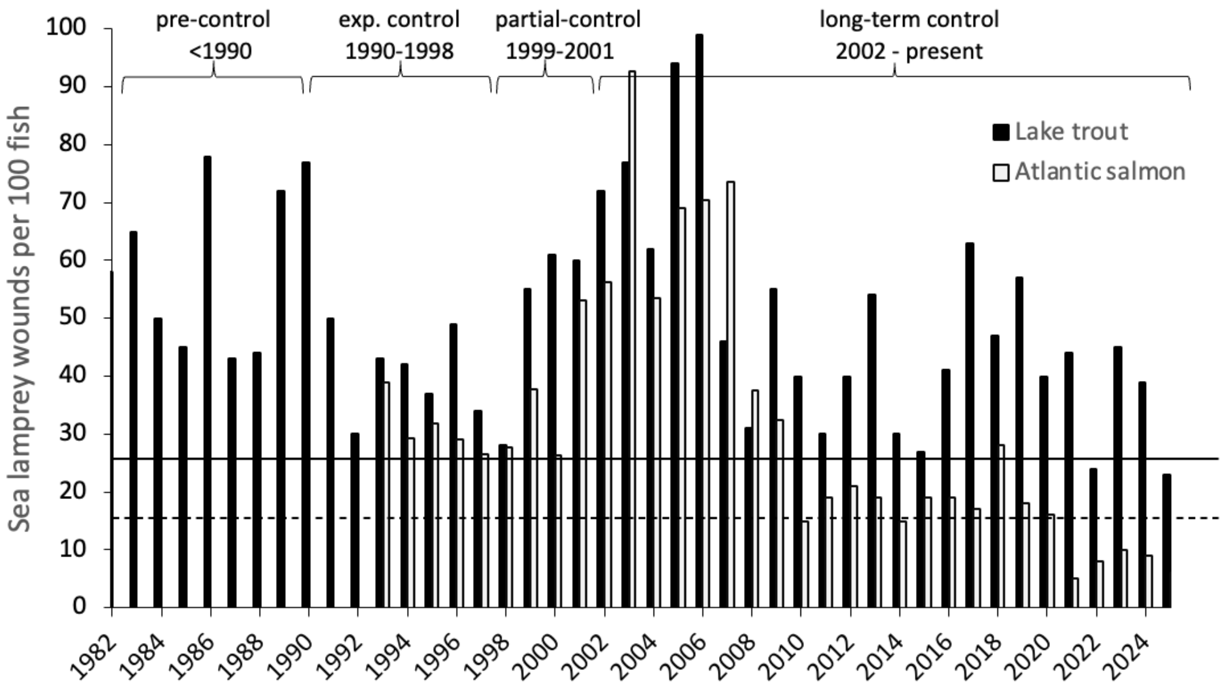

Figure 5. Sea lamprey wounding of lake trout and Atlantic salmon in Lake Champlain since 1982. Wounding data represent number of wounds per 100 fish between 533 and 633 mm TL for lake trout, and between 432 and 533 mm TL for Atlantic salmon. The management goals for lake trout (25) and Atlantic salmon (15) are indicated with a solid and a dashed line. Data from USFWS; further details of the program are described by Young et al. 2021.

Appendix 1. Details on the history of biological surveys and research infrastructure in Lake Champlain

The first published information on the biology of Lake Champlain, encompassing fish, molluscs, and terrestrial taxa, was part of a comprehensive natural history of Vermont published in the mid-1800s (Thompson, 1853). The next survey did not occur until the 1920s, when the New York Department of Environmental Conservation conducted a thorough synoptic survey of fishes and a few focused studies on rainbow smelt, 'vermin' species (bowfin, gar, and burbot), and fish diets (Greeley, 1930). Fishes were surveyed again by the Vermont Fish and Wildlife Department in the 1950s and 1970s (Anderson, 1978; Halnon, 1954). The latter survey included relative abundance (CPUE), average lengths and weights, age, growth, and diet data for several species including yellow perch, walleye, northern pike, chain pickerel (*Esox niger*), and smallmouth bass.

Commercial fishery harvests were recorded in annual reports of the Vermont Fish and Game Commission in the late 1800s and early 1900s. Some of the data from lake whitefish, walleye, and lake sturgeon were included in a review by Hanlon (1963) who also reported on records from hatchery logbooks, warden reports, town reports, and newspapers. Whitefish harvest data for the Quebec waters of Missisquoi Bay were reported by Trioreau (1985). Walleye monitoring was conducted annually in Missisquoi Bay, where walleye had historically been commercially fished, from 1953 to 1966, then shifted to 5-year sampling from 1985 to the present. Walleye have been assessed in the Poultney River since 1992 with spawning surveys since 2003 (Good, 2022); spawning populations are sampled each spring in a subset of tributaries (Missisquoi, Lamoille, and Winooski rivers and Otter Creek). Subsequent sporadic and often short-term surveys and assessments are recorded in annual reports by VTFWD.

Early lake trout and Atlantic salmon assessment occurred from 1977 to 1980 using gillnets in summer in the Main Lake, Northeast Arm, and Malletts Bay (Plosila and Anderson, 1985). Gillnetting was continued from 1982 to 1997 to assess the effectiveness of the long-term experimental sea lamprey control program at reducing wounding rates and increasing survival of lake trout. Since 1990, lake trout and Atlantic salmon have also been assessed in autumn at spawning sites in the Main Lake - a breakwall at Gordon Landing and natural sites in Whallon Bay and Willsboro Bay (Figure 2). Sampling is conducted using electroshocking, but switched to trapnets at Gordon Landing in 2009. These assessments record length, weight, sex, lamprey wounds, and fin clips, but the sampling methods do not yield abundance estimates. Atlantic salmon are also monitored at fish passages on the Boquet, Saranac, and Winooski rivers (Figure 1).

The forage base for cold- and cool-water predators primarily consists of rainbow smelt and slimy sculpin, with the recent addition of invasive alewife. Concerns about higher survival of salmonids due to lamprey suppression led to initiation of a forage fish survey in 1990 using midwater trawling; in response to the invasion of alewife in 2003, hydracoustic data were added in 2005, and fine-mesh surface gillnets in 2008 (Kirn and Labar, 1991; Pientka and Staats, 2018). The survey was discontinued in 2015. With the discovery of wild lake trout recruitment, the need for forage fish data and assessment became acute; a potential redesign for a new survey based on bottom trawling was developed, and the earlier survey using midwater trawling and hydroacoustic surveys was repeated beginning in 2024 for direct comparison.

Intermittent and largely short-lived surveys of fish communities occurred in the 1970s in the Main Lake and Northeast Arm. Modern and longer-term fish surveys include assessment of northern pike age and growth using trapnets in the South Lake beginning in 2008, black bass surveys in the South Lake since 2010, and warm- and cool-water fish community gillnetting surveys throughout the lake beginning in the 2010, largely focused on white perch and yellow perch. Juvenile lake trout bottom trawl monitoring for relative abundance and proportion of unclipped fish was conducted by UVM from 2015-23, and supplemented by a summer gillnet survey for adults beginning in 2021 led by VTFWD. Ammocoete sampling for the sea lamprey assessment program has been conducted continuously in tributaries lake-wide since 1990, with post-assessment surveys after lampricide treatments (Marsden et al., 2003; Young et at., 2021). Spawning-phase sea lamprey have been assessed in a subset of tributaries since 1982 using portable assessment traps in spring; data from these traps also includes bycatch of other fish species (Marsden et al., 2003).

The limnology of Lake Champlain was extensively studied in the 1960s and 1970s, but most of the work was documented only in technical reports, conference proceedings, and graduate theses, with the rare exception of a published summary of the chemistry of Lake Champlain in the 1960s (Potash and Henson, 1975, also summarized by Smeltzer et al., 2012). A notable unpublished work is a 428-page treatise on the physical, chemical, and biological limnology of Lake Champlain which continues to serve as a key reference for the lake (Myer and Gruendling, 1979). In anticipation of major changes to the benthos after zebra mussels appeared in the lake in 1993, an extensive survey of benthic macroinvertebrates on rocky shoals was conducted in the Main Lake in 1994-95 (Fiske and Levey 1996a), although the survey has not been followed up to document post-invasion changes to the benthic invertebrate community. Native mussel beds have also been extensively surveyed (Fiske and Levey 1995). A Long-Term Water Quality and Biological Monitoring Project was initiated in 1992 with sampling at 52 sites, and was subsequently reduced to 15 lake sites and 21 major tributaries, including stream gauges (https://dec.vermont.gov/watershed/lakes-ponds/monitor/lake-champlain-long-term-monitoring-project#Project%20History). Sampling is conducted every two weeks from late spring to late autumn. Data collected include chemical (pH, conductivity, phosphorus, dissolved oxygen, Ca++, Na+, potassium), physical (Secchi depth, temperature) and biological (phytoplankton and zooplankton) variables, summarized in part by Smeltzer et al. (2012) and Mihuc et al. (2012). Sampling for zebra mussel veligers and settled juveniles was added in 1994 (Marsden et al., 2013). Long-term monitoring chemical and physical data and subsets of biological data are available online at https://anrweb.vermont.gov/dec/_dec/LongTermMonitoringLakes.

Supplementary Materials.

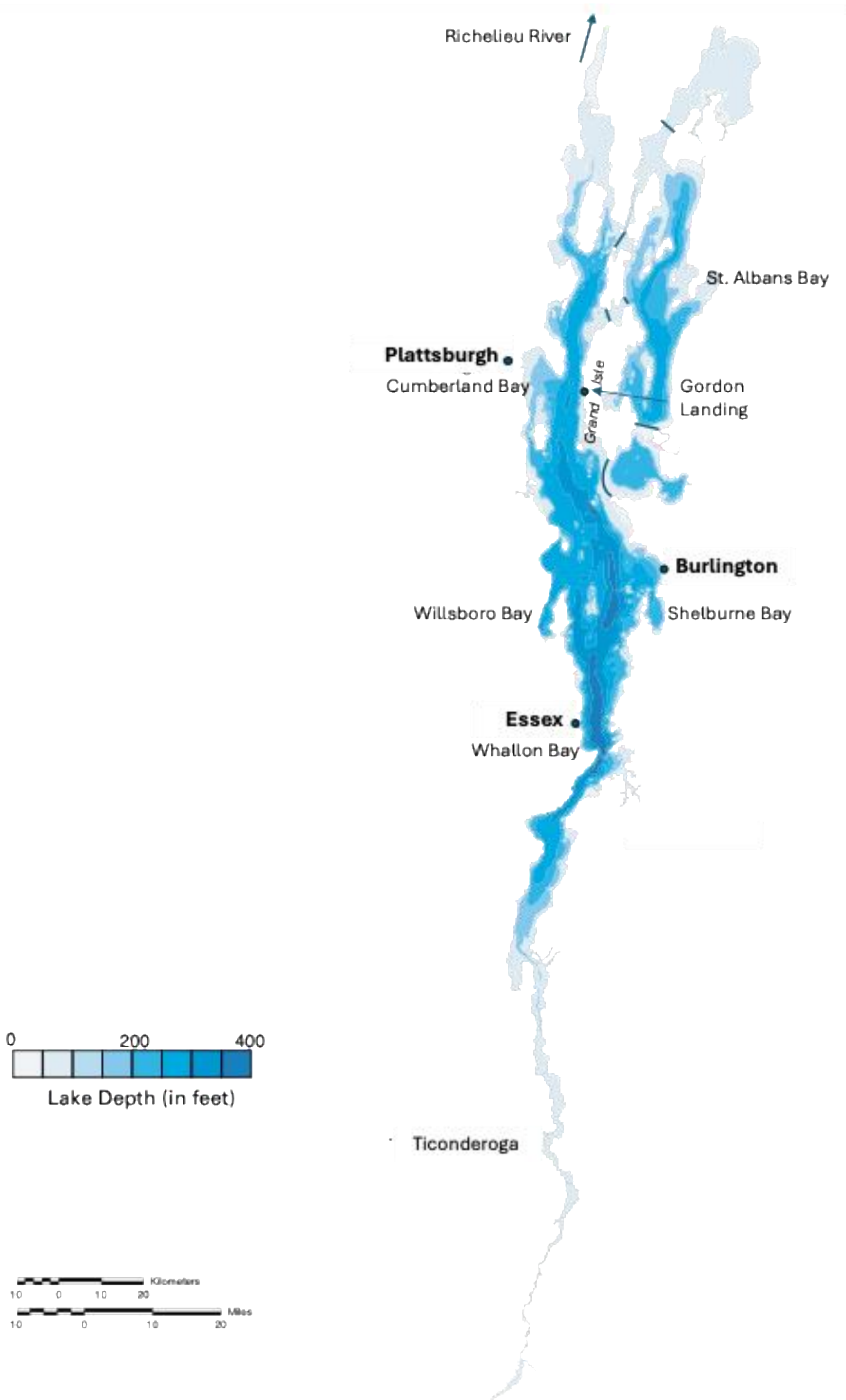

Figure S1. Lake Champlain bathymetry, showing major causeways and towns, with bays referenced in the text. Map data are from Northern Cartographic.

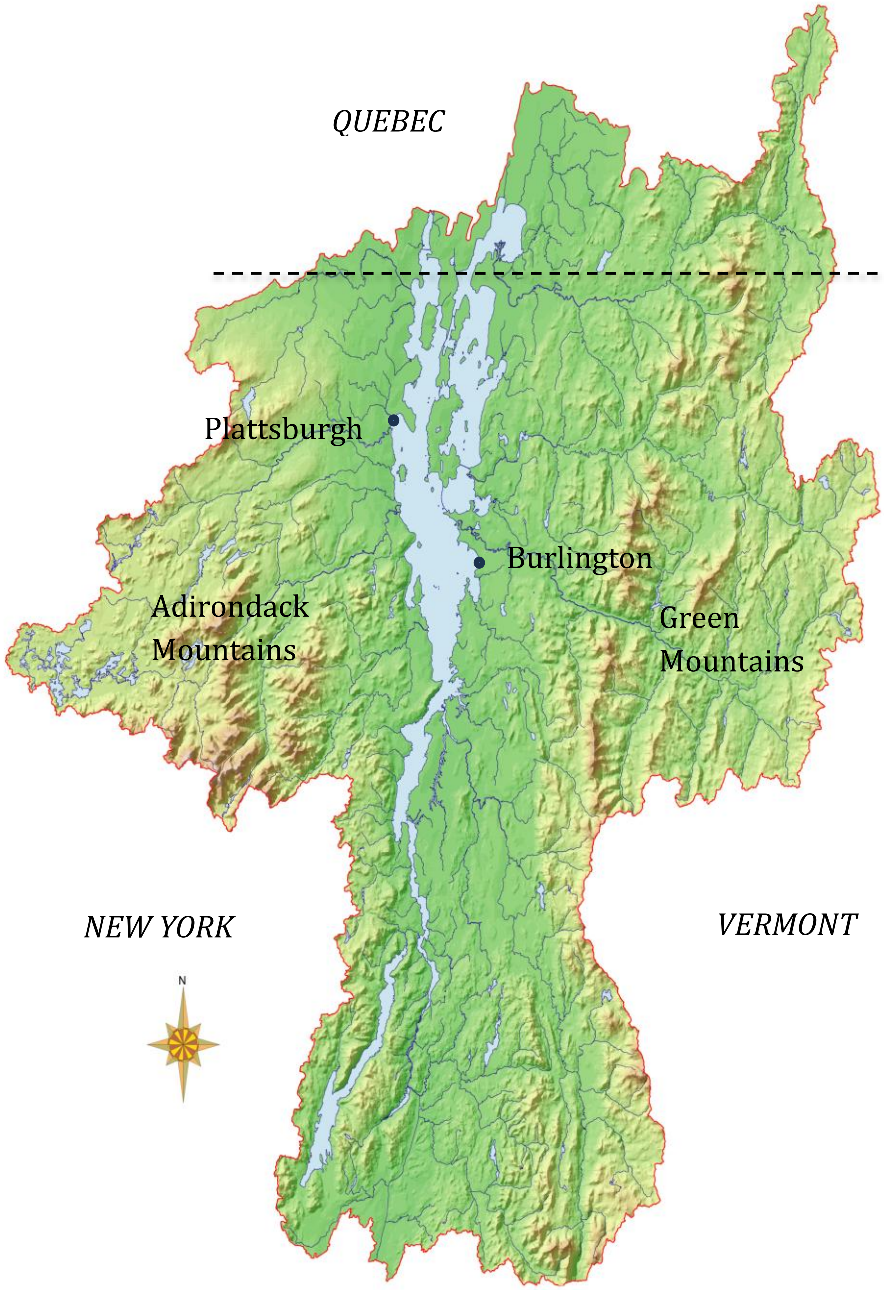

Figure S2. Lake Champlain watershed showing topography of the basin that contributes to high water, sediment, and nutrient inputs to the lake. Map data are from Northern Cartographic.