Lake Champlain Basin Program

STATE OF THE LAKE

AND ECOSYSTEM INDICATORS REPORT

2012

ABOUT THE LAKE CHAMPLAIN BASIN PROGRAM

The Lake Champlain Basin Program (LCBP) was created by the Lake Champlain Special Designation Act of 1990. Our mission is to coordinate the implementation of the Lake Champlain management plan, *Opportunities for Action*. Program partners include New York, Vermont, and Québec, the US Environmental Protection Agency (US EPA) and other federal agencies, the New England Interstate Water Pollution Control Commission, and local government leaders, businesses, and citizen groups.

The Lake Champlain Steering Committee leads the LCBP. Its members include many of the program partners, and the chairpersons of technical, cultural heritage and recreation, education, and citizen advisory committees. The LCBP's primary annual funding is received through a US EPA appropriation under the Federal Clean Water Act. The New England Interstate Water Pollution Control Commission manages business operation of the LCBP on behalf of the Steering Committee.

Visit www.lcbp.org to learn more.

FIGURE 1 | THE LAKE CHAMPLAIN BASIN OR WATERSHED

COVER: The Adirondacks from the Lake Champlain shoreline in Vermont.

CREDITS: BACKGROUND AND INSETS, LCBP

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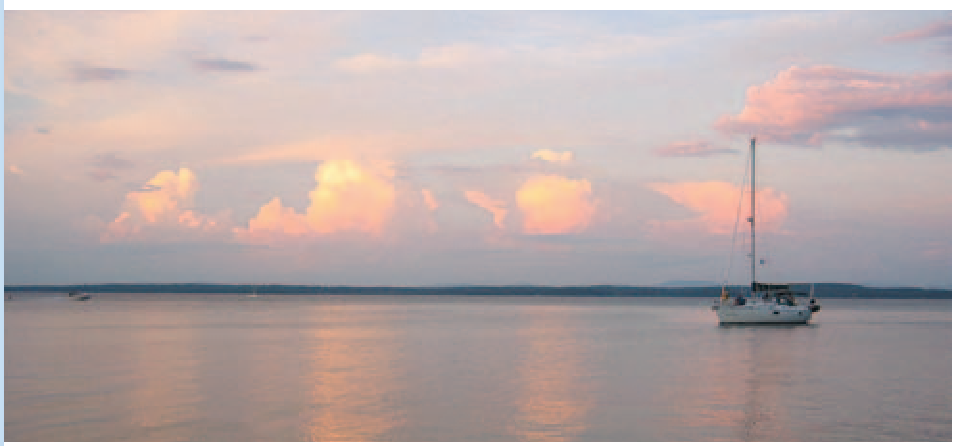
WHAT IS THE **STATE OF THE LAKE** REPORT?

Each year, Lake Champlain and its tributary watersheds provide inspiration, rejuvenation, and sustenance for hundreds of thousands of residents and visitors. As much as these citizens rely on the Lake, the Lake relies on them, too. They are the keys to the future health of the Lake Champlain Basin. Informing the public about the condition of the Lake is a critical part of the Lake Champlain Basin Program's (LCBP) mission of restoring and protecting water quality and the diverse natural and cultural resources of the Basin. By enhancing the public's understanding and appreciation of water quality, fisheries, wetlands, wildlife, recreation, and cultural heritage, the LCBP aims to foster a sense of personal responsibility that leads to improved stewardship of the Basin's resources. The primary purpose of the *State of the Lake 2012* report is to inform citizens and resource managers about the Lake's condition and provide a better understanding of threats to its health and opportunities to meet the challenges ahead.


LCBP

The Lake Champlain Basin's striking landscapes and vivid colors have inspired sailors, artists, and writers for centuries.


CROSS VERMONT TRAIL ASSOCIATION

Volunteers with the Cross Vermont Trail Association help to stabilize a streambank.

The report is an update for our representatives in Congress—US Senators Patrick Leahy and Bernie Sanders of Vermont and Charles Schumer and Kirsten Gillibrand of New York, and Representatives Bill Owens and Chris Gibson of New York and Peter Welch of Vermont—who have supported management of Lake Champlain through congressional authorizations, major federal appropriations, and guidance. It is also an important update for Governor Peter Shumlin of Vermont, Governor Andrew Cuomo of New York, and Premier Jean Charest of Québec, who have made vital commitments to implement the Lake Champlain management plan *Opportunities for Action* (OFA). *State of the Lake 2012* provides an account of today's stewardship challenges and management efforts to the US Environmental Protection Agency (US EPA)and other state, federal, and international partners that have endorsed OFA and provided support for the program.

In the two decades since the Lake Champlain Basin Program was created by an act of Congress, these public partners have led a collaborative, nonpartisan effort to address regional water quality and environmental challenges that cross political boundaries in a large watershed. This process also has benefitted from the expertise and dedication of nonprofit and business organizations, academic researchers, and scientists. The public provides critical input at Citizens Advisory Committees and other LCBP committee meetings. This *State of the Lake 2012* report is an opportunity to acknowledge this collaboration and keep all stakeholders apprised of the results of their collective efforts.

Summer 2012 is a particularly good time in the history of Lake Champlain Basin management to reflect on the state of the Lake. The historic flood events of 2011 brought issues of water quality, ecosystem health, and climate change to the forefront of public consciousness, challenging the concepts of natural systems held by scientists and policy makers and heightening the public's awareness and appreciation of the power and complexity of these systems. Experts are re-examining flood resiliency and disaster response in an era of shifting land use and changing climatic conditions and flow regimes. Waterfront property owners, farmers,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Often a source of solitude, Lake Champlain rejuvenates recreationists of all types.

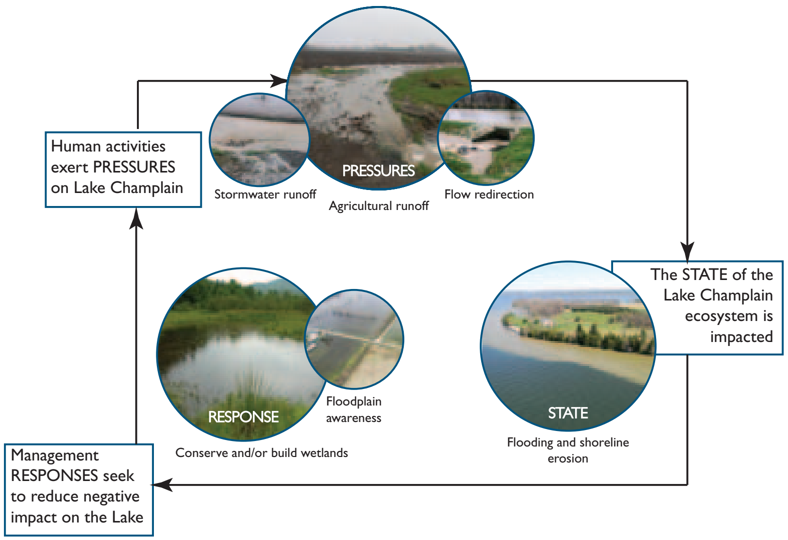

FIGURE 2 | THE PRESSURE-STATE-RESPONSE MODEL, USING FLOODING AS AN EXAMPLE

and concerned citizens from all corners of the Basin have given new thought to issues of shoreline stabilization, floodplain management, lawn care, and the variety of ways that their daily activities affect the Lake's health. A special section of *State of the Lake 2012* examines the impacts of the 2011 flood events on the health of the Basin and the ways in which stakeholders are preparing for future floods.

The 2011 flood events also offer a good lens with which to view the Pressure-State-Response (PSR) indicators framework (Figure 2) adopted by the LCBP for assessing Basin resources. The central focus of this framework is the condition of the ecosystem or its "State." To understand why this condition exists, we track human activities that can exert "Pressures," which can result in complex, long-term, and cumulative ecosystem impacts. Many of the flooding impacts of 2011 were influenced directly by human activities that pressured the system. Changes to the "State" that result from these "Pressures" often elicit a management "Response," such as new environmental policies or management actions. Proper resource management can reduce pressures to bring about a more desirable "State" of the Lake.

State of the Lake 2012 continues the use of the Ecosystem Indicators Scorecard (pages 20-21). This scorecard was first used in the *State of the Lake 2008* report to provide information about the condition of the ecosystem with a set of measures that represent or indicate its overall state. The indicators in this report were chosen with the guidance of dozens of scientists and state, provincial, and federal technical experts.

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Like much of the lakeshore, the Burlington, VT waterfront was flooded by record high lake levels during the spring 2011 floods.

WHAT YOU CAN DO

Citizen awareness and appreciation of water quality issues was heightened by the 2011 flooding. More people now realize the direct role the Lake plays in their daily lives and the importance of sharing the responsibility to sustain the Lake's health. There are many opportunities for individuals to get involved, either through formal programs or individual actions. Local watershed organizations throughout the Basin work to improve a river, bay, or other favorite place. Contact one near you and volunteer! Look for other What You Can Do sidebars in each section of this *State of the Lake* report.

Learn more at **www.lcbp.org.**

WHAT'S NEW IN THE LAKE CHAMPLAIN MANAGEMENT PLAN?

Opportunities for Action (OFA) is the management plan—signed by the governments of both New York and Vermont and the US Environmental Protection Agency and endorsed by the Province of Québec—to restore and protect water quality and the diverse natural and cultural resources of the Lake Champlain Basin. The Lake Champlain Basin Program continues to encourage and support public involvement and respond to current management, research, and monitoring needs to develop and implement OFA. The first version of the plan was signed in 1996, the second version in 2003. In the current version, partners have committed to specific management tasks based on funding available in 2010 and anticipated in subsequent years.

The 2010 update of OFA is available as a paperless, dynamic management plan, accessible to the public through the LCBP website. This online format gives all stakeholders access to the entire plan or to information about specific lake segments. To promote accountability, search tools allow website visitors to track progress on goals and tasks that the lead partners have identified. The plan is updated as new information becomes available. This approach allows OFA to remain current.

View the plan at http://plan.lcbp.org.

QUE SOUHAITE PRÉSENTER L'ÉTAT DU LAC 2012?

Chaque année, lac Champlain et ses bassins versants tributaires sont une source d'inspiration, rajeunissement et de subsistance pour des centaines de milliers de résidents et de visiteurs. Autant que ces citoyens ont besoin du lac que le lac a besoin d'eux. Ils sont la clé de la santé future du bassin du lac Champlain. Informer le public sur la condition du lac est un élément essentiel du Program Lake Champlain Basin (LCBP) qui découle de sa mission de restauration, la protection de la qualité de l'eau et les diverses ressources naturelles et culturelles du bassin. En favorisant la compréhension et l'appréciation de la qualité de l'eau, pêche, zones humides, la faune, loisirs et patrimoine culturel par le public, le LCBP vise à favoriser un sentiment de responsabilité personnelle qui permet une meilleure gestion des ressources du bassin. Le but principal de l'État du Lac est d'informer les citoyens et les gestionnaires des ressources sur la condition du lac et de fournir une meilleure compréhension des menaces pour sa santé et sur les possibilités de relever les défis à venir.

Le rapport est également une mise à jour pour nos représentants au Congrès - US sénateurs Patrick Leahy et Bernie Sanders du Vermont et Charles Schumer et Kirsten Gillibrand de New York et des représentants Peter Welch du Vermont et Bill Owens et Chris Gibson de New York - qui ont pris en charge la gestion du lac Champlain suite à l'autorisation du Congrès (crédits fédéraux importants et d'orientation). C'est aussi une importante mise à jour pour le gouverneur Andrew Cuomo, de New York, le gouverneur Peter Shumlin du Vermont et le premier ministre du Québec Jean Charest, qui ont pris des engagements essentiels à mettre en œuvre le Plan de gestion de lac Champlain Perspectives d'Action (OFA). Le rapport l'État du Lac offre aujourd'hui un portrait des défis et des efforts de tous les partenaires soit le US Environmental Protection Agency (EPA) et autres partenaires de l'État, fédérales et internationales qui ont approuvé l'OFA et fourni leur appui au programme.

Au cours des deux décennies comme le LCBP a été créé par une loi du Congrès, ces partenaires publics ont mené un effort collectif, non partisan pour la qualité de l'eau régionaux et relevé des défis environnementaux qui traversent les frontières politiques dans ce grand bassin. Ce processus a également bénéficié de l'expertise et le dévouement des organisations sans but lucratif, des chercheurs universitaires, des scientifiques et des entreprises. Les citoyens ont fournit des commentaires constructifs lors des réunions de Comité du LCBP et par le biais de comités consultatifs dans chaque juridiction. Ce rapport de l'État du Lac est une occasion de reconnaître cette collaboration et de garder tous les intervenants au courant des résultats de leurs efforts collectifs.

Le printemps 2012 est un moment particulièrement intéressant dans l'histoire de la gestion du bassin du lac Champlain pour réfléchir sur l'État du Lac. Les inondations historiques de 2011 on fait remis les enjeux de qualité de l'eau, la santé des écosystèmes et le changement climatique à l'avant-garde de la conscience du public, a permis de revoir les concepts de systèmes naturels avancés par les scientifiques et les responsables des politiques, accroître la sensibilisation du public et l'appréciation de la puissance et la complexité de ces systèmes. Des experts sont à réexaminer la résilience aux inondations et la réponse aux catastrophes dans contexte de changement d'utilisation du territoire, des conditions climatiques et régimes de débit. Les propriétaires du riverains, les agriculteurs et les citoyens concernés de tous les coins du bassin ont été obligé de revoir les problèmes relié à la stabilisation des rives, la gestion de la plaine d'inondation, de la pelouse et les diverses façons que leurs activités quotidiennes affectent la santé du lac. Une section spéciale de l'État du Lac 2012 examine les impacts des inondations sur la santé du bassin et les façons dont les intervenants sont préparées face aux inondations futures.

Les inondations de 2011 offrent également une bonne occasion d'évaluer le cadre d'indicateurs basé sur l'approche pression état réponse (Figure 2) adopté par le LCBP pour l'évaluation des ressources du bassin. L'élément central de ce cadre est la condition de l'écosystème ou son « état ». Pour comprendre pourquoi cette condition existe, nous avons suivi les activités humaines qui peuvent exercer des « pressions », qui peuvent entraîner des impacts cumulatifs, complexes et à long terme sur l'écosystème. Plusieurs des impacts suite aux inondations de 2011 ont été influencés directement par les activités humaines qui font pression sur le système. Les changements de « état » qui résultent de ces « pressions » ont souvent obtenu une gestion « réponse », tels que les nouvelles politiques environnementales ou des mesures de gestion. Avec une gestion des ressources appropriées, les pressions peuvent être réduites afin de parvenir à un état du lac plus souhaitable.

État du Lac 2012 continue à utiliser des indicateurs du l'écosystème (pages 4 et 5). Cette approche a été d'abord utilisée dans l'État du Lac 2008 pour fournir des informations sur l'état de l'écosystème avec un ensemble de mesures qui représentent ou « indiquer » son état général. Les indicateurs dans le présent rapport ont été choisis avec l'aide de dizaines de scientifiques et des experts techniques fédéraux, des états et de la province du Québec.


QUÉBEC MDDEP

Durant les inondations du lac le printemps 2011, les rues inondés comme celle-ci à Venise-en-Québec étaient fréquents le long des rives de la baie Missisquoi.

HOW ARE **PHOSPHORUS LEVELS** IN LAKE CHAMPLAIN?

Phosphorus levels in most areas have been stable or increasing slightly since 2007. In 2010, the average in-lake phosphorus concentrations exceeded established targets at nine of the thirteen lake segments. The historic floods of 2011 caused a spike in phosphorus concentrations in many parts of the Lake to the highest levels observed since 1990.

Phosphorus is an essential nutrient that, when in excess, negatively affects water quality by promoting too much plant and algae growth. When this occurs, other aquatic organisms are affected by the reduced sunlight and lower oxygen levels that develop as the organic matter decomposes. While we frequently hear about phosphorus in the news, we hear less about how phosphorus gets into the Lake. In managing the water chemistry of Lake Champlain, resource managers must consider sediment, which carries phosphorus, nitrogen, other nutrients, and occasionally toxic substances to the Lake, reducing water quality and affecting habitat.

Over the last 20 years, phosphorus concentrations across most of the Lake segments have generally been stable or have increased (Figure 3). However, monitoring data show that the last five years have seen increasing trends in phosphorus concentrations in some segments, particularly the Main Lake, Burlington Bay, and near Port Henry. Missisquoi Bay phosphorus concentrations have been increasing steadily over the last two decades and, although they have been relatively stable in the last five years, remain well above their established annual targets. St. Albans Bay, the Northeast Arm (Inland Sea), and South Lake A also exceed their targets. Much work remains to be done in these lake segments and their watersheds including the identification, prioritization, and reduction of pollution sources. Although other lake segments are close to their phosphorus targets, continued monitoring of all lake segments is essential to ensure that improvements continue.

Because phosphorus is the primary nutrient of concern for the Lake, state,

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Sediment that is carried off the landscape by runoff is a significant source of phosphorus.

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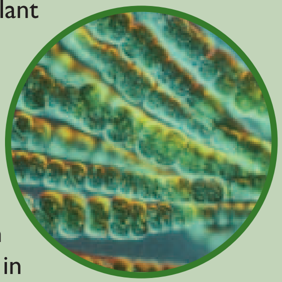
Excessive phosphorus can promote the growth of algae and aquatic plants such as this watermilfoil found in Shelburne Bay.

What is the link between phosphorus and algae blooms?

Generally, three environmental conditions trigger algae blooms: excess phosphorus available in the water column, warm water temperatures, and calm water. When these three conditions occur together, noxious algae blooms can form. Phosphorus is one of the most important nutrients in lake ecosystems, driving the growth of algae, plants, and upper-level organisms, such as fish. However, too much phosphorus in the Lake triggers excessive plant growth and may create nuisance conditions, such as algae blooms and dense beds of aquatic vegetation, including invasive Eurasian watermilfoil and water chestnut. More information on the toxicity of cyanobacteria (blue-green algae) blooms can be found in the Human Health and Toxins section of this report. See the Biodiversity & Aquatic Invasive Species section for more information on water chestnut management in Lake Champlain.



CYANOBACTERIA

provincial, and federal resource managers have established target concentrations for phosphorus in 13 segments of Lake Champlain (Figure 3). Phosphorus targets are higher for some lake segments than others because their shape, depth, and ecology differ. For example, the target concentration for the Main Lake is 10 micrograms of phosphorus per liter of water (µg/l) and the target for the southernmost lake segment (South Lake B) is 54 µg/l. When these targets were established, resource managers recognized that the Main Lake and the South Lake are ecologically very different. The South Lake may never have had phosphorus concentrations as low as 10 µg/l. Therefore a target that low for South Lake B is not a realistic goal.

The Lake Champlain Total Maximum Daily Load (TMDL) is the total amount of phosphorus that the Lake can receive and still meet the in-lake targets.

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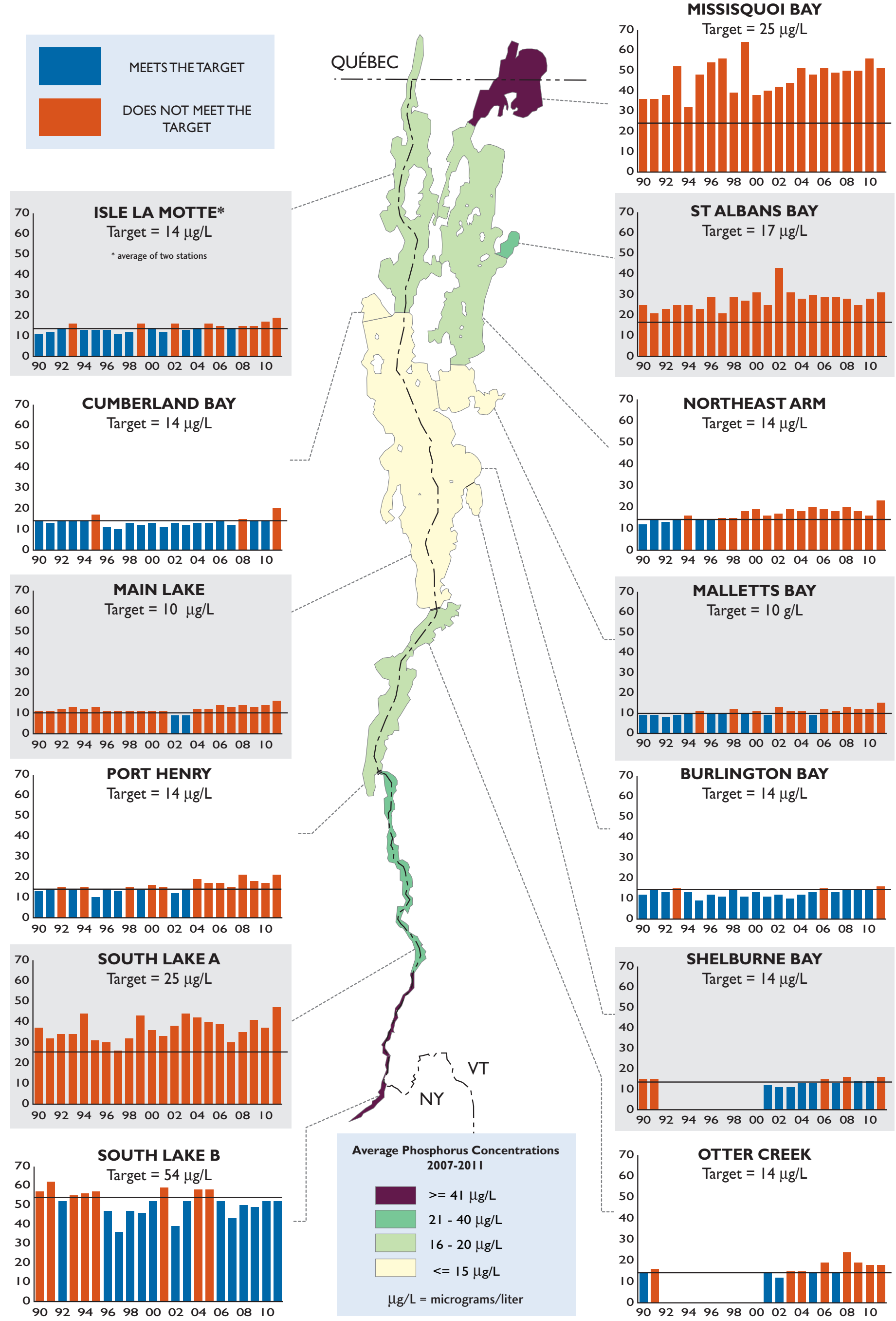
Data collected by the Long-Term Monitoring Program is critical to managing water quality in the Lake Champlain Basin. Dissolved oxygen, being measured here, is reduced as aquatic plants promoted by excess phosphorus decompose.

The US EPA first approved the TMDL for the New York and Vermont portions of the Lake in 2002. In 2011, the EPA disapproved the Vermont portion of the TMDL based on two concerns: the TMDL did not provide sufficient assurance that phosphorus reductions from polluted runoff would be achieved, and there was not an adequate margin of safety to account for uncertainty in the original analysis (particularly for four segments of the Lake: Missisquoi Bay, St. Albans Bay, Northeast Arm, and South Lake). EPA is working in collaboration with technical experts in the region to establish a new TMDL for Vermont by the end of 2013.

Information and data used to develop the TMDL and examine the Lake's condition are only possible because of the established monitoring network. The Long Term Monitoring Program (LTMP) has been collecting important water quality data on Lake Champlain and its tributaries since 1990. Water temperature, dissolved oxygen, water clarity, phosphorus, and nitrogen are among the 21 physical, chemical, and biological parameters measured at 15 in-lake sites from April to October each year. Similarly, water quality parameters are measured year-round at 22 tributary monitoring stations during high-flow storm events and at lower baseline flows. The LTMP regularly checks the pulse of the Lake and is essential to determine where and how resources should be directed for pollution reduction.



DATA SOURCE: Long Term Monitoring Program (LCBP, VTANR, NYSDEC)

FIGURE 3| LAKE CHAMPLAIN PHOSPHORUS CONCENTRATIONS BY LAKE SEGMENT

WHERE DOES THE **PHOSPHORUS** COME FROM?

All land uses contribute some amount of nutrients to the Lake. Even forests and other undeveloped lands provide a base level of nutrients. Lands that have been most disturbed, particularly urban areas and agricultural land, contribute the greatest amount. The application of fertilizers also increases the risk of nutrient contamination of runoff.

Tributaries deliver nutrients and other materials to the Lake from runoff in the watershed (called nonpoint source pollution) along with discharges from wastewater treatment facilities (WWTFs) and other discrete sources (point sources) (Figure 4). The Lake's watershed is 18 times larger than the area of the Lake itself, so runoff from the watershed has a major impact on water quality. Therefore, while scientists and resource managers monitor the phosphorus levels in the Lake, much of the work they do to improve these levels is done on the ground in the watersheds upstream. And while water quality monitoring data show steady or slightly increasing phosphorus concentration trends in the Lake, some recent analyses suggest that, apart from the impact of the 2011 floods, phosphorus loads delivered from tributaries are decreasing.

A recent analysis by the Vermont Agency of Natural Resources (VT ANR) suggests that, despite increased conversion of land to development in the Basin, phosphorus loads from tributaries to most regions of the Lake were stable or decreasing from 1991 to 2008. This is further supported by a US Geological Survey (USGS) study that shows decreasing phosphorus concentrations in several tributaries since 1999, most notably the LaPlatte and Pike Rivers and Otter Creek, when annual variations in flow are accounted for statistically.

Taken as a whole, these results indicate that we have at least held the line on phosphorus loading to Lake Champlain over the 1991-2010 period, and there are indications that phosphorus reduction actions are starting to produce detectable results in several watersheds. It will still take time, however, for these observed reductions in the watersheds to become visible in the Lake itself.

One notable challenge in the management of phosphorus in Lake Champlain is the relationship of phosphorus loading to river flow (Figure 5). The historic spring Lake flooding of 2011, followed by Tropical Storm Irene in

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Runoff from agricultural fields is a significant source of phosphorus loading to the Lake.

Why do we use "concentration" and "load"?

When a sample of water is collected and brought back to the laboratory for analysis, the "concentration" of phosphorus in the sample is measured. The concentration is the amount of phosphorus per unit volume of water, typically reported as micrograms of phosphorus per liter of water, or µg/l. When that sample is collected from a stream with a measured flow (a measured volume of water moving down the stream at a measured speed), that concentration can be converted into a "loading rate," expressed in units such as metric tons of phosphorus per year. The phosphorus "loading rate" is the concentration of phosphorus in the stream at a given time, multiplied by the amount of water moving through the stream at that time and location. "Tributary loading" generally refers to both the portion of phosphorus that comes from nonpoint sources and from WWTFs; phosphorus contributions from upstream wastewater discharges are subtracted from the total phosphorus load to determine an estimate of the nonpoint source load. Load information is very important for determining the amount of phosphorus delivered to the Lake by a stream over a period of time. Since measuring stream flow allows us to calculate the amount of phosphorus being delivered to the Lake, it is important to maintain a network of stream flow gages in the Basin to augment concentration measurements.

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August, delivered enormous volumes of water to the Lake. Preliminary load calculations for three tributaries during 2011 (Winooski, Missisquoi, and Otter) show that phosphorus loads in these rivers were 1.7 to 2.8 times their long-term annual averages. In-lake phosphorus concentrations increased due to the 2011 flooding and elevated tributary phosphorus loads. This impact of the 2011 floods may become evident in further increases in the occurrence of cyanobacteria blooms. The direction of long-term phosphorus loading trends will depend to some extent on the frequency of severe weather events in the future.

Load from Developed Land Use

A significant amount of nutrients come from developed lands, including urban and suburban lands, roads, lawns, and and the built environment. Trees and vegetation intercept raindrops as they near the ground and slow water movement across the landscape, increasing percolation into the soil. As vegetation is removed and replaced with impervious surfaces such as pavement, rooftops, and even some lawns, water movement increases and percolation into the soil is reduced, causing more water to reach the tributary network quickly, resulting in higher, more rapid peak discharges during storm events (Figure 6).

As the Basin's population increases, the challenge of managing phosphorus loads will only grow. A 2007 study funded by the VT ANR estimated phosphorus loads from three different types of land use in the Basin (Figure 7). On an acre-by-acre average basis, developed land can contribute up to four times more phosphorus than agricultural land and seven times more than forested or natural areas. As forested and agricultural lands are developed with increased amounts of impervious surface area, runoff-reduction measures must be implemented. Best management practices

LAKE SEGMENT WATERSHED	NONPOINT Load	NONPOINT Target ▲	WWTFs Load	WWTFs Target ▲	TOTAL Load	TOTAL Target ▲	Reduction Needed *
Main Lake (VT)	170.2	51.3	8.6	25.3	178.8	76.6	102.2
Otter Creek (VT)	151.3	44.1	4.4	12.0	155.3	56.1	99.2
Shelburne Bay (VT)	8.3	10.0	0.5	2.0	8.8	12.0	0.0
Burlington Bay (VT)	⊘	1.4	2.9	4.4	⊘	5.8	⊘
Isle LaMotte (VT)	⊘	0.2	0.0	0.1	⊘	0.3	⊘
Port Henry (VT)	⊘	0.1	0.0	0.0	⊘	0.1	⊘
Port Henry (NY)	⊘	2.5	0.6	0.9	⊘	3.4	⊘
Main Lake (NY)	67.3	29.5	2.5	4.2	69.8	33.7	36.1
Isle LaMotte (NY)	31.7	18.9	1.3	3.4	33.0	22.3	10.7
Cumberland Bay (NY)	24.7	8.1	12.2	17.1	36.9	25.2	11.7
MAIN LAKE TOTALS	453.5	166.1	32.7	69.4	482.6	235.5	247.1
MISSISQUOI BAY TOTALS*	200.2	93.0	2.4	4.2	202.6	97.2	105.4
South Lake B (NY/VT)	101.3	41.2	1.1	3.5	102.4	44.7	57.7
South Lake A (NY)	2.7	3.3	4.0	7.9	6.7	11.2	0.0
South Lake A (VT)	⊘	0.4	0.1	0.2	⊘	0.6	⊘
SOUTH LAKE TOTALS	104.0	44.9	5.2	11.6	109.2	56.5	52.7
MALLETTS BAY TOTALS	54.1	25.4	1.1	3.2	55.2	28.6	26.6
Northeast Arm (VT)	⊘	1.2	0.0	0.0	⊘	1.2	⊘
St. Albans Bay (VT)	⊘	5.2	0.8	2.8	⊘	8.0	⊘
NORTHEAST ARM TOTALS	⊘	6.4	0.8	2.8	⊘	9.2	⊘

NONPOINT STATUS

- GOOD — Average load meets TMDL target
- POOR — Average load does not meet TMDL target

WWTFs STATUS

- GOOD — Load meets TMDL target
- POOR — Load does not meet TMDL target

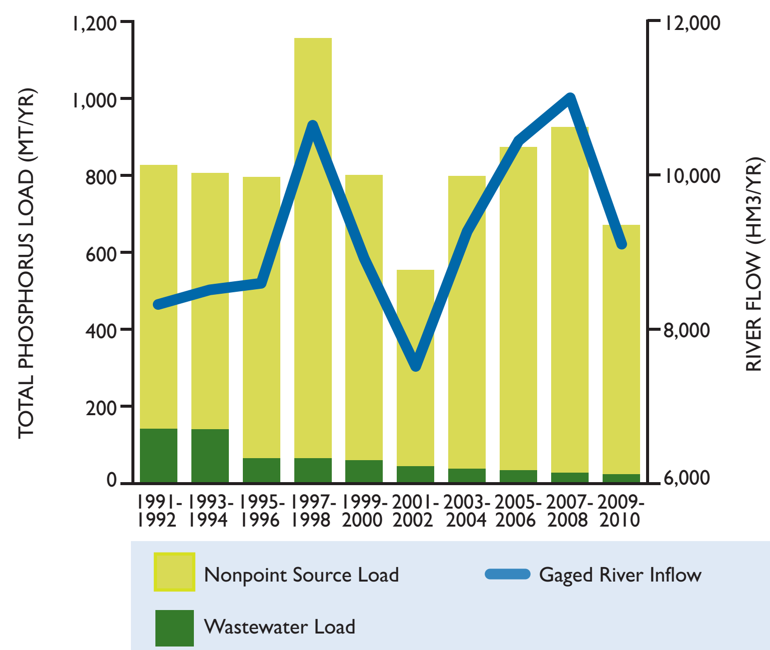
⊘ Data not available (No tributaries monitored during 2009-2010 or less than 75% of area monitored.)

NOTES: Nonpoint loads are averaged over water years 2005-2010 wastewater loads are for calendar year 2010. Nonpoint load estimates include extrapolations for unmonitored portions of lake segment watersheds. South Lake B (VT/NY) as well as Missisquoi Bay (VT/QC) segments were combined because of shared tributaries. The Missisquoi Bay WWTF load and target are for VT only. * Reduction needed is an approximation.

▲ VT TMDL target is currently under revision

DATA SOURCE: Long Term Monitoring Program (LCBP, VTANR, NYSDEC)

FIGURE 4 | PHOSPHORUS LOADS TO LAKE FOR NONPOINT SOURCES AND WASTEWATER TREATMENT FACILITIES IN METRIC TONS/YEAR



DATA SOURCE: LCBP/VT ANR Lake Champlain Long-Term Monitoring Program.

FIGURE 5 | TOTAL PHOSPHORUS LOAD TO LAKE CHAMPLAIN COMPARED TO RIVER FLOW

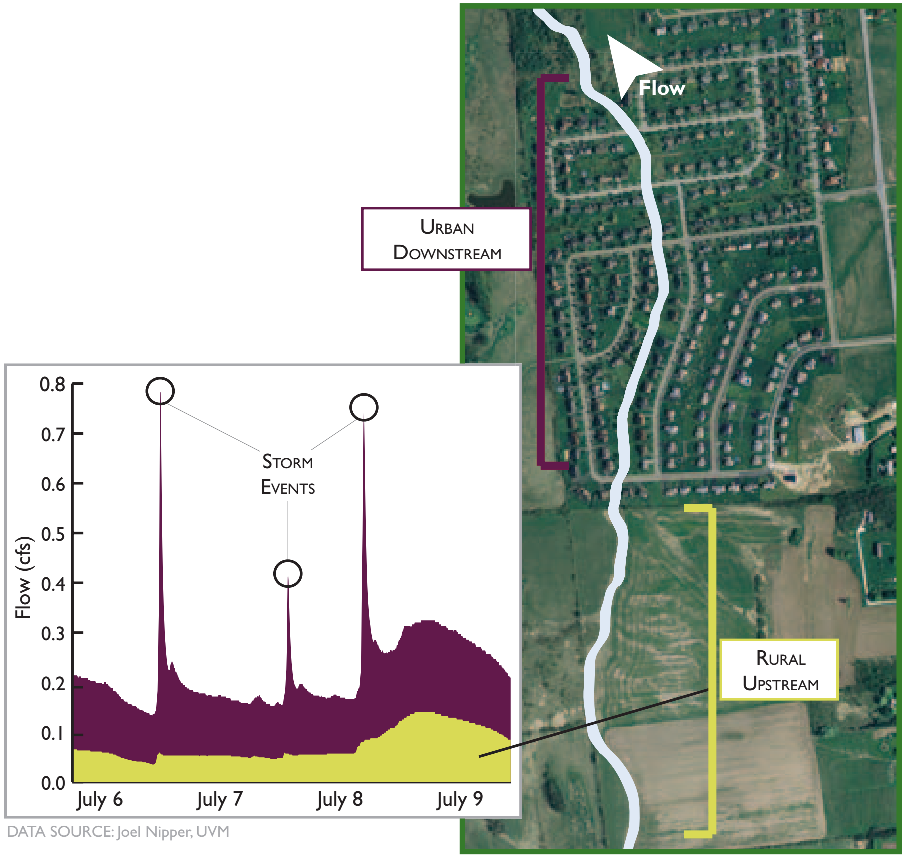
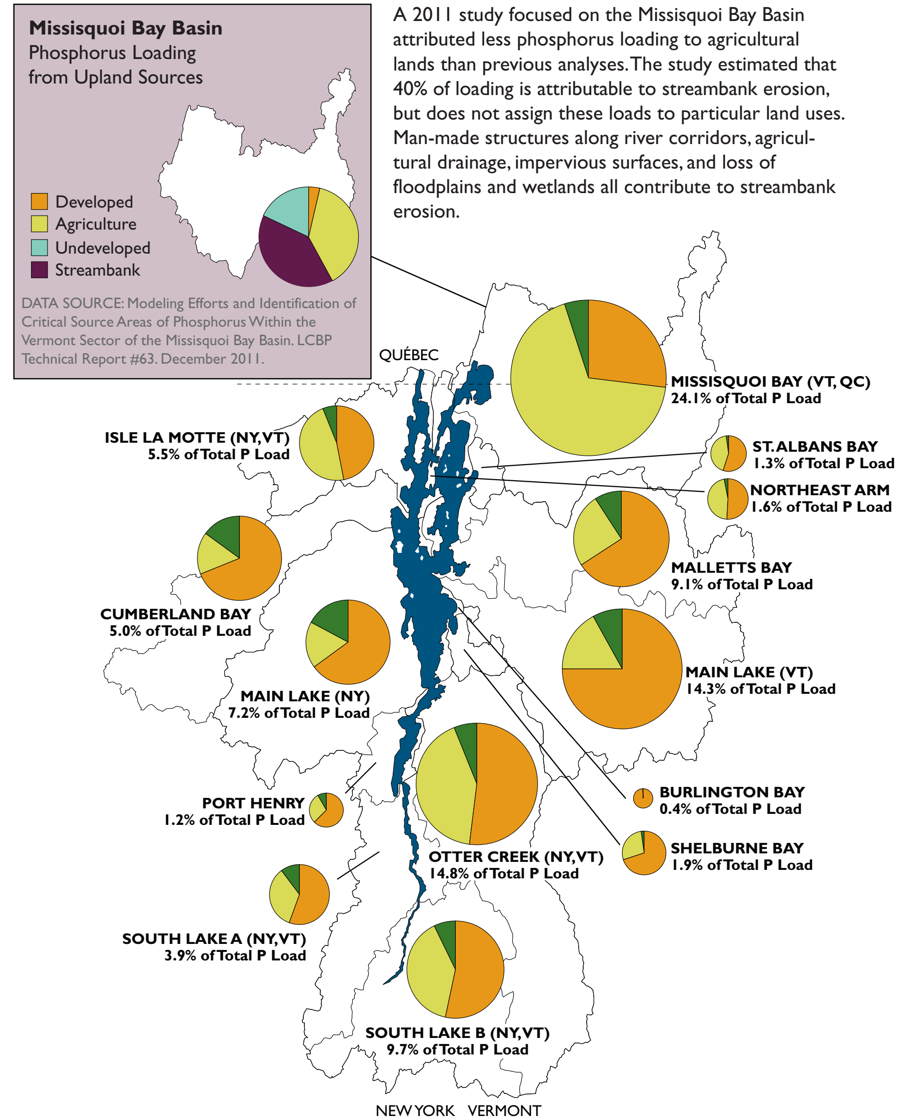


FIGURE 6 | THE EFFECT OF URBANIZATION ON FLOODING

(BMPs) will help slow the movement of water across the landscape and into the tributary network, reduce erosion, and decrease delivery of nutrients and harmful toxins to Lake Champlain.

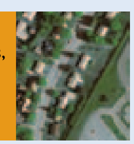
Historically, WWTFs have been a significant source of phosphorus, but with recent technological advances, these facilities have become very efficient at removing phosphorus (Figure 8). While these facilities have become quite effective, they also have aged. More than ten percent of WWTFs are beyond their expected lifespan, and another ten percent are within five years. Investment in this infrastructure will be essential in future efforts to control phosphorus pollution.

In Québec, all point sources of phosphorus from public and private treatment facilities are treated to achieve an effluent concentration of 1.0 mg/l or less. These facilities are monitored regularly by the Ministère du Développement durable, de l'Environnement et des Parcs (MDDEP; Ministry of Sustainable Development, Environment, and Parks), to ensure their effectiveness. The load from these point sources accounts for approximately 4-5% of the total phosphorus load from Québec to Missisquoi Bay.

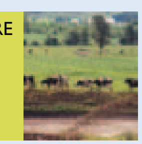


LAND USE TYPES

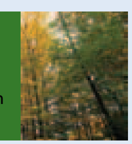
DEVELOPED
All roads, cities, suburbs, lawns and large-lot buildings.



AGRICULTURE
Crop and livestock production.



FORESTED
Areas covered primarily with trees.



NOTE: The land use data is from 2001 satellite imagery— the most recent comprehensive and complete data for this region.
DATA SOURCE: Updating the Lake Champlain Basin Land Use Data to Improve Prediction of Phosphorus Loading. LCBP Technical Report #54. May 2007. Page 45, Table 2-11.

FIGURE 7 | ESTIMATED NONPOINT SOURCE PHOSPHORUS LOADING BY LAND USE TYPE

Load from Agricultural Land Use
The agriculture sector's impact on water quality in some areas of the Lake Champlain Basin receives a lot of attention. Reduction of nutrient runoff from agricultural land is indeed essential to achieve phosphorus loading targets for all of the watersheds within the Lake Champlain Basin. A 2011 study of the Missisquoi Bay Basin attributed less phosphorus to agricultural lands than previous analyses have suggested.

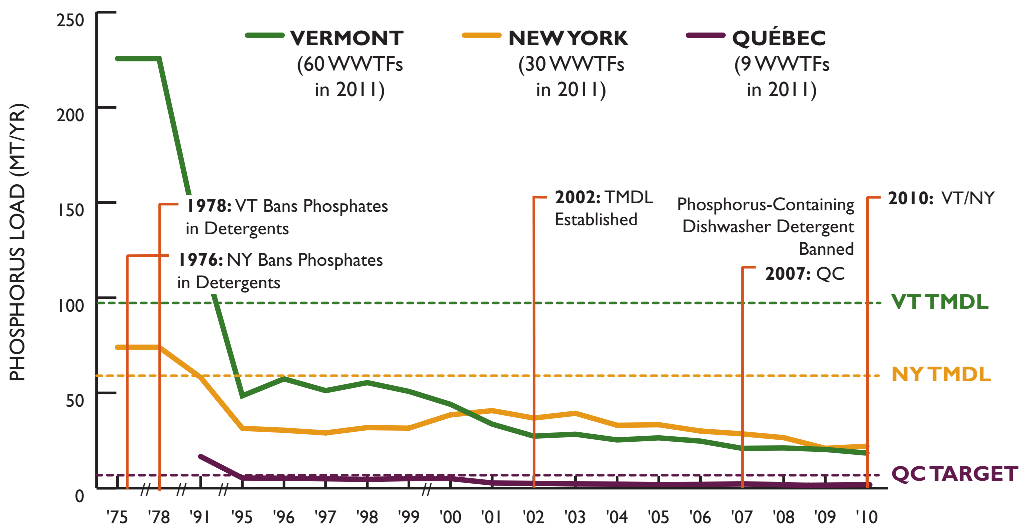
This study, conducted using more detailed data sets than previous studies, identified Critical Source Areas (CSAs) of phosphorus loading to Missisquoi Bay. CSAs are those portions of a landscape that have both a source of phosphorus and a waterway that carries phosphorus from that source downstream to the Lake. CSAs deliver proportionally more phosphorus to a waterway than other locations in the watershed. The 20% of CSAs with the highest phosphorus loads were predominantly pasture or fields planted in permanent corn, corn-hay rotations, and permanent hay.

Sub-watersheds with the greatest percentage of agricultural land (e.g. Rock River and Mud Creek) were estimated to have the highest phosphorus loading rates in the Missisquoi Bay Basin. Heavily forested sub-watersheds (e.g. Trout River and Tyler Branch) had lower phosphorus loading rates. The project identified land in corn-hay rotations as the greatest contributor of phosphorus per acre. The CSA analysis provides resource managers with an unprecedented level of detail about sources of phosphorus on the landscape. Other watersheds in the Lake Champlain Basin with different topograpic and land use characteristics may have somewhat different types of significant critical source areas.

Streambank sediments have been found to be a significant source of phosphorus loads to the Lake.

Streambank sediments
Recent studies show that rivers and streams themselves also can contribute significant amounts of sediment and phosphorus to the Lake. The USDA Agricultural Research Station's National Sedimentation Laboratory (NSL), with funding from LCBP and VT ANR, examined this issue for the Missisquoi River watershed. Preliminary findings from this study indicate that as much as 36% of the annual phosphorus load (52 metric tons of phosphorus per year) and up to 36% of the annual sediment load in the Missisquoi River comes from streambank sediments. The 2011 Missisquoi CSA study verified this finding by attributing 40% of phosphorus loading to streambank erosion (Figure 7 inset map).

Factors contributing to stream instability and bank erosion include encroachments on river corridors by roads and buildings, modifications to streams for agricultural drainage purposes, accelerated stormwater runoff from impervious surfaces, and loss of protective features such as floodplains and wetlands.



DATA SOURCE: VTANR, NYSDEC, MDDEP

FIGURE 8 | PHOSPHORUS LOAD FROM WASTEWATER TREATMENT FACILITIES, 1975-2010

WHAT IS BEING DONE TO **REDUCE PHOSPHORUS** CONCENTRATIONS?

Effective planning, informed by a well-constructed monitoring program, is the key to managing the critical "hot spots" in the Basin. This process allows resource managers to target funds toward efforts that will reduce pollutant loads.

Natural resources management agencies around the Basin have initiated dozens of programs to reduce nutrient pollution. More information on each of these programs can be found on the appropriate agency websites (see www.lcbp.org for a list). Examples of nutrient reduction programs include:

- Back roads maintenance programs
- Stormwater management
- Forest management
- Wetland protection
- Wastewater management
- Basin planning
- Agricultural Best Management Practices
- Nutrient Management Planning on farms
- Planning and Implementation grants to local municipalities and organizations

The "Don't P on Your Lawn" campaign initiated in 2007 targeted retail sale of phosphorus fertilizers through workshops and public service announcements. New York and Vermont have since passed legislation banning the use of phosphorus-containing fertilizer on established lawns unless a soil test indicates the need for additional phosphorus. The Lawn-to-Lake Workgroup developed signs to help Vermont retail storeowners meet requirements to provide information about the new restrictions.

The term "adaptive management" describes a carefully planned sequence of activities that effectively add up to "learning by doing." In this approach, resource managers evaluate a range of implemented management actions against one another to clarify how well each has supported water quality goals. This information forms the basis for the next cycle of management actions. Adaptive management helps decision makers determine the best ways to manage large and diverse areas of land and achieve results in reasonable time spans.

Adaptive management will become an increasingly useful method for integrating local science with decision-making. It provides tools to directly apply what we know about managing phosphorus, and it provides for mid-course corrections as new information renders old information and goals obsolete. The LCBP has been incorporating many of the principles of adaptive management in its work to coordinate the management of Lake Champlain and is now developing a formalized framework to use the adaptive management process in the management of phosphorus. As the LCBP and its partners implement this process, new relevant knowledge about the Basin will be gained and the efficiency of collective management decisions will improve.


TOWN OF PLAINFIELD, VT

Rain gardens help to filter stormwater runoff and the phosphorus pollution it can carry.

WHAT YOU CAN DO

Test your Turf: Test your lawn and garden soil before you fertilize. You may need less than you think or none at all.

Leave it on the Lawn: Use your grass clippings as mulch on your lawn. This adds nutrients and decreases the need for watering.

Rein in the Rain: Plant a rain garden and/or install a rain barrel.

Wash Cars on the Lawn: Wash your car on the lawn instead of on the driveway to help prevent detergents from washing into the Lake.

Shore up the Water's Edge: Plant native vegetation along shorelines and river banks to hold soil in place and reduce erosion!

Visit **www.lcbp.org/lcstate.htm** for more tips.

IS IT **SAFE TO SWIM** IN LAKE CHAMPLAIN?

Yes it is, most of the time and in most of the Lake. There are generally only two reasons why it might be unsafe to swim in the Lake during the summer: the risk of exposure to coliform bacteria following storms or to toxins that can be produced where cyanobacteria (blue-green algae) blooms occur.

Coliform bacteria are found in the waste products of all birds and mammals, and at elevated levels, can cause severe illness in humans. Combined sewer overflows (CSOs), which occur when sanitary sewer systems become overwhelmed by the large amounts of stormwater that enter through connected pipes, sometimes cause beach closures. Other causes of high bacteria counts can include faulty private septic systems, agricultural runoff, flocks of birds, pet waste, and large wind events that churn up sediment and release soil-borne bacteria into the water. Elevated stream flows caused by large storms may carry sewage overflow, manure, or sediments that are high in bacteria, increasing risk of exposure to large quantities of coliform bacteria at nearby beaches for a period of days.

LCBP

Most beaches on Lake Champlain are safe to swim at most of the time.

Each jurisdiction—New York, Québec, and Vermont— has developed its own recreational water quality standards, none of which is specific to Lake Champlain. All three jurisdictional standards reflect a common indicator of coliform bacteria: *Escherichia coli*. When counts of *E. coli* bacteria are too high, people recreating in nearby waters may be at high risk of contracting an illness through ingestion. CSOs are less frequent now than in the past, but still trigger occasional beach closures in the Basin (Figure 9) and can be a health risk to homeowners along the lakeshore who draw their drinking water directly from the Lake.

For these reasons, public health agencies around the Lake recommend that all water collected directly from the Lake be treated at a minimum with an ultraviolet light or chlorination system prior to use (for both drinking and bathing). Most public beaches are monitored for bacteria levels on a regular basis throughout the recreational season. For more information about local beach monitoring, contact your local health department.

Of the 35 public beaches on Lake Champlain that were evaluated for this report, closures due to coliform bacteria totaled 66 temporary closures and three extended closures (more than one week), between 2008 and 2011. Beach closures due to cyanobacteria blooms have been even less frequent with eight closures in the same time period. Public beaches in Missisquoi Bay were closed for significant periods of time in 2008 and 2011 due to cyanobacteria blooms. Beaches in Burlington and Shelburne, VT were the only locations to have at least one closure annually due to coliform bacteria or cyanobacteria.

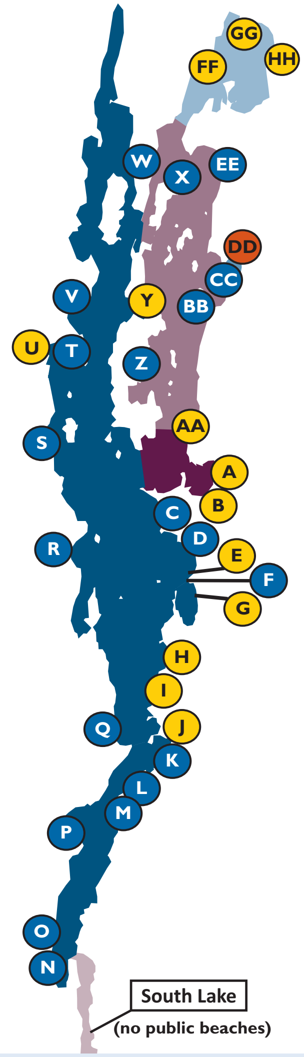
E. coli and cyanobacteria samples can take between 24-48 hours to analyze; therefore harmful conditions often subside before results from these samples are released from the laboratory. For 24 hours after intense rainstorms, it is a good idea to stay out of the Lake where streams enter, to minimize your exposure to *E. coli*. If the water looks unusually green, has clumps of algae in it, or smells noxious—signs of a cyanobacteria bloom—it is best for you and your pets to stay out of the water.

QUÉBEC MDDEP

Cyanobacteria blooms can produce harmful toxins, and should be avoided by swimmers and pets.

		Beach	2008	2009	2010	2011
MALLETTS BAY	A	Niquette Bay State Park	1		1	1
	B	Bayside Beach		2	2	2
MAIN LAKE	C	Leddy Beach			2	
	D	North Beach				1
	E	Blanchard Beach	1	1	2	1
	F	Oakledge Beach			1	1
	G	Red Rocks Beach	2	2	2	
	H	Shelburne Town Beach	1	2	2	1
	I	Charlotte Town Beach		2		1
	J	Kingsland Bay State Park	2			1
	K	Ferrisburgh Town Beach			1 (cyanobacteria)	1 (longer than one week)
	L	DAR State Park				
	M	Button Bay State Park				
	N	Bulwagga Bay Beach				
	O	Port Henry Municipal Beach				
	P	Westport Town Beach	closed for season (lack of lifeguard)	closed for season (lack of lifeguard)		
	Q	Noblewood Park Beach				
	R	Port Douglas Beach				
	S	Ausable Point State Park		1		1
	T	Cumberland Bay State Park				closed for season (flood damage)
	U	Plattsburgh Municipal Beach		1	1	2
	V	Point Au Roche State Park	1		1	
	W	Alburg Dunes State Park	1		1	
NORTHEAST ARM	X	North Hero State Park			1	
	Y	Knight Point State Park	1		2	
	Z	Grand Isle State Park			1	
	AA	Sand Bar State Park	3		1	2
	BB	Burton Island State Park				
	CC	Kill Kare State Park				
	DD	St. Albans Bay State Park	1 (longer than one week)		5	4
	EE	Cohen Park				
MISSISQUOI BAY	FF	Saint Georges de Clarenceville	1 (cyanobacteria)			2 (cyanobacteria)
	GG	Venise en Quebec	1 (cyanobacteria)		1 (cyanobacteria)	2 (cyanobacteria)
	HH	Saint Armand	1 (cyanobacteria)			2 (cyanobacteria, longer than one week)

NOTE: The number in each circle represents a single closure, but the closure may have been for more than one consecutive day.
DATA SOURCES: Town Offices, UVM, NYS DOH, MDDEP



STATUS (2008-2011)

- GOOD — Closed 0-2 times
- FAIR — Closed 3-7 times
- POOR — Closed 8+ times
- Closed due to bacteria
- Closed due to cyanobacteria
- Closed for longer than one week
- Closed for the season, due to flood damage
- Closed for the season, due to lack of lifeguard

FIGURE 9 | PUBLIC BEACH CLOSUSRES ON LAKE CHAMPLAIN, 2008-2011

WHAT IS THE PROBLEM WITH CYANOBACTERIA?

Cyanobacteria blooms develop in some part of the Lake each year. Blooms release toxins that are harmful to humans and other animals. The flooding of 2011 may cause an increase in the severity of blooms while phosphorus concentrations remain elevated.

In response to a highly publicized dog poisoning attributed to cyanobacteria (blue-green algae) toxins in 1999, the LCBP initiated an investigation of the occurrence of cyanobacteria and their potential toxins in Lake Champlain. This effort has evolved to document the presence and extent of cyanobacteria blooms in Lake Champlain and the levels of cyanotoxins they may produce.

Cyanobacteria are a normal part of Lake Champlain biology, and are common in lakes worldwide. Excess nutrients, combined with warm, calm water can increase cyanobacteria density. High densities of cyanobacteria can form blooms, and may produce harmful toxins. These toxins, when ingested, can cause gastrointestinal problems, skin irritation, and other symptoms. It is difficult to determine if a cyanobacteria bloom contains toxins, which is why monitoring and an early warning system have been developed. These blooms

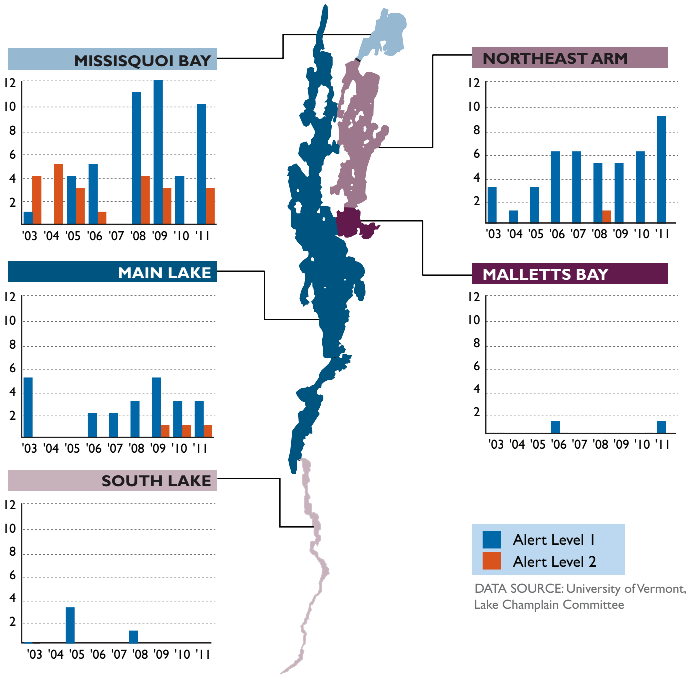


FIGURE 10 | WEEKS OF CYANOBACTERIA BLOOMS AT ALERT LEVELS

occur worldwide, indicating excessive nutrients in many lakes.

University of Vermont, in partnership with the LCBP Long Term Monitoring Program and with citizen monitors recruited by the Lake Champlain Committee, conducted regular monitoring from 2003 to 2011. The program maintains a tiered-alert system in which public alerts are announced when counts of cyanobacteria and associated toxin levels reach certain thresholds. Warnings arising from this program are released on the Vermont Department of Health website during the summer recreational season.

Alert Level 1 indicates that there is a large amount of accumulated algae near the surface of the water in the affected area. Toxins in this accumulated material could potentially reach concentrations that pose a risk to humans and animals. Alert Level 2 indicates that significant toxin concentrations have been documented in the affected area, and a public health advisory may be issued concerning recreational activities and water consumption (Figure 10).

In late 2011, the LCBP began to transition the responsibility of program coordination to the State of Vermont. The new program relies on both qualitative and quantitative observations of trained volunteers and paid staff to identify bloom conditions in both New York and Vermont; volunteers can submit photos to program staff to determine the need for sample collection. This system allows warnings to be issued before test results are available following the logic "if it looks bad, don't go in it." Trained staff still collect samples for laboratory analysis for the traditional tiered-alert system that has been in place since 2003. This approach reduces laboratory costs and time elapsed before public health and recreation warnings are issued.

	VERMONT		NEW YORK		QUEBEC*	
FISH SPECIES	**Women/Child (A)**	**All Others**	**Women/Child (B)**	**All Others**	**Women/Child**	**All Others**
Brown Bullhead	5	no advisory	4	4	8	8
Pumpkinseed	5	no advisory	4	4	no advisory	no advisory
Walleye	0	1	0	> 19" (48cm): 1*	8 < 20" / 4 > 20" (50cm)	8 < 20" / 4 > 20" (50cm)
Lake Trout	1	3	4	4	no advisory	no advisory
Lake Trout >25" (63cm)	0 (incl. child <15)*	1*	0	1*	no advisory	no advisory
Trout: Brook/Brown/Rainbow	3-4	no advisory	4	4	no advisory	no advisory
Chain Pickerel	1	3	0	4	no advisory	no advisory
American Eel	1	3	0	4 (in Cumberland Bay: 1)	no advisory	no advisory
Largemouth Bass	2	6	0	4	8	8
Smallmouth Bass	1	3	0	4	8	8
Northern Pike	2	6	0	4	8	8
Yellow Perch <10" (25cm)	3-4	no advisory	4	4	8	8
Yellow Perch >10" (25cm)	2-3	6	0	4	8	8
White Perch	no advisory	no advisory	no advisory	4	8	8
White Sucker	no advisory	no advisory	no advisory	4	8	8
Redhorse Sucker	no advisory	no advisory	no advisory	4	8 < 14" / 4 > 16" (40cm)	8 < 14" / 4 > 16" (40cm)
All Other Fish Species	2-3	9	0	4	no advisory	no advisory

* = Advisory specific to Lake Champlain. All other advisories are state-wide in NY and VT. The QC advisories are all specific to Missisquoi Bay.
A = The VT advisory applies to women of childbearing age, particularly pregnant women, women planning to get pregnant and breastfeeding mothers, as well as children age six or younger.
B = The NY advisory applies to women of childbearing age, infants and children under the age of 15.
SOURCES: NY Department of Health, 2011-12; VT Department of Health, 2007; QC Department of Health, April 2006

FIGURE 11 | LAKE CHAMPLAIN FISH CONSUMPTION ADVISORIES

CAN I **EAT THE FISH** FROM LAKE CHAMPLAIN?

Yes, within reason. Residents and visitors can enjoy catching and consuming a wide variety of fish from the Lake year round. However, it is important that fish caught in Lake Champlain and surrounding water bodies are consumed responsibly.

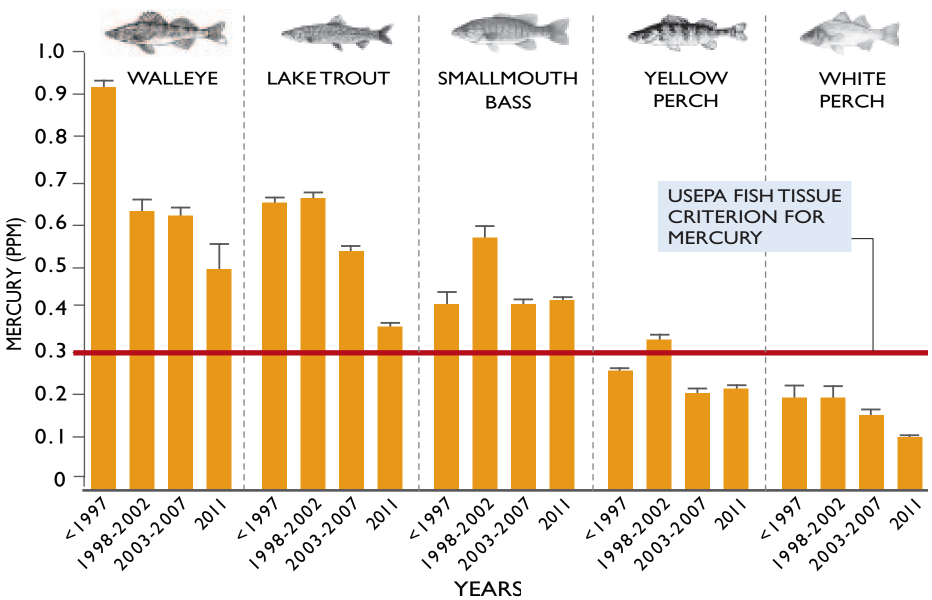
New York, Québec, and Vermont have fish consumption advisories for Lake Champlain that, while not identical, do provide careful guidance about the risks of fish consumption (Figure 11). Consumption advisories are developed to protect humans from harmful levels of mercury, polychlorinated biphenyls (PCBs) and other toxins that bioaccumulate in fish tissue. Generally, as a fish increases in size, so does the concentration of these toxic substances. Children and women of childbearing age are at a higher risk from these toxins because children's internal organs are more sensitive to toxins, and women could pass the toxins to a developing fetus or to children through their breast milk.

Data collected in 2011 for sportfish in Lake Champlain reveal substantial declines in mercury levels in the tissue of three of the five most common sportfish (Figure 12). Average sized lake trout are approaching the US EPA criterion for consumption. This new research is an encouraging indicator that regional mercury reduction programs are having positive effects on local fish populations, and will be considered when health authorities next review consumption advisories. Fish mercury levels should continue to improve with newly issued US EPA regulations on mercury emissions from coal-fired power plants. New York State's revocation of special consumption advisories for Cumberland Bay (near Plattsburgh) as a result of significant declines in PCB levels in fish tissue is further good news on this front.

CORPORATION BASSIN VERSANT BAIE MISSISQUOI

CORPORATION BASSIN VERSANT BAIE MISSISQUOI

The most recent data show substantial declines in mercury levels in many sportfish.



NOTE: The values are mean mercury concentrations, normalized to the average length of the fish. Bars show standard errors.
DATA SOURCE: Vermont Agency of Natural Resources; 2011 data from Biodiversity Research Institute.

FIGURE 12 | MERCURY IN LAKE CHAMPLAIN FISH BY INDICATOR SPECIES

WHAT IS BEING DONE TO REDUCE **SOURCES OF MERCURY**?

Mercury reduction efforts range from national policies aimed at curbing atmospheric mercury deposition to local industry-specific initiatives in the Basin to eliminate sources such as thermometers and dental amalgams.

Mercury—the most widespread toxin of concern in Lake Champlain—is a naturally occurring element, but human activities have increased the amount released to the environment by five to six times in the Northeast. The main source of mercury to Lake Champlain is atmospheric deposition, originating from coal-fired power plants, diesel combustion, and medical and municipal waste incinerators outside the Basin. Other sources include wastewater treatment effluent and leachate from landfills containing mercury-bearing products. Amalgams that go down the drain during dental work and products such as gages, thermometers, thermostats, batteries, fluorescent light bulbs, paint, and switches and relays are additional sources. In the environment, microbes transform mercury into a more toxic form, methyl mercury, that bioaccumulates in fish, resulting in fish consumption advisories.

The reduction of atmospheric sources of mercury is being addressed at the regional and national levels. The 2007 Northeast mercury TMDL, implemented in response to concerns from the New England states and New York, requires a 98% reduction in anthropogenic atmospheric sources of mercury originating from waste combustion sources in up-wind states outside of the region. Management of waste-combustion sources prior to this led to a regional reduction of greater than 60%. In 2011 US EPA issued the Mercury and Air Toxics Standards (MATS) to reduce the emissions of mercury and other toxins from coal- and oil- fired power plants, which are the largest contributors to atmospheric deposition of mercury in the US, by 90%.

On a more local level, hazardous waste and recycling programs are in place to encourage the proper disposal of mercury-bearing products. Additional regulations have been enacted to prevent mercury from being released into the environment, such as consumer product labeling laws and recycling requirements for mercury-contaminated dental wastes in New York and Vermont. Both states have banned the sale of many mercury-bearing products including thermometers and novelty items.

From 2006-2008, over 6,000 pounds of mercury-bearing products, 82 pounds of elemental mercury, and 9 pounds of mercury from fluorescent bulbs were collected in Vermont by municipal solid waste districts and other programs for proper disposal (Figure 13). New York's Clean Sweep program and county solid waste departments also provide environmentally-safe collection and disposal of hazardous wastes, including mercury. Exchange programs for mercury-bearing products—including thermometers, thermostats, and dairy manometers—also have successfully reduced local sources.

Industry-specific measures have been implemented in Vermont for nearly a decade. In 2002 the LCBP and the Vermont Agency of Agriculture, Food & Markets (VAAFM) collected and properly disposed of half of the known mercury-bearing dairy manometers (42), each containing up to ½ pound of mercury. In 2008 VT Department of Environmental Conservation and VAAFM facilitated a mercury-bearing thermometer exchange replacing 250 syrup or candy thermometers with free digital thermometers. In 2011-2012, the LCBP funded the Mercury Thermometer Replacement Program with UVM's Proctor Maple Research Center to replace 350 additional mercury thermometers with digital thermometers, preventing the possible release of 30 pounds of mercury to the environment.

6,000 | **82** | **9**

Pounds of products and trash collected containing mercury.*

Pounds of elemental mercury collected.

Pounds of mercury from fluorescent lamps collected.+

ISTOCK PHOTOS

NOTES: *Includes the weight of mercury and non-mercury containing components. +Estimated.
DATA SOURCE: Vermont Agency of Natural Resources, MercVT Program.

FIGURE 13 | MUNICIPAL MERCURY COLLECTION IN LAKE CHAMPLAIN BASIN TOWNS IN VERMONT, 2006–2008

ARE THERE OTHER **TOXINS** OF CONCERN IN THE LAKE?

Traditional sources of toxic chemicals, such as pesticides, along with "new generation contaminants" from pharmaceuticals and personal care products pose potential threats to both humans and wildlife.

Toxic substances are a diverse group of chemicals whose physical properties, quantity, and persistence in the environment are cause for concern. Several known toxic substances have been documented in Lake Champlain, such as medications, fragrances, and anti-microbial additives, but the long-term effects of persistent, low-level exposure to many chemicals on the ecosystem, aquatic life, and human health are not well understood. Certain types of chemicals may affect the reproduction, development, behavior and survival of aquatic organisms at very low concentrations.

Pesticides (insecticides, herbicides, lampricides, and fungicides) are designed to control or eliminate a nuisance plant, animal, or fungus. Frequently, non-target species are adversely affected by these treatments. For example, the pesticide TFM used to control sea lamprey—though regulated by the US EPA and used at concentrations safe for human health—can be harmful to non-target organisms, which may include threatened or endangered species like American brook lamprey and very young lake sturgeon. During the 2008 TFM treatment of the Missisquoi River, traces of the lampricide were detected at a Québec water treatment facility. Although concentrations were still below US EPA thresholds, this was cause for concern.

Like nutrients, chemical contaminants enter the watershed in runoff as well as from wastewater treatment systems. New chemicals introduced to the consumer market for domestic, agricultural, and industrial purposes are used commonly within the Lake Champlain Basin. Unfortunately, precautionary measures are not always taken prior to a chemical's introduction to the market. A 2006 study by the USGS found 70 different "new generation contaminants" present in low levels in Lake Champlain Basin waterways. These products include fire retardants, plasticizers, pesticides, fragrances, stimulants, and detergents associated with potential human health and ecosystem quality risks.

Monitoring and regulation of new generation contaminants is not consistent throughout the Basin's three jurisdictions and is often minimally enforced at a local level. The LCBP and its partners developed a Toxic Substance Management Strategy in 2011 with the aim of identifying toxic substances of concern, monitoring their presence and impact in Lake Champlain, and determining threats to ecosystem and human health. The strategy works under the premise of the precautionary principle: preventive measures are advised if any potential risk to ecosystem or human health exists, unless the substance is known to be harmless.

LCBP

Traditional toxins and "new generation contaminants" enter the Lake from WWTFs and runoff.

ISTOCK PHOTO

WHAT YOU CAN DO

Reduce application of pesticides applied to your lawn or garden.

Use Less toxic cleaners and personal care products.

Do not Flush left-over pharmaceuticals; throw them in the trash or bring them to a pharmacy drop-off location.

Properly dispose of mercury-bearing items, including non-digital thermometers and thermostats, and compact fluorescent light bulbs (CFLs).

Visit **www.lcbp.org/lcstate.htm** for more tips.

WHAT IS BEING DONE TO PRESERVE **BIODIVERSITY IN THE BASIN?**

Removing barriers to fish and wildlife passage and reducing habitat fragmentation by restoring and protecting wetland, shoreline, and river bank habitats are priorities throughout the Basin. Reducing the introduction and spread of aquatic invasive species also is critical.

FRIENDS OF THE WINOOSKI

The Friends of the Winooski retrofitted this stream crossing to eliminate the dropoff from the culvert, reduce stream velocity, and increase depth, improving passage for fish and other aquatic organisms.

The Lake Champlain Basin contains a rich diversity of plants, fish, and wildlife and an abundance of high-quality habitat. This dynamic ecosystem changes with the seasons and includes a variety of natural communities from the highest points in the watershed to the greatest depths of Lake Champlain. Yet, the Lake and its watershed have seen significant human impacts, including the alteration of natural habitats and introduction of many non-native species.

Wetlands, lakeshores, and river corridors are especially important, providing critical habitat connections in the landscape while also serving to reduce human impacts on water quality. The improvement of fish passage and habitat connectivity has become a high conservation priority in the Lake Champlain Basin. Fish and other aquatic species require unrestricted movement through streams and rivers to maintain healthy populations. Habitat fragmentation in streams prevents fish such as landlocked Atlantic salmon, eastern brook trout, American eel, and the threatened lake sturgeon from reaching historic spawning waters. Many natural resource management agencies, watershed groups, and local municipalities have directed funding, volunteer efforts, and other resources toward improvement of aquatic organism passage (AOP). The LCBP alone awarded 13 grants in 2010 that specifically addressed this issue in several watersheds throughout the Basin.

An example of the partnerships involved in these projects is work on the Browns River, a tributary of the Winooski River, which serves as habitat for brook trout. Existing culverts connecting fish to upstream habitat are not adequately designed to allow fish passage; they often flow out above the stream channel, are too long, and do not provide resting places. With funding from the LCBP, the Winooski Natural Resources Conservation District (WNRCD) worked with local municipalities to design retrofits for four high-priority culverts to improve passage for brook trout and other aquatic organisms. The Winooski NRCD will install the designed retrofits with funding from the US Fish and Wildlife Service (USFWS).

The Lake Champlain Basin is considered to have some of the highest quality wetland habitat in the North-

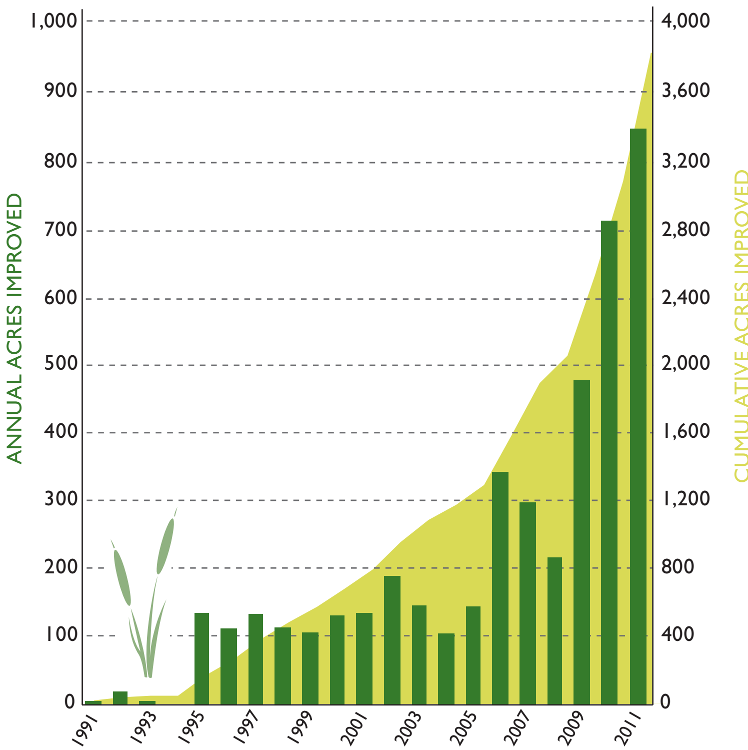
THE NATURE CONSERVANCY

Wetlands provide critical habitat for fish and wildlife, and also help filter pollution from surface water.

east, yet estimates place wetland habitat loss at 35% to 50% since European settlement. Similarly, development and agricultural practices have threatened riparian habitat. Progress has been made in the last two decades to reverse these trends. The US Fish and Wildlife Service's Partners for Fish and Wildlife Program, in collaboration with local landowners, other federal and state agencies and many other non-government conservation groups, has restored and enhanced nearly 4,000 acres of wetlands (Figure 14) and approximately 300 miles of riparian habitat (Figure 15) by annually planting 30,000 trees as buffers along stream banks in the Basin. Non-profit organizations also have been important advocates for these projects. The Nature Conservancy alone has conserved hundreds of acres of wetlands and important upland habitat, restoring critical links in the watershed.

The New York State Department of Environmental Conservation (NYS DEC) recently partnered with the Natural Resources Conservation Service (NRCS) to coordinate a major tree and shrub planting effort in the Basin—known as the "Trees for Tribs" program—as part of President Obama's America's Great Outdoors initiative. The program's goals are to restore and protect stream corridors that connect to Lake Champlain, particularly in communities affected by swollen rivers after Tropical Storm Irene in 2011.

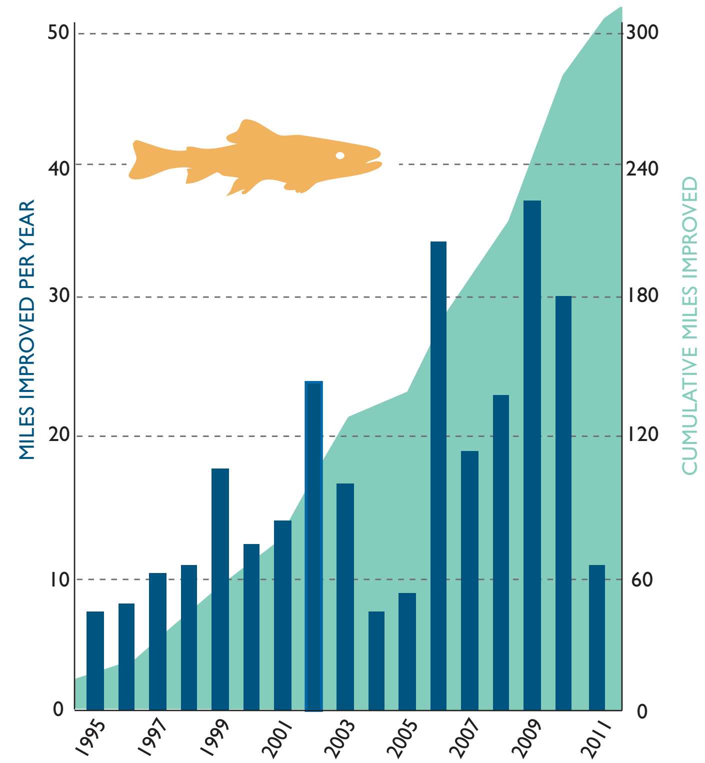
The introduction of non-native species also has serious implications for the Lake Champlain Basin ecosystem. The zebra mussel invasion in Lake Champlain has led to serious declines in native mussel populations. In Vermont, eight of the Basin's fourteen native mussel species are threatened or endangered, including the black sandshell, pocketbook, and pink heelsplitter mussels. To address these concerns, grant programs for aquatic invasive species (AIS) spread prevention, habitat improvement, shoreline protection, and aquatic organism passage projects in the Lake Champlain Basin have received increased support since 2009.



Acres of wetland habitat restored, enhanced and managed through the U.S. Fish and Wildlife Service's Partners for Fish and Wildlife Program. Accomplishments reflect the Service partnership with local landowners, other Federal and State agencies and numerous other non-governmental conservation groups.

NOTE: No wetlands were improved in 1994 in the Lake Champlain Basin.
DATA SOURCE: US Fish and Wildlife Service

FIGURE 14 | ACRES OF WETLAND HABITAT IMPROVED IN LAKE CHAMPLAIN BASIN, 1991–2011



Miles of riparian habitat restored and enhanced in the Lake Champlain Basin through the U.S. Fish and Wildlife Service's Partners for Fish and Wildlife Program. Accomplishments reflect the Service's partnership with local landowners, other Federal and State agencies and numerous other non-governmental conservation groups.
DATA SOURCE: US Fish and Wildlife Service

FIGURE 15 | MILES OF RIPARIAN HABITAT IMPROVED IN LAKE CHAMPLAIN BASIN, 1995–2011

2012 ECOSYSTEM INDICATORS SCORECARD

The 2012 Ecosystem Indicators Scorecard assesses the health of Lake Champlain in its five major lake segments: Missisquoi Bay, Northeast Arm, Malletts Bay, Main Lake, and South Lake. These segments have been used by scientists since the 1970s to describe the major regions of the Lake. The surrounding watersheds of these segments have different physical characteristics and land uses that influence the health of the segment.

For the 2012 report, the scorecard provides updated information on the nine original ecosystem indicators presented in the *State of the Lake 2008* report, reflecting the most current data available for each of these indicators. The indicators have been grouped into three overarching issues: phosphorus, human health and toxins, and biodiversity. Three indicators have been developed for each issue; it is these nine indicators that are used to comprehensively characterize the state of Lake Champlain in this document. Each indicator is scored as good, fair, or poor for each major lake segment. A more detailed explanation of each indicator and the criteria used to determine the scores are presented in the relevant section of this report. Please refer to the page numbers noted after each issue on the scorecard for more information. Trends for each of the indicators also are presented for individual lake segments. The trends are an assessment of whether each condition is improving, staying the same, or declining as of 2012. The trends are typically evaluated for the duration of the available data—20 years in the case of water chemistry monitoring. The status of each indicator also is presented— this is an evaluation of recent data for an indicator, typically from 2008-2011, if data are available. Status information also is related to specific criteria, or targets, that have been established by resource managers in the Basin.

STATUS	
(blue)	GOOD
(yellow)	FAIR
(orange)	POOR
(slash)	NO STATUS DATA IS AVAILABLE

TREND	
(thumbs up)	IMPROVING
(wave)	NO TREND (neither improving nor deteriorating)
(thumbs down)	DETERIORATING
(slash)	NO TREND DATA IS AVAILABLE

INDICATORS by LAKE SEGMENT

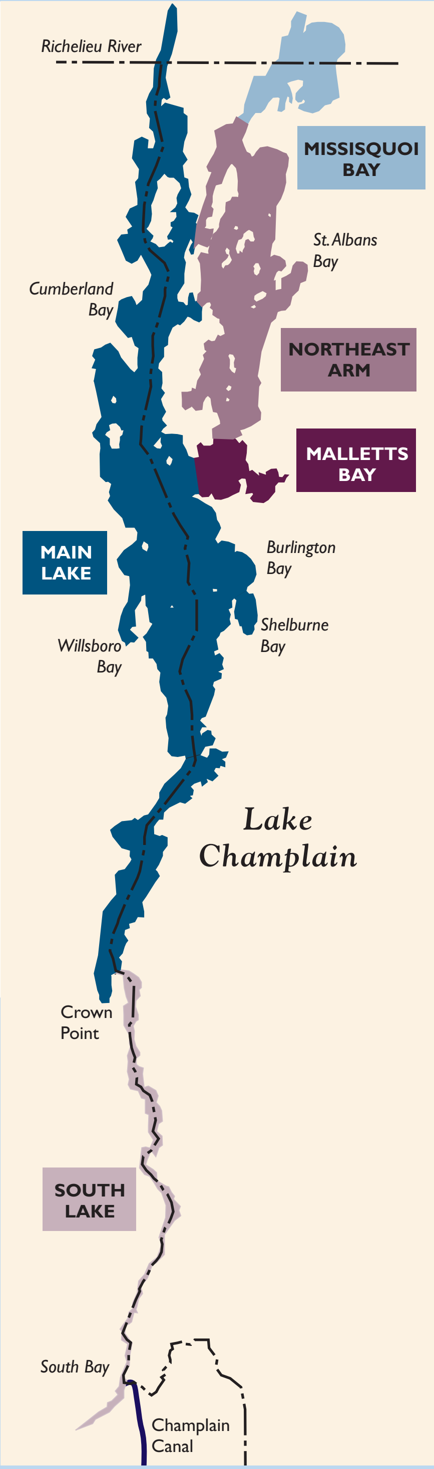
		MISSISQUOI BAY		NORTHEAST ARM	
		STATUS	TREND	STATUS	TREND
PHOSPHORUS	Phosphorus in Lake (p. 5)	Poor	Deteriorating	Poor	Deteriorating
	Nonpoint source loading to Lake (p. 7-8)	Poor	No trend*	No status data	No trend data*
	Wastewater facility loading to Lake (p. 10)	Good	Improving	Good	Improving
		* The Pike R. has improved, but no other rivers show a trend.		* There are no monitored tributaries in the NE Arm.	
HUMAN HEALTH & TOXINS	Beach closures^ (p. 12-13)	Fair	No trend data	Poor	No trend data
	Cyanobacteria blooms^ (p. 14)	Poor	No trend data	Fair	No trend data
	Fish advisories for toxins+ (p. 14)	Fair	No trend data	Fair	No trend data
BIODIVERSITY & AQUATIC INVASIVE SPECIES	Sea lamprey wounds+ (p. 26)	Fair	Improving	Fair	Improving
	Aquatic invasive species arrivals (p. 27)	Fair	Deteriorating	Good	No trend
	Water chestnut infestations (p. 30)	Fair	Improving	Good	No trend

^ *Because beach closures are weather dependent, data is not appropriate for trend analysis.*
\+ *These indicators are lake-wide; therefore, scores are the same across all lake segments.*

MISSISQUOI BAY is shallow, with a maximum depth of about 15 ft (5m), and warm water. It exceeds phosphorus targets and has had cyanobacteria blooms in some summers. Agricultural land in sub-basin is a major source of phosphorus.

THE NORTHEAST ARM or "Inland Sea" has extensive agricultural land and urban growth that results in nonpoint source phosphorus concerns and periodic cyanobacteria blooms. The waters are an important bass fishery.

LCBP PHOTOS



INDICATORS by LAKE SEGMENT

	Malletts Bay Status	Malletts Bay Trend	Main Lake Status	Main Lake Trend	South Lake Status	South Lake Trend	
Phosphorus in Lake (p. 5)	Orange	Thumbs down	Orange	Thumbs down	Orange	~	PHOSPHORUS
Nonpoint source loading to Lake (p. 7-8)	Orange	~	Orange	~*	Orange	~	PHOSPHORUS
Wastewater facility loading to Lake (p. 10)	Blue	Thumbs up	Blue	Thumbs up	Blue	Thumbs up	PHOSPHORUS
Beach closures from bacteria (p. 12-13)	Yellow	∅	Yellow	∅	∅*	∅	HUMAN HEALTH & TOXINS
Cyanobacteria blooms (p. 14)	Blue	∅	Yellow	∅	Blue	∅	HUMAN HEALTH & TOXINS
Fish advisories for toxins⁺ (p. 14)	Yellow	∅	Yellow*	∅	Yellow	∅	HUMAN HEALTH & TOXINS
Sea lamprey wounds⁺ (p. 26)	Yellow	Thumbs up	Yellow	Thumbs up	Yellow	Thumbs up	BIODIVERSITY & AQUATIC INVASIVE SPECIES
Aquatic nuisance species arrivals (p. 27)	Blue	~	Blue	~	Yellow	Thumbs down	BIODIVERSITY & AQUATIC INVASIVE SPECIES
Water chestnut infestations (p. 30)	Blue	~	Yellow*	Thumbs up	Orange	Thumbs up	BIODIVERSITY & AQUATIC INVASIVE SPECIES

* The LaPlatte R. has improved, but no other rivers show a trend

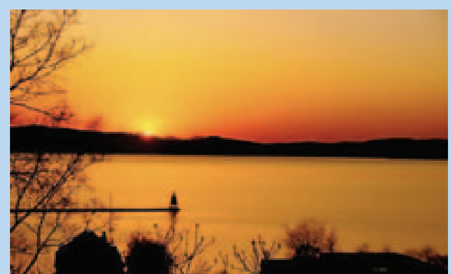
*Special advisories have been lifted for Cumberland Bay, NY.

* The South Lake has no monitored public beaches.

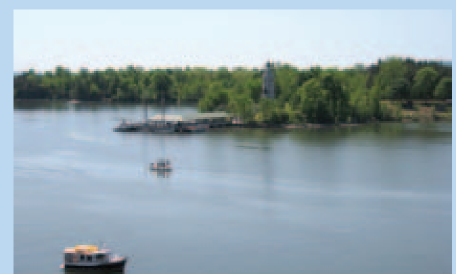
* Water chestnut is hand-pulled between Little Otter Creek and Crown Point; the rest of the Main Lake has no infestation.

⁺ These indicators are lake-wide; therefore, scores are the same across all lake segments.

MALLETTS BAY has deep cold water (up to 100 ft / 32m). Although its phosphorus target is low, increased runoff from developed land is a concern. The bay is popular for boating and fishing activities.



THE MAIN LAKE contains 81% of the Lake's water including the deepest, coldest water (up to 400 ft /129m). Population growth and mixed land use dominate the Vermont side and urban runoff is a concern. The New York side is more forested.



THE SOUTH LAKE includes all the waters south of the Crown Point Bridge. The segment is shallow and narrow, and phosphorus levels are high. Water chestnut and Eurasian watermilfoil interfere with recreation. The segment is popular for bass fishing.

LCBP PHOTOS

HOW IS THE **LAKE CHAMPLAIN FOOD WEB** CHANGING?

Recent studies have revealed long-term shifts in zooplankton populations that coincide with the introduction of aquatic invasive species. These changes affect the Lake's dynamic food web and may be associated with increases in cyanobacteria (blue-green algae) blooms.

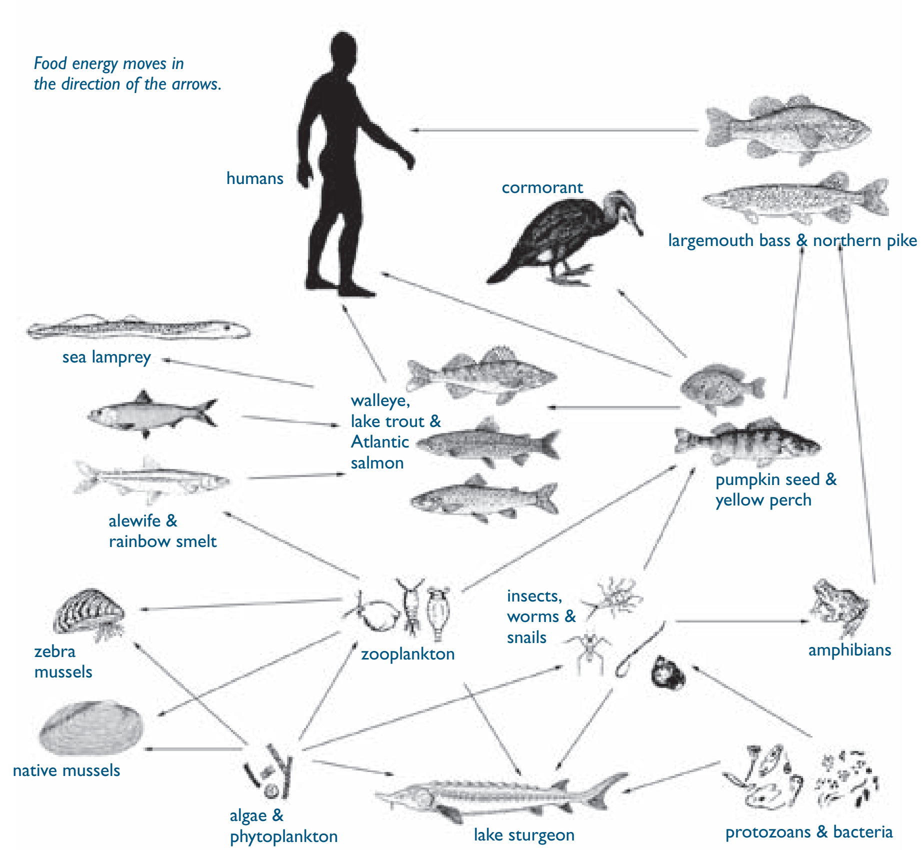


FIGURE 16 | LAKE CHAMPLAIN FOOD WEB


BERNIE PIENTKA, VT FWD

Invasive alewife (bottom) outcompete Lake Champlain's rainbow smelt (top).

Plankton—including microscopic floating plants (phytoplankton), animals (zooplankton), and bacteria—are the base of the food chain in Lake Champlain (Figure 16). Creating energy from nutrients and sunlight, they in turn fuel the entire lake ecosystem. Plankton populations vary widely by both season and Lake segment. Scientists have documented recent changes in the structure of these biological communities, such as declines in zooplankton populations. Changes in these populations can cause a ripple effect all the way up to the top predators, including Atlantic salmon and lake trout. White perch, zebra mussels, and alewife are among the invasive species in Lake Champlain that may be altering the plankton population, and there is no effective means for controlling these species.

White perch feed on zooplankton, including some larger species (*Daphnia*) that prey on cyanobacteria, potentially contributing to the cyanobacteria blooms in Missisquoi Bay. The white perch was first documented in the Lake in 1984, and is now the dominant fish species found in Missisquoi Bay. White perch feed on other fish eggs (especially walleye), and out-compete yellow perch and minnows for food.

Zebra mussels have heavily colonized the shallow-waters of the Main Lake, South Lake and parts of the Northeast Arm, but their populations in these lake segments appear to have stabilized. Zebra mussel populations in Malletts and

PIERRE LEDUC

Zebra mussels encrust an anchor that was submerged in Missisquoi Bay.

Missisquoi Bays are increasing, although at a much slower rate. Zebra mussels filter plankton out of the water column, increasing water clarity, but may improve conditions for cyanobacteria. Zebra mussels also out-compete native mussels, often colonizing on the hard surface of the larger native mussels and suffocating them.

Alewife are a small, nonnative invasive fish species, first found in Lake Champlain in 2003. Like white perch and zebra mussels, alewife prey on larger plankton, improving conditions for cyanobacteria. They compete with native fish such as rainbow smelt but are an unreliable food supply for larger fish such as salmon and trout. Alewife are sensitive to rapid changes in water temperature and are subject to large fluctuations in abundance that sometimes result in mass die-offs.

In 2008, a widespread alewife die-off occurred in the Lake, confirming that a large population had become established. The full impacts of alewife on Lake Champlain are yet to be realized. Biologists are concerned that the establishment of this fish species in the Lake and other Basin waters could become a major threat to native forage and game fish populations.

Alewife have become the dominant forage base in the Lake, replacing native rainbow smelt and, as a result, sport fish such as lake trout and Atlantic salmon now have diets rich in alewife. However, these altered diets cause reproductive problems in lake trout and salmon due to a thiamine vitamin deficiency.

The USFWS and Vermont Fish and Wildlife Department (VT FWD) conduct annual surveys of the open-water fish community. Data from these surveys suggests that native rainbow smelt numbers are declining while alewife are becoming more abundant. Alewife growth rates here are higher than those observed in Great Lakes populations, suggesting that alewife populations are still expanding in Lake Champlain.

HOW ARE THE **POPULATIONS OF SPORTFISH** CHANGING?

Increased angler catch rates and fish sizes at tournaments indicate a growth in the Lake's bass fishery, and Atlantic salmon have made record returns in recent years. However, stocking still is necessary to maintain the Atlantic salmon and lake trout fishery.

Lake Champlain has become a popular fishing destination, with more than 90 native and non-native fish species found in the Lake and its tributaries. A few of these are the foundation of an important sport fishery that provides many social and economic benefits.

LCBP

Larger fish caught at increasingly popular bass tournaments on Lake Champlain suggest growth of the fishery.

Lake Champlain has a reputation as a world-class bass fishery. The Lake's abundant smallmouth and largemouth bass are sought in increasing numbers during competitive tournaments each year. The angler catch rates and the size of fish at tournament weigh-ins have increased over the past four to five years. Other popular sport fish include the coldwater landlocked Atlantic salmon, lake trout, and cool-water species including pike, walleye, and perch.

The Basin's fish populations historically have been affected by overfishing and habitat destruction, increased pollution, and sedimentation. More recently, aquatic invasive species have emerged as a growing threat to native fish populations and habitat. Non-native fish that have colonized the Lake Champlain Basin include the alewife, tench, and white perch. Nuisance species, especially sea lamprey, also have significant impacts on salmon and trout.

Young lake trout are stocked by New York and Vermont agencies to re-establish their population and support recreational fishing. Although these stocked fish grow well and reproduce, there is little survival past the first year of life. Causes of mortality are not well understood; researchers who have observed predation pressure in shallow spawning areas believe that restoration may be more successful at deeper offshore sites.

Efforts to return landlocked Atlantic salmon to the Basin's rivers include stocking, habitat restoration, and improving fish passage. Record catch rates at fish passage ladders on the Boquet and Winooski Rivers illustrate the recent success of the management of the salmon fishery. Strong spawning runs in 2010 and 2011 broke annual catch records for both rivers. In 2011, 189 salmon were collected in the fish lift at the Winooski One hydroelectric facility, exceeding all previous records since the lift began operating in 1993. This improvement may likely be tied to changes in the stocking program as well as the resumption of a full-scale sea lamprey management program (see p.25 for details).

Efforts also are underway to restore Lake Champlain's population of muskellunge—commonly known as muskies. Now rare, these fish once were common in most of Lake Champlain. Since 2008, the VT FWD has released thousands of young muskies into the Missisquoi River and Missisquoi Bay in an effort to improve this fishery.

Lake sturgeon populations in Lake Champlain dropped dramatically in the first half of the 1900s due to commercial fishing and loss of spawning habitat, and the sturgeon is now a threatened species in New York and endangered in Vermont. VT FWD biologists have documented spawning activity in the Winooski, Lamoille, and Missisquoi Rivers, which are three of the four known historical spawning sites. Habitat improvements, public education, and continued protection efforts could put Lake Champlain's lake sturgeon on the road to recovery.

Lake whitefish are commercially important in the Great Lakes and were harvested in Lake Champlain until the fishery closed in the early 1900s. Currently their populations appear to be stable in the Main Lake, but they have become rare in Missisquoi Bay and the Northeast Arm, likely in part due to habitat degradation. Great Lakes populations have declined due to loss of prey and a switch to eating invasive zebra and quagga mussels; in contrast, the diet of lake whitefish in Lake Champlain is stable and they are not consuming zebra mussels.

Lake Champlain fishery management is coordinated by the Lake Champlain Fish and Wildlife Management Cooperative, a partnership of NYS DEC, VT FWD, and USFWS. Cooperative activities include assessing populations of salmon, trout, walleye and northern pike in Lake Champlain. The Lake Champlain Fisheries Technical Committee, a sub-committee of the Cooperative, released the Strategic Plan for Lake Champlain Fisheries in 2009. The new Strategic Plan is comprehensive and addresses fish communities and fisheries issues in Lake Champlain from salmon to smelt. The 2009 plan can be found at: http://www.fws.gov/lcfwro/FishTech.html.


LCBP

Atlantic salmon have returned to their spawning grounds in greater numbers as a result of more intensive stocking and control of predatory sea lamprey.

HOW HAS THE **IMPACT OF SEA LAMPREY** ON SALMON AND TROUT CHANGED?

The benefits of the long-term Lake Champlain Sea Lamprey Control Program initiated in 2001 have begun to be realized. Sea lamprey wounding on lake trout and salmon has dropped to the lowest rates since monitoring began in 1985.

Sea lamprey spawn in most tributaries to Lake Champlain, requiring management throughout the Basin (Figure 17). The sea lamprey control program in the Lake Champlain Basin uses tools and techniques such as barriers, traps, lampricides, and experimental projects including pheromones.

VT FWD

Sea lamprey wounding rates on lake trout have declined in recent years.

Sea lamprey populations were very high prior to these efforts, possibly as a consequence of past ecological imbalance and habitat changes that favor their growth.

The benefits of the long-term Lake Champlain Sea Lamprey Control Program initiated in 2001 have become apparent from salmon and trout assessments. Sea lamprey wounding rates decreased from a high of 79 wounds/100 fish to meet the target of 15 wounds/100 fish on Atlantic salmon in 2010. Both lake trout and salmon were within 5 wounds/100 fish of the targets set in 2011 for the first time since wounding rates were monitored in 1985 (Figure 18). Recent changes to the Program include improvements in tributary delta survey methods and more efficient chemical treatments, and the addition of new tributary systems (Lamoille, Missisquoi, and Winooski) to the treatment program.

There is still progress to be made, however. Substantial sea lamprey populations have been found in the LaPlatte River, for which control options are being evaluated. Sea lamprey spawning barriers are being considered for the Little Ausable River in New York and Morpion Stream, a secondary tributary of the Pike River, in Québec.

The application of lampricides to Lake Champlain tributaries has been a controversial management decision in the watershed. TFM (3-trifluoromethyl-4-nitrophenol) was discovered as an effective tool for controlling sea lamprey in the 1950s and was first used in the Basin in 1990 during the experimental sea lamprey control program (1990-1998). TFM is extremely effective at controlling sea lamprey in streams before they migrate to the Lake. As with any pesticide, there are non-target impacts; typically, amphibians bear the brunt of these impacts. Other native fish and invertebrates—particularly those that are already stressed—may be affected, although these impacts have generally been minimal for most of the lampricide applications in the Lake Champlain Basin. Fish species known to be sensitive to lampricide treatments include channel darter, stonecat, lake sturgeon, American brook lamprey, and eastern sand darter.

LCBP

The Great Chazy sea lamprey barrier prevents the species from moving upstream.

Strict regulations, permits, and coordinated management efforts in the

USFWS

A portable assessment trap captures sea lamprey as they swim upstream to spawn.

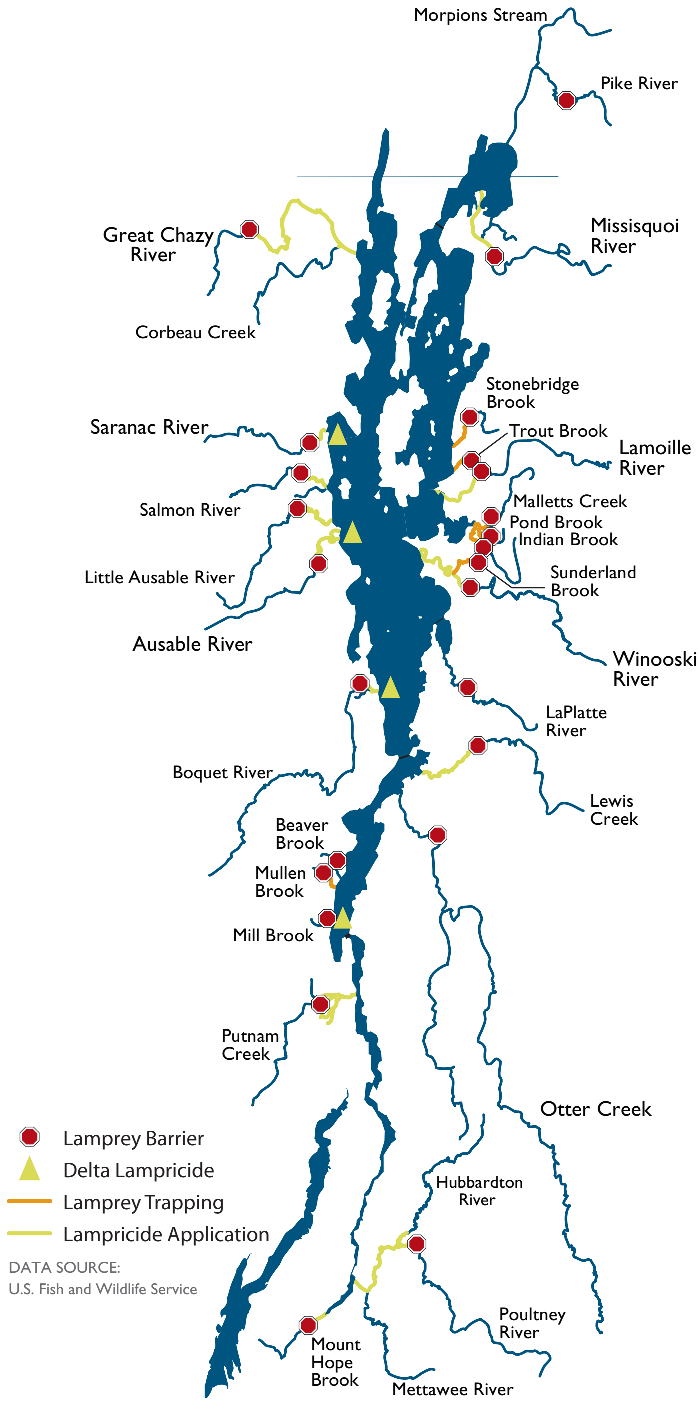
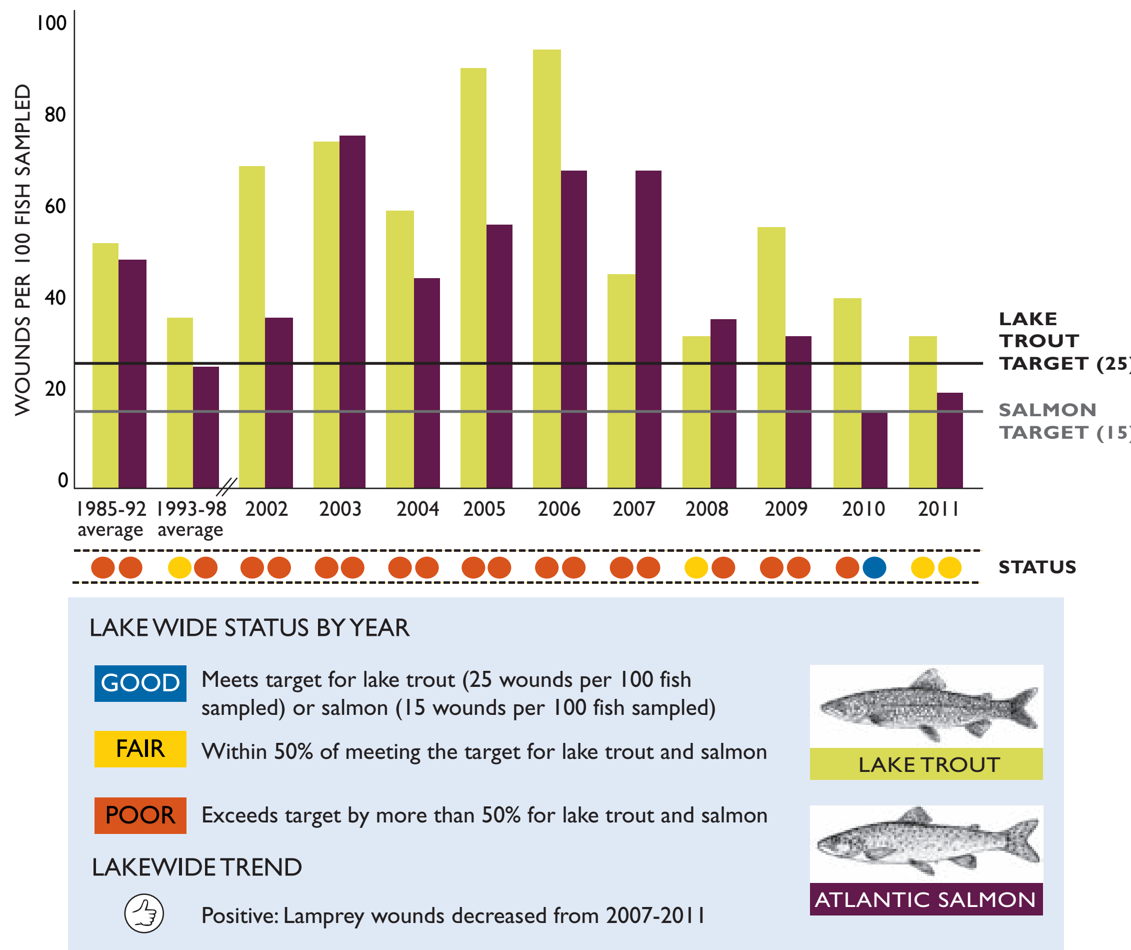


FIGURE 17 | LAKE CHAMPLAIN SEA LAMPREY CONTROL, THROUGH 2011



NOTES: Lake trout were 533-633mm (21-25 in) in length. Salmon were 432-533 mm (17-21 in) in length. 1982-92 was pre-control and experimental control was during 1993-98.

DATA SOURCE: Lake Champlain Fish and Wildlife Management Cooperative

FIGURE 18 | SEA LAMPREY WOUNDING RATES ON LAKE TROUT AND ATLANTIC SALMON

Basin among New York, Québec, and Vermont partners ensure that lampricide treatments are carried out safely and efficiently. Lampricide-treated tributaries and lake water quality are monitored closely before, during, and after treatments with proper public notice. Public water-intake facilities have the proper technologies to treat water during lampricide treatments. The Sea Lamprey Alternative Control Workgroup meets regularly in the Basin to explore and evaluate alternative non-chemical controls for sea lamprey with a goal of reducing chemical treatments in the Basin.

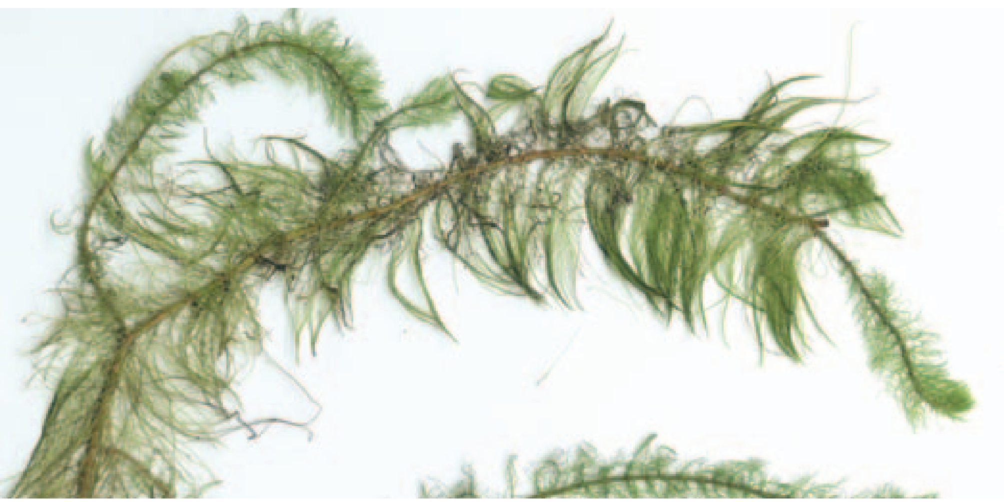
WHAT **NEW AQUATIC INVASIVE SPECIES** HAVE INVADED THE LAKE?

The most recent aquatic invasive species discovered in the Lake—and the only one since alewife in 2003—is variable-leaf watermilfoil (VLM).

As of 2011, Lake Champlain is home to 49 known aquatic non-native species, many of which are invasive (Figure 19). Aquatic invasive species (AIS) are non-native species (also referred to as alien, exotic or non-indigenous) that harm the aquatic environment, biodiversity, economy, or human health. AIS include aquatic plants, animals, and pathogens, and they may be intentionally or unintentionally introduced to the Basin. Once introduced into Lake Champlain, AIS have the potential to spread to other inland waters in the Basin.

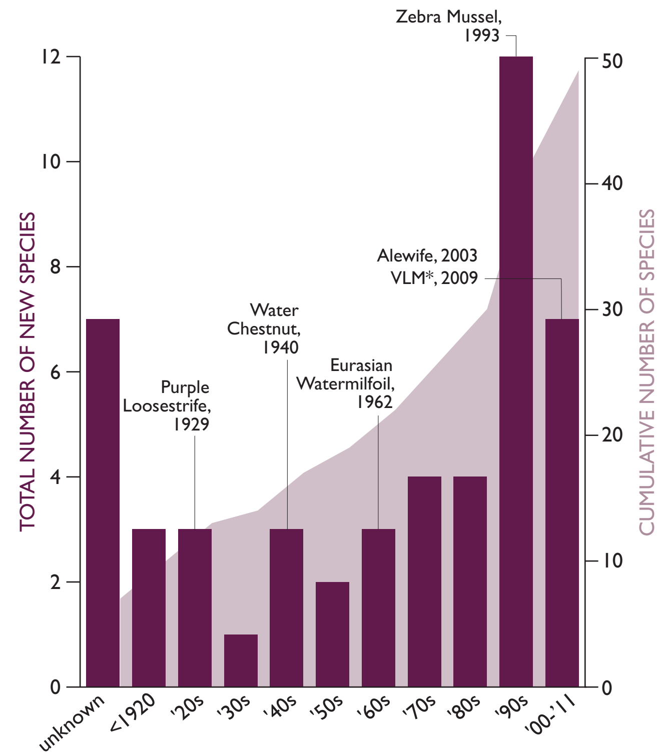
The arrival of new non-native and invasive species is an important indicator of the Lake's health. The indicator status is considered good if no non-native or invasive aquatic organisms have arrived in the past five years, fair if one or two have arrived, and poor if greater than two species have arrived.

Variable-leaf watermilfoil (VLM) is a rooted freshwater perennial plant that has similar impacts to lakes as Eurasian watermilfoil, but it is considered more invasive because it tolerates a wider range of habitat conditions. VLM was found in the US section of Missisquoi Bay in September 2009 by Vermont Department of Environmental Conservation (VT DEC) during a routine survey in a semi-isolated area. A spread of over 80 acres was also discovered in 2011 during a VT DEC water chestnut survey on the New York side of the South Lake. A species risk analysis, survey of the infestation, and review of management options were conducted by LCBP's Aquatic Invasive Species Rapid Response Task Force; the group determined that management action was not feasible due to the size of the infestation.



VTDEC

Variable-leaf watermilfoil is the most recent aquatic invasive species in Lake Champlain.



*Variable-leaf watermilfoil
NOTE: The data reflect the arrival decade or first reported sighting of the species.
DATA SOURCE: Ellen Marsden, University of Vermont

FIGURE 19 | AQUATIC NON-NATIVE AND INVASIVE SPECIES ARRIVALS TO LAKE CHAMPLAIN

WHAT AQUATIC INVASIVE SPECIES OUTSIDE THE BASIN POSE A THREAT?

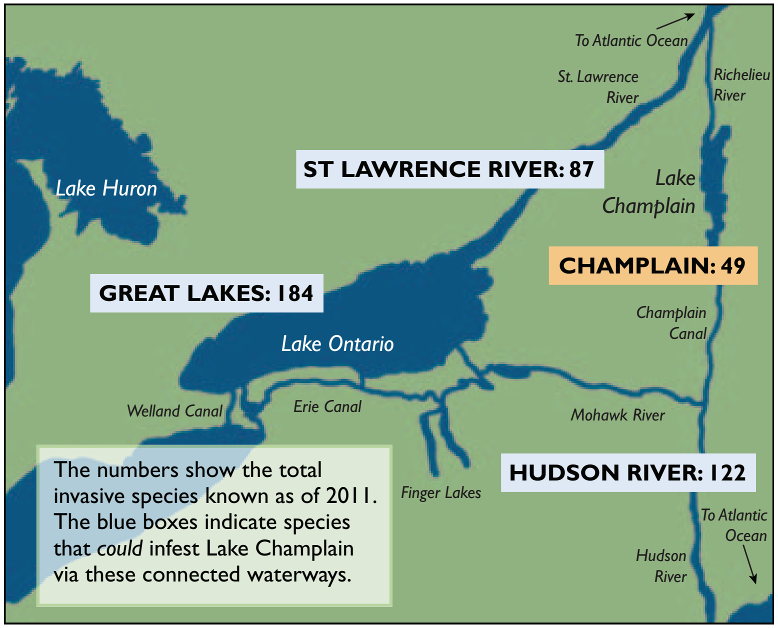
Round goby, documented in the Erie Canal and the St. Lawrence and Richelieu Rivers, Asian clam in Lake George, and spiny water flea in the Glens Falls Feeder Canal are three of the more threatening invasive species that are "on the doorstep" of Lake Champlain.

Invasive plants, animals, and pathogens can enter Lake Champlain through a variety of pathways, including release or movement of live bait, aquarium dumping, hitchhiking on boats and trailers, canal passage, and intentional stocking.

Waterways in the regions surrounding the Lake Champlain Basin are home to many invasive species that are not already in Lake Champlain (Figure 20). The Chambly Canal in Québec bypasses the rapids on the Richelieu River, which is north and downstream of Lake Champlain. This canal connects the 87 known non-native and invasive species in the St. Lawrence River to the Basin, while the Champlain Canal to the south is a conduit to the 122 species in the Hudson River. The Lake also is linked to the Great Lakes' vast number of threats by the Erie Canal. Many of the aquatic invasives that pose the greatest threat to Lake Champlain arrived to North America in ships' ballast water. These species include the spiny waterflea, Asian clam, hydrilla, quagga mussel, viral hemorrhagic septicemia, Asian carp, and round goby. All of the 49 known aquatic non-native and invasive species in Lake Champlain also can be found in these connecting systems.

Round goby are small-bottom dwelling fish, introduced to the Great Lakes through ballast water, that have spread rapidly through bait buckets and connected waterways after introduction. They are aggressive eaters that consume the eggs of native species such as trout. This species is moving east in the Erie Canal and south through the St. Lawrence and Richelieu Rivers.

In 2010, scientists discovered Asian clam in Lake George, NY, which drains to Lake Champlain through the Lachute River. While this is the first documented occurrence of this species in the Lake Champlain Basin, Asian clam also has been found in the Hudson drainage of the Champlain Canal, several other New England states, and Québec. This species was detected at an early stage



DATA SOURCE: UVM, Lake Champlain Sea Grant, Great Lakes Environmental Research Laboratory, Lafontaine and Costan 2002, and Strayer 2012.

FIGURE 20 | NON-NATIVE AND AQUATIC INVASIVE SPECIES THREATS TO LAKE CHAMPLAIN FROM CONNECTED WATERWAYS

MICHIGAN SEA GRANT

Round goby is one of several aquatic invasive species that are poised to enter the Basin.

in its invasion, improving chances of control. This small bivalve can impair water quality, out-compete native clams, and clog water intake systems. It also has been linked to algae blooms in Lake Tahoe. The Lake George Asian Clam Rapid Response Task Force was formed to explore how to best manage this population in Lake George. Post-treatment monitoring has shown that benthic barrier mats installed on the Lake bottom have been greater than 99% effective at smothering the clams. For more information about this program, go to: www.stoptheasianclam.info.

LAKE GEORGE ASSOCIATION

Researchers collect water samples from under benthic barrier mats to determine if Lake George's Asian clam treatment is successful.

WHAT ARE WE DOING TO PREVENT THE **ARRIVAL OF NEW INVASIVES** AND MANAGE THOSE ALREADY HERE?

Close collaboration among stakeholders is critical to the dynamic nature of invasive species management. Public education and outreach and new regulations that prohibit the transport of aquatic plants and certain invasive and nuisance species have been important management tools.

Once a species becomes established in the Lake, it is very difficult to control, making proactive early detection and monitoring programs critical when a new species arrives. Given the ease and speed with which invasives can travel among watersheds, coordination among jurisdictions is essential. Many partners work together in the Basin and at the regional and national levels on AIS early detection, control, spread prevention, education and outreach, and management. The LCBP is a member of the Northeast Aquatic Nuisance Species (NEANS) Panel and the National Aquatic Nuisance Species Task Force. The NEANS Panel recently created an online tool (www.northeastans.org/online-guide/) that enables local organizations to customize and print their own field guides to include the species most important to their work.

The LCBP has an Aquatic Nuisance Species Management Plan that sets priorities for AIS control and management in the Basin. This plan is eligible for USFWS funding to support programs such as water chestnut control and boat launch steward programs. Once a new invasive species has been identified, the Lake Champlain Basin Rapid Response Task Force will determine if control of the species is feasible.

The Lake Champlain Steward Program, supported by the LCBP since 2007, is modeled after the Paul Smith's College Adirondack Watershed Institute Stewardship Program. Each summer, stewards from Lake George, Lake Champlain, Paul Smith's College, and local lake associations train together to ensure a consistent AIS message is delivered to the public. Stewards collect data such as the state of vessel registration, the last body of water the vessel was in during the previous two weeks, and whether the boat owner takes measures to prevent the spread of AIS. These data document the potential risk of overland transport and help track spread prevention behavior over time.

LCBP

Transport on boats and trailers is a primary means of dispersal for aquatic invasive species.


LCBP

Volunteers who pull water chestnut by hand have been critical to the reduction of the invasive plant.

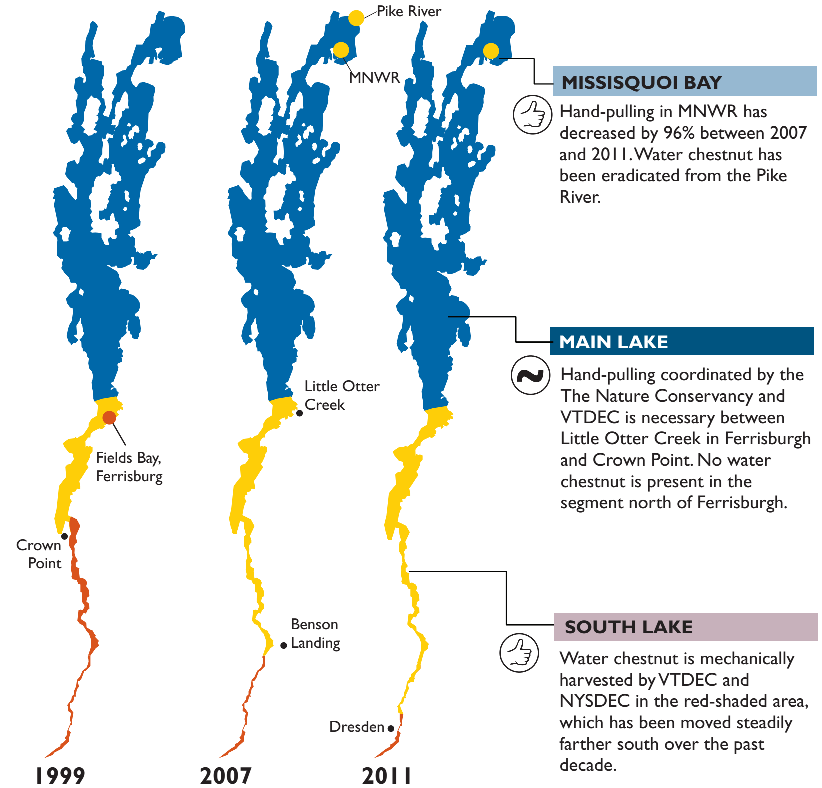
In 2010, eight stewards stationed around Lake Champlain inspected over 9,000 boats, trailers and equipment and spoke to over 19,000 lake users. An aquatic plant, animal or mud was found on 990 (11%) of these boats, 730 of which were AIS. Only 58% of users reported taking spread prevention measures. Many people trailer their vessels from waterbodies in other states and provinces in less than two weeks to Lake Champlain. The lake steward program is an important education and outreach initiative to prevent the introduction and spread of AIS hitchhiking on boats and trailers.

Water chestnut remains a major problem in Lake Champlain, but partners have made notable progress in controlling this species (Figure 21). It is known to occur in three places in Lake Champlain but also has infested other inland water bodies in the Basin. In the South Lake segment, it forms dense mats, limits boat traffic and recreational use, crowds out native plants, and creates an oxygen-depleted zone uninhabitable to fish and other organisms.

Mechanical harvesting has reduced the infestation steadily for the last decade, and in 2011 gained another mile of progress south, reaching a point 6.5 miles south of Benson, VT. An estimated 203 acres were mechanically harvested in 2011.

Partnerships with organizations like the Adirondack Park Invasive Plant Program and local watershed organizations are needed to reduce the spread of AIS. The New York State Canal Corporation has requested the US Army Corps of Engineers to conduct a feasibility study for an invasive species barrier on the Champlain Canal. The Lake Champlain Long-Term Monitoring Program has helped with early detection of spiny waterflea and Asian clam by monitoring the canals.

Local organizations working with state agencies have identified ways to improve AIS management in the Basin. General permits and quicker permitting processes for control activities have been developed to enable a rapid response to new infestations. New baitfish regulations prohibit the movement of live fish from one body of water to another and support the use of disease-free certified bait. In Vermont, an aquatic transport law enacted in 2010 prohibits transport of aquatic plants or quagga and zebra mussels on boats, trailers, and equipment; New York is developing similar legislation. Felt-soled waders have been prohibited in Vermont since 2011 in an effort to prevent the movement of river species such as didymo and New Zealand mudsnail.



STATUS

GOOD	No water chestnut present and no management needed
FAIR	Water chestnut present with less than 25% coverage (typically managed hand-pulling)
POOR	Water chestnut present with greater than 25% coverage (typically managed by mechanical harvesting) in an area covering greater than 10% of the segment

TREND

- Improving: water chestnut is decreasing
- No trend: neither improving nor deteriorating
- Deteriorating: water chestnut is increasing
- No trend data is available

DATA SOURCES: VTDEC, NYSDEC, QC MDDEP

FIGURE 21 | STATUS OF WATER CHESTNUT INFESTATIONS IN LAKE CHAMPLAIN

HOW DO **CORMORANTS** AFFECT FISH POPULATIONS IN THE LAKE?

Although some anglers have expressed concern that foraging by double-crested cormorants may be bad for fishing, there is no scientific information linking cormorants to the suppression of fish populations in the Lake.

Many people consider the double-crested cormorant to be a nuisance species in Lake Champlain. The islands where these large fish-eating birds nest become defoliated due to their highly acidic droppings. In the past, researchers noted that cormorants on Lake Champlain foraged mostly on yellow perch, but more recently, a major shift to alewife (invasive fish) has been clearly documented. Claims that double-crested cormorants have affected fish populations have not yet been validated. Management agencies are developing a new population goal for the Lake Champlain cormorant population, which will help determine if a response in fish populations can be detected.

Double-crested cormorants do, however, impact populations of other colonial nesting birds, including the common tern. The common tern is a Vermont state endangered species that nests on small islands in Lake Champlain. The tern population declined from more than 300 pairs to just 50 pairs in the late 1980s as a result of nocturnal avian predation, competition for nest space with ring-billed gulls and double-crested cormorants, and human disturbance. With LCBP funding, Vermont Audubon and VT FWD partnered in the Vermont Common Tern Recovery Project to protect common tern nesting grounds through management and acquisition. As a result, common tern populations have been restored to just over 200 pairs.

Management techniques for reducing the double-crested cormorant population on Lake Champlain include egg-oiling and culling with firearms. From 2008-2011, the growth of nesting cormorant populations stabilized as a result of management. However, continued oiling of eggs and an aggressive culling program in 2011 resulted in a drop of more than 50% of the nesting population on Lake Champlain.


LCBP

Audubon Vermont protects common tern habitat from cormorant and other species.


LCBP

Nesting populations of cormorants were down 50% in early 2012.

WHAT YOU CAN DO

Inspect Your Boat: Remove mud and plants before leaving any body of water. Remove anything you find to prevent the spread of aquatic hitchhikers.

Drain all Water: Empty the bilge, live well, and engine cooling system

Dry Your Boat: (and trailer) Keep it in the sun for at least five days, or clean your boat if using it sooner.

Plant Native: Flowers, trees and shrubs should be native species.

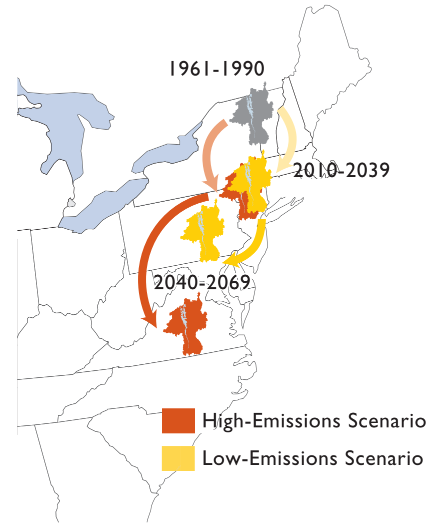
Visit **www.lcbp.org/lcstate.htm** for more tips.

HOW DOES **CLIMATE CHANGE** AFFECT LAKE CHAMPLAIN?

Slight changes in climate result in significant ecological consequences, which already are affecting fish, wildlife, and plant communities as well as human uses of the Lake.

Water temperature, air temperature, and precipitation data collected within the Lake Champlain Basin provide strong evidence that accelerated changes to our climate have been occurring here for decades and are likely to continue. Resource managers and stakeholders recognize the need for both individuals and communities to adapt to climate change. Climate adaptation strategies mitigate the environmental, economic, and social risks associated with climate change.

The economic, social, and political choices that are made, both locally and globally, in the coming years will determine whether the climate of the Lake Champlain Basin will more closely resemble those of Pennsylvania or Northern Virginia 60 years from now (Figure 22). Predicted climate change outcomes based on published emissions scenarios describe a compelling need for policies to reduce regional and global emissions of greenhouse gases. Responsible stewardship of the Lake Champlain Basin requires management and policy planning to address likely outcomes of different future scenarios in order to mitigate increasing environmental pressures and protect Lake water quality and ecosystem integrity.



Red arrows track the shift in the Lake Champlain Basin's summer climate over the next 60 years if we continue under a high-emissions scenario. Yellow arrows track the shift under a low-emissions scenario.

DATA SOURCE: Adapted from Union of Concerned Scientists.

FIGURE 22 | LAKE CHAMPLAIN CLIMATE CHANGE PROJECTIONS

Trends in climate data in the Lake Champlain Basin

Scientists have noted significant changes in meteorological and surface monitoring data. Average August surface water temperatures have increased in Lake Champlain as much as 6.8°F (3.8°C) since monitoring began in 1964. Additionally, the average air temperature in the region increased by 2.2°F (1.2°C) from 1976 to 2005. This increase corresponds with data throughout the Northeastern United States and Great Lakes. Precipitation also is showing an upward trend; the average annual

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Lake flooding and sediment loading likely will increase with more frequent extreme storm events.

What is the difference between weather and climate?

In the ongoing debate about climate change, some people wonder what scientists mean by "global warming" when winter in the Lake Champlain Basin often still includes bitter low temperatures, blustery wind, and snow and ice. The temperature or precipitation observed during any given storm event is *weather*—the atmospheric conditions at a particular point in time. An average of temperatures and precipitation over several decades is *climate*—the major weather pattern over time. The term "climate change" refers to a long-term shift in weather patterns on a global scale.


LCBP
Reduced mountain snowmelt in the spring will mean lower lake and groundwater levels.

precipitation over the past 40 years has increased 3 inches as compared to the prior 80 years.

Changes in the Basin's climate and potential consequences

Climate change is causing seasonal weather shifts within the Lake Champlain Basin. More winter precipitation now falls as rain than snow as a result of increased air temperatures. With less snowmelt, spring lake and groundwater levels are reduced, altering the natural fluctuation in water level that is necessary to maintain wetlands and support spring spawning of fish and amphibians. Climate changes can have a detrimental impact on the reproductive success of many native flora and fauna.

The number of storm events in the summer months is decreasing, but the intensity of those storms is increasing. Heavy rains during intense storms lead to flash floods in rivers and streams. Streambank erosion and municipal combined sewer overflows are hazards during flood events, carrying increased nutrient and contaminant loads to the Lake. Increased nutrient levels in Lake Champlain promote the growth of potentially toxic algae blooms. Biodiversity also is affected by high flood waters, which increase access for invasive species to spread to new areas.

Climate change and water temperature

Records dating back to 1816 show that Lake Champlain's average surface water temperatures have been increasing for some time. Lake Champlain has frozen-over less frequently in the last 50 years than in the prior 130 years and the data show that this trend might be accelerating. Reduced ice cover causes the Lake to warm earlier in the calendar year. Long-term declining ice cover certainly will limit ice fishing, a popular winter activity linked to local economies.

Increases in maximum surface water temperatures lengthen the season when water layers are different temperatures at different depths. This long-term thermal stratification, combined with enhanced nutrient content, may intensify potentially toxic algae blooms. Toxic or not, algae blooms degrade water quality and reduce dissolved oxygen, depriving fish and other aquatic life of oxygen needed for respiration. In addition to these ecological impacts of algae blooms, toxic algae blooms threaten human and animal health.

Upward trends in water temperature also threaten Lake Champlain's capacity to support native cold-water fish species. In many parts of North America, warmer water temperatures reduce spawning success of native cold-water fish (salmon and trout) and cool-water fish (walleye and northern pike). Simultaneously, warm-water fish species (bass and invasive white perch) have increased.

Climate change and ecological disturbance

Climate change affects the physical environment and the chemical composition of water in Lake Champlain. Flooding and other changes in the physical and chemical environment put highly adaptive invasive species at an advantage over native species. Climate change coupled with the potential spread of invasive species is the largest threat to the Lake Champlain Basin's biodiversity.

Climate adaptation: Increasing resiliency in the Lake Champlain Basin

Stakeholders in the Basin are now focused on climate adaptation through increased resiliency. By addressing sources of water quality degradation that are still within human control, stakeholders can reduce the potential impacts of climate change on the Lake. Floodplain planning and mitigation of stormwater runoff are two measures being implemented to increase the Lake Champlain Basin's resiliency to global climate change.

A recently completed LCBP-funded study found that, due to the increasing likelihood of more intense storm events, phosphorus loads from the Missisquoi River Basin could increase as much as 46% and sediment loads as much as 57% over current loading rates. Given these predictions, implementation of best management practices in the most critical areas of this watershed are all the more important to mitigate impacts from intense storms by reducing the amount of nutrients washed into the Lake.

WHAT YOU CAN DO

Plant Buffers: Volunteer to plant riparian buffers with a local watershed group. The roots will hold the soil in place and protect habitat and water quality downstream.

Defend against Invaders: Plant native plants that will compete with invasives for habitat.

Dump NO Bait in the Lake: Dispose of your leftover bait in trash receptacles away from waterbodies.

Get More Pervious: Minimize impervious surfaces like driveways, sidewalks, and roofs.

Catch the Drip: Install rain barrels to catch your roof runoff…. then water your flower garden.

Visit **www.lcbp.org/lcstate.htm** for more tips.

WHAT WERE **THE HUMAN IMPACTS** OF THE 2011 FLOODING?

Prolonged record spring Lake levels and flash flooding during Tropical Storm Irene in August caused loss of life and damage to riparian habitat, crops, homes, and infrastructure in five of the Basin's eight major watersheds.

High winter snowmelts coupled with intense spring rainfall led to an extended period of record-high lake levels. A new record of 103.2 ft for Lake Champlain was set in May, 2011 (Figure 23). At this level, the Lake's surface area increased by nearly 15% and its volume increased 13% above normal. Wave action in the high water conditions caused extensive shoreline erosion, damaging property and contributing enormous volumes of sediment to the Lake. Landslides and slope failures along streams were reported throughout the period of high water, which lasted from mid-April through June. Road damage totaled nearly $8 million dollars in New York and Vermont. Along the Richelieu River in Québec, 3,000 homes were damaged or destroyed and nearly 1,000 people displaced. Unsafe drinking water and sanitation issues plagued waterfront communities for weeks. Québec Premier Charest, upon viewing the damage said, "Il faut, devant des circonstances exceptionnelles, prendre des moyens exceptionnels." ("We must, in these exceptional circumstances, take exceptional measures.")

In August, more than 230 municipalities were directly affected by the sudden catastrophe of Tropical Storm Irene. Projected restoration costs are greater than $150 million in New York and Vermont. As of November 2011, 8,075 individuals and families had registered for aid through the Federal Emergency Management Agency (FEMA). The Vermont state highway system reported more than 500 miles of damaged road and the loss of 200 bridges. New York recorded 400 road segments and bridges were impaired as a result of the storm. Many more municipal roads were destroyed or compromised.

All agricultural crops touched by flood waters were deemed unfit for consumption by the US Food and Drug Administration and had to be destroyed, at a loss of over $10 million. Many successful farms lie on fertile floodplains, making them particularly vulnerable to damage during high-flow events. Loss of a single year's crop may impact a farm's revenue for years afterward. Sediments, hazardous waste and fuel spills contributed to contaminated water supplies and extensive crop losses. These damages illustrate the hazards and vulnerabilities of both the built and natural environments in the region.

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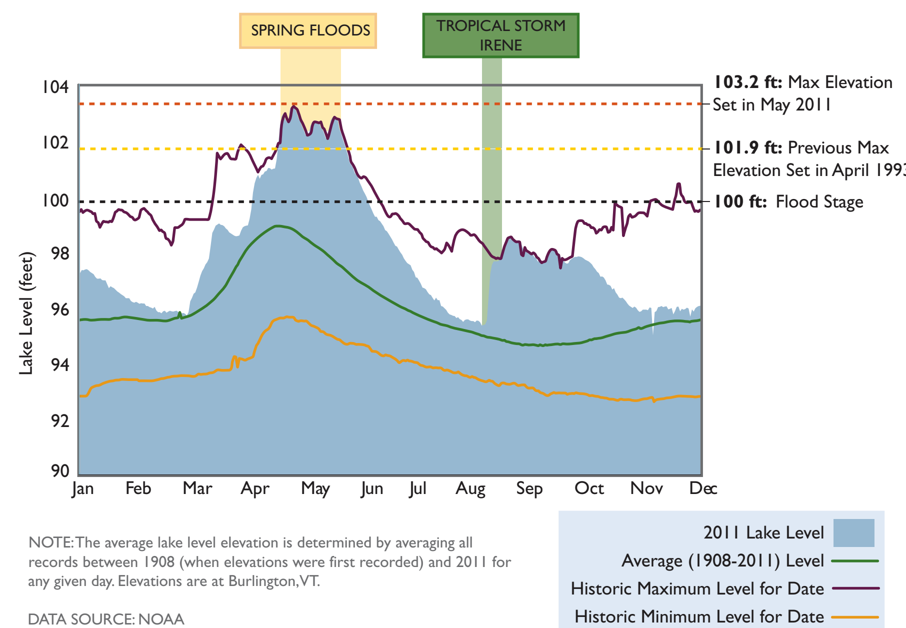
Damage to infrastructure and property in the wake of Tropical Storm Irene was extensive and devastating.

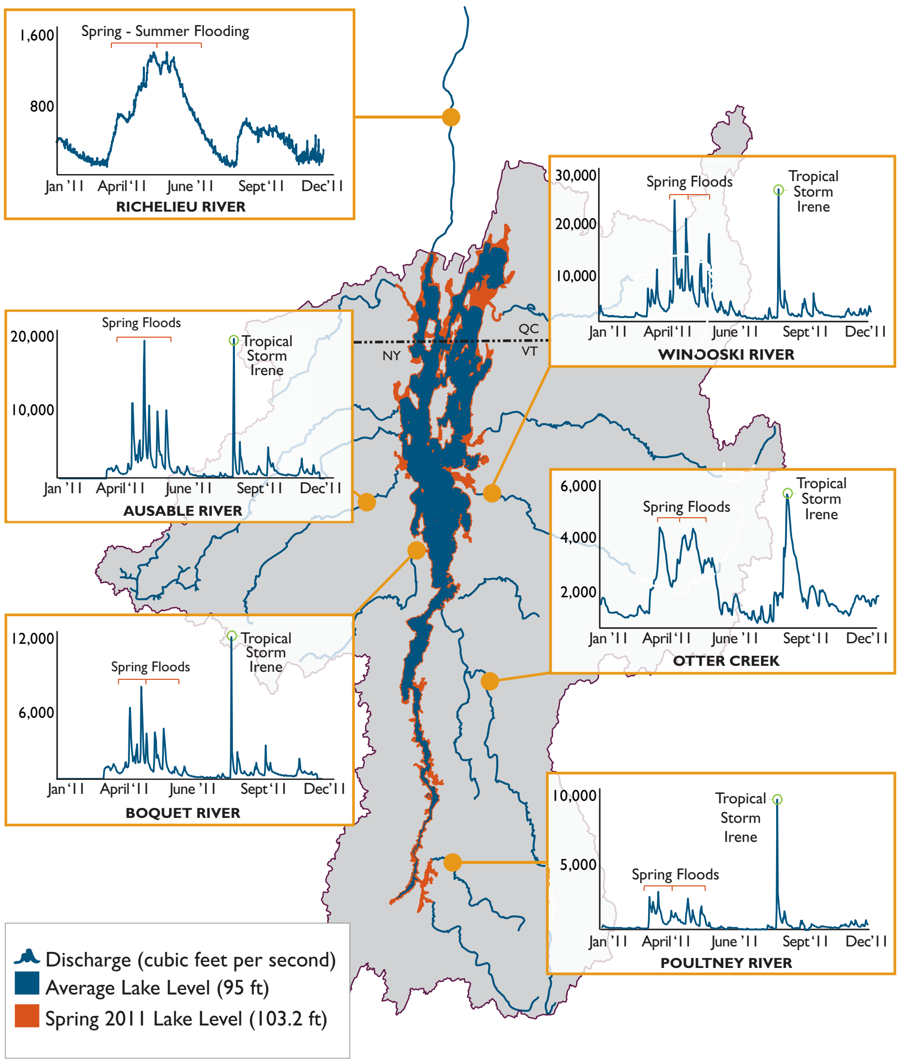


NOTE: The average lake level elevation is determined by averaging all records between 1908 (when elevations were first recorded) and 2011 for any given day. Elevations are at Burlington, VT.

DATA SOURCE: NOAA

FIGURE 23 | 2011 LAKE CHAMPLAIN ELEVATION

WHAT WERE SOME KEY **ENVIRONMENTAL IMPACTS** OF THE 2011 FLOODS?



NOTE: Scaling of vertical axes is different among graphs.
DATA SOURCE: USGS, Environment Canada.

FIGURE 24 | TRIBUTARY FLOW DURING SPRING 2011 FLOODING

The extent to which the 2011 floods affected the Lake Champlain Basin's environment is not yet fully known. Spread of invasive species, an unprecedented sediment load, and increased cyanobacteria (blue-green algae) blooms as a result of an enormous phosphorus load are the most likely outcomes.

Degraded water quality was one of the greatest concerns after the floods. While preliminary data suggest the spring flooding of 2011 did not produce significant coliform

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The Winooski River delivered an enormous load of sediment and phosphorus to the Lake during the spring 2011 flooding.

Powerful wave action can deliver nutrients to the Lake from shoreline erosion.

LCBP

bacterial contamination of Lake Champlain, the enormous tributary discharge did result in increased sediment load, decreased water clarity, and elevated nutrient levels (Figure 24). The long-term effect of the substantial phosphorus loads in flood-affected tributaries is uncertain, but increased cyanobacteria blooms were observed in summer of 2011. Waterborne bacteria were considered a major human health threat during the long-lasting spring floods in Québec. Potentially hazardous waste was mobilized along shorelines, possibly contaminating downstream sediments. Several wastewater treatment facilities in Vermont reported compromised systems and one facility in New York stopped functioning during the Irene flooding. Many septic systems failed as well. Several municipalities have since planned modifications to existing wastewater treatment structures to prevent future flood-related damage.

Though fish and macroinvertebrate populations are often known to survive catastrophic hydrologic events, it is still unclear what long-term effects the flooding will have on aquatic organisms in the Basin. Invasive species—such as Japanese knotweed, which grows by sprouting from broken plant roots and rapidly colonizes disturbed ground—were spread along with flood debris and high water.

Scientists have studied river dynamics and fluvial geomorphology for decades to better understand river, shoreline, and wetland responses to human disturbance and environmental events. Significant impacts on these features from intense rain events and floods highlight the need to allow rivers to access their floodplains, which will reduce erosion and damage to infrastructure. Rivers and streams are best able to absorb the impacts of major weather events when they are allowed to move naturally. In some cases, allowing the river to access the floodplain will help to slow the flow of water and provide an area for sediment deposition. In other cases, streambank restoration projects may include vegetative buffers to help protect against erosion, thus reducing the amount of sediment-bound phosphorus coming into the Lake and further protecting habitat and biodiversity. The USFWS continues to partner with LCBP, New York, and Vermont to identify valuable wetlands in need of restoration, and funding sources to protect those areas.

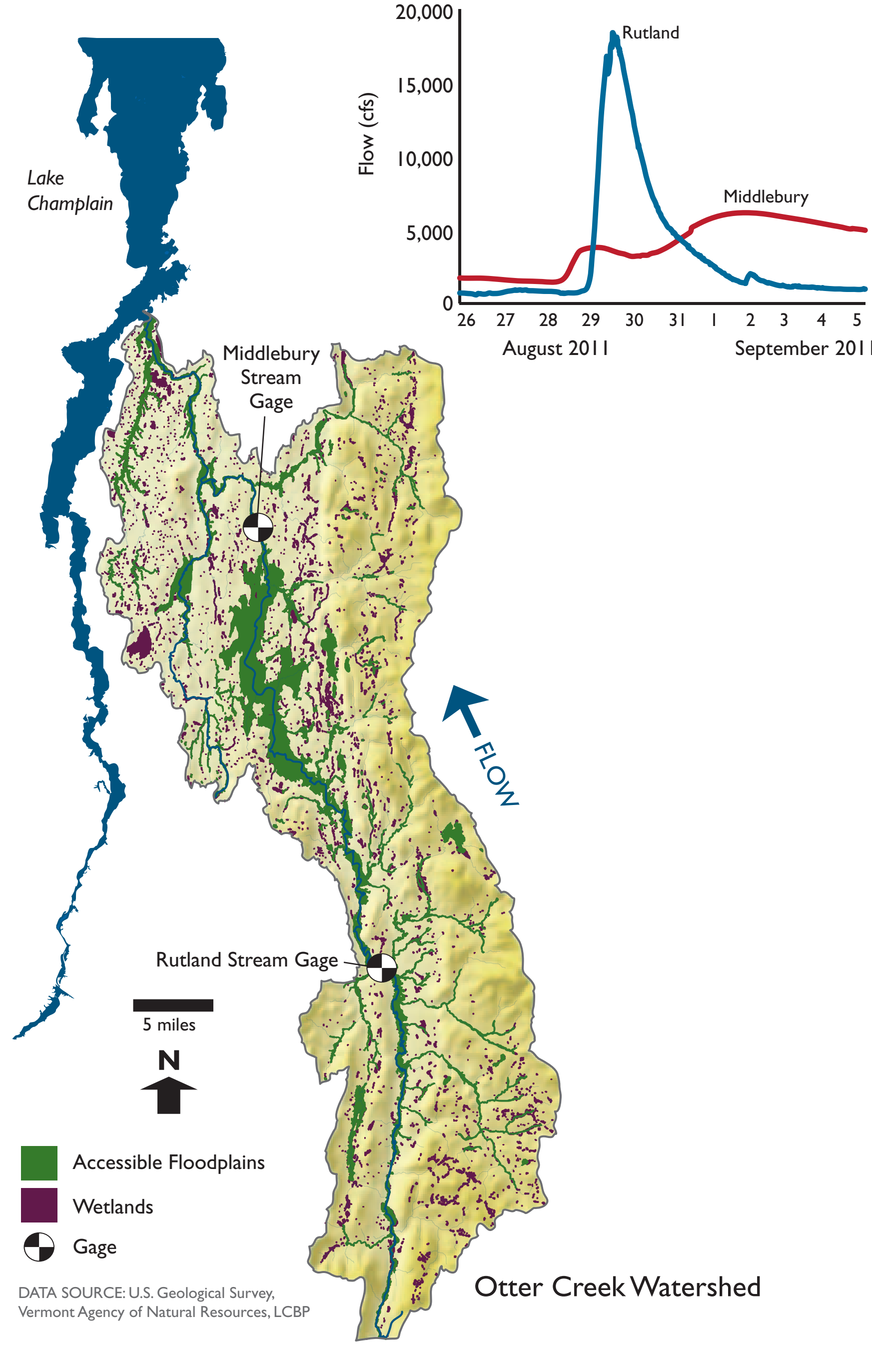


FIGURE 25 | FLOODPLAIN ACCESS IN OTTER CREEK WATERSHED

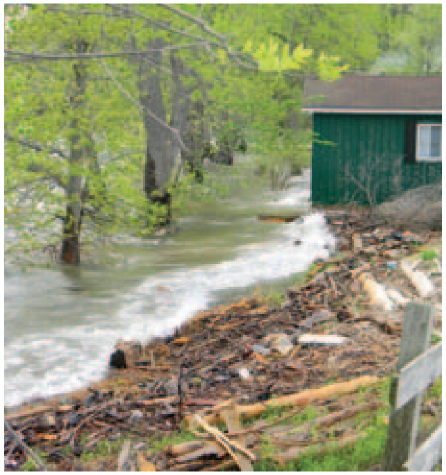
WHAT WORKS TO **PREVENT DAMAGE** FROM FUTURE FLOODS?

The most important action we can take to prevent flood damage is to build less in flood-prone areas and to ensure that rivers have access to their floodplains.

With climate change data suggesting more frequent high-intensity rainfall events in the future, it is important to plan ahead and accommodate future flooding by minimizing flood zone development and ensuring that floodwaters, and the sediments and nutrients they carry, can flow into broad floodplains.

Future restoration strategies will promote flood-resilient communities, considering both the short- and long-term consequences of change. A focus on protecting our shorelines with natural vegetation and promoting sustainable development that can coevolve with the natural ecosystem has become sharper since the floods. The Otter Creek watershed is a good example of a stream that is connected to its floodplain, with lower downstream peak flows than those on channelized streams with developed floodplains (Figure 25). Every action which hastens the drainage of water within the watershed also increases the rate at which rivers rise during floods.

While residents of all communities at risk of flood damage should have national flood insurance, community participation in the National Flood Insurance Program must not be equated with a license to encourage development in harm's way. The floods of 2011 clearly demonstrated that minimum standards for flood zone planning in the Lake Champlain Basin are woefully inadequate to address the flood resiliency needs of the future.


LCBP

Floodplain zoning standards will help alleviate damage from future storms.


LCBP

Floodplains and wetlands absorb floodwaters and filter sediment and pollution during extreme rain events.

Big Yellow Machines in the Streams

Good river management practices limit channel dredging and gravel extraction from streambeds due to habitat damage and the risk of increased downstream flooding. The shape of a stream reflects the balance of water, slope and sediment, a balance that changes during a large flood. Immediately after Irene hit, there were efforts to return eroded streams back to their pre-flood shape. In an emergency state, some dredging was permitted for the sake of preserving human life and property. Active "Big Yellow Machines" in the streambed was a necessary, localized, short-term strategy to ensure public safety in highly damaged areas. Unfortunately, in some streams, the excavations and site work went beyond addressing public safety needs, creating conditions in which future flood events could cause even greater damage. Long-term designs are needed to promote flood resilience and river corridor protection for the benefit of both the natural environment and the community. The experience of Tropical Storm Irene has motivated managers in each jurisdiction to redesign their emergency response procedures to ensure that short-term flood response measures keep long-term management needs in mind.


VT DEC

WHAT IS THE STATE OF THE LAKE?

Excess phosphorus remains a concern throughout the Lake. Wastewater treatment facilities are meeting their targets, and loading trends in a few tributaries have improved over the last decade, but much work remains in reducing nutrients from the landscape. Until phosphorus concentrations in the Lake are reduced, algae blooms will occur when weather conditions are favorable. Beach closures are less frequent than in the past, but they do continue, especially near urban areas. Improvements to WWTFs and reductions of combined sewer overflow will help reduce closures in the future.

Management of fish, plants, and wildlife remains a vitally important challenge. Sea lamprey control efforts have been very successful in achieving targets for lake trout and Atlantic salmon but at the cost of introducing lampricides into waterways. Fish consumption advisories for mercury and PCBs remain in place for many species, but New York's recent lifting of special consumption advisories for Cumberland Bay and recent data showing decreases in mercury in fish tissue are encouraging. New invasive species are poised to enter the Basin from all directions, but the rate of invasions has been reduced since 2000. Asian clam, now in Lake George, is one step closer to Lake Champlain, and infestations of a new watermilfoil species have been found at both ends of the Lake. Much progress has been made in the effort to control the impact of water chestnut.

Flood resiliency has dominated lake and tributary discussions since 2011. Preliminary analyses indicate that nutrient delivery to the Lake from most tributaries was well above the 20-year average, and in-lake phosphorus concentrations were above average as well. Management agencies around the Basin are developing flood resiliency plans to mitigate impacts of flood events in the future.

A more detailed answer must be given in terms of the five segments of Lake Champlain; each has its own conditions, and its own story. The map here summarizes water quality (WQ), human health (HH), and aquatic invasive species (AIS) issues for each Lake segment.

NORTHEAST ARM

WQ: The Northeast Arm and St. Albans Bay consistently exceed phosphorus targets, and the long-term trend is increasing. WWTFs are well below established targets, so the primary problem is nonpoint source loads.

HH: Algae blooms, though rarely toxic, occur frequently. Some public beaches have been closed numerous times since 2008. The St. Albans Bay State Park was closed on nine occasions from 2010-11.

AIS: No new invasives have been found in this lake segment. Growth of nuisance vegetation continues to be a concern for lakeshore residents.

MISSISQUOI BAY

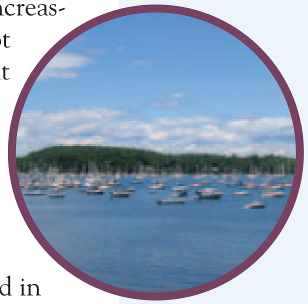
WQ: Annual phosphorus concentrations are still well above target, but have been fairly stable since 2004. Phosphorus loads from the Pike River have decreased, but loads from other tributaries have not significantly changed.

HH: Excess nutrients still cause frequent harmful algae blooms in most but not all recent years, affecting water supplies and leading to closure of public beaches.

AIS: The water chestnut infestation in the Missisquoi National Wildlife Refuge is steadily decreasing, although infestations from a new species—variable-leaf watermilfoil found here in 2009—are cause for concern.

MALLETTS BAY

WQ: Phosphorus concentrations have been increasing slightly since 1979; annual targets have not been met consistently since the mid-1990s, but the target for Malletts Bay is very rigorous (10 µg/l).



HH: Algae blooms are not yet a problem here. Beach closures due to bacteria do occur occasionally.

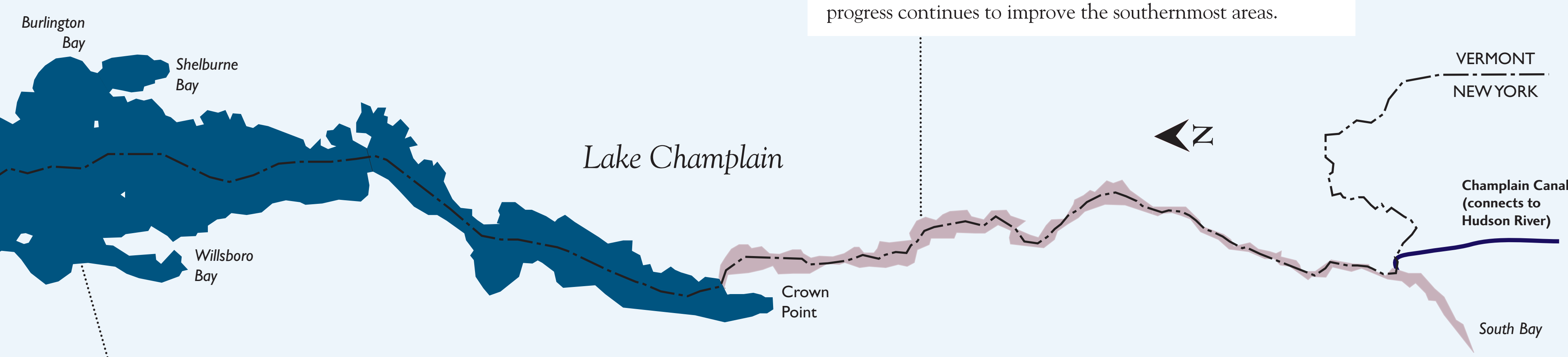
AIS: No new invasive species have been found in this lake segment.

SOUTH LAKE

WQ: The southernmost section (South Lake B) has a very high annual phosphorus target (54 µg/l) which has been achieved consistently since 2006. South Lake A has never met its target (25 µg/l) and frequently is well above it. Phosphorus from WWTFs is well below the target for this segment.

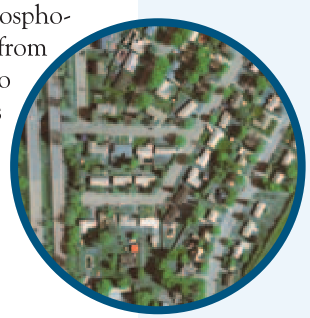
HH: Despite high phosphorus levels, algae blooms are infrequent. There are no public beaches in this lake segment.

AIS: A new invasive species, variable-leaf watermilfoil, was documented here in 2011. Dense water chestnut infestations are now more than 20 miles south of where they were in 1999, a notable success story. Infestations north of Dresden Narrows have been effectively managed, and progress continues to improve the southernmost areas.



MAIN LAKE or BROAD LAKE

WQ: Burlington, Shelburne, and Cumberland Bays have all met annual phosphorus targets at least seven times in the last 10 years. Phosphorus contributed from WWTFs is less than half of the target, but nonpoint sources are estimated to deliver three times more than target levels. A few tributaries contribute less phosphorus to the Lake now than in 1990.



HH: Small, localized algae blooms have become more frequent, and toxic bloom conditions have been detected for brief periods in local areas every year since 2009. Beach closures occur occasionally in Chittenden and Addison counties of Vermont and the Plattsburgh, New York area.

AIS: No new invasive species have been found in this Lake segment.

WQ: water quality
HH: human health
AIS: aquatic invasive species

HOW ARE **RECREATION AND A HEALTHY ENVIRONMENT** RELATED?

Severe weather events, which are predicted to be more common as a result of climate changes, can affect much of the natural and cultural resources and infrastructure on which recreation in the Basin depends.

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Windsurfers flock to Cumberland Bay on windy days.

The Lake Champlain Basin has a wealth of recreational opportunities. From downhill skiing to water skiing, hunting to hiking and birding to boating, the economy of the region relies on a healthy environment. Recreational experiences in the Basin foster appreciation of the watershed and increase personal commitments to stewardship.

Tourism studies have shown that visitors describe the region as "beautiful", "natural", "authentic", and "respectful of the environment." Environmental issues, including cyanobacteria blooms, beach closures and alewife die-offs, can threaten these public perceptions. Increasingly, recreation and the tourist economy are directly affected by environmental changes and events such as the floods of 2011. Predicted climate change such as warmer temperatures and reduced ice cover will further affect recreation, especially winter activities like ice fishing, ice skating, and skiing.

Fishing is especially important to the quality of life and economy of the Lake Champlain Basin. Of over 90 species of fish in the Basin, about 20 are sportfish prized by anglers. While the 2011 spring flooding may have helped some species, Tropical Storm Irene devastated habitats for fish that spawn in the Lake's tributaries, such as brook trout. Sedimentation caused by streambank erosion reduced spawning habitats by covering up gravel needed for spawning. In addition, recovery efforts after the floods included stream channelization and dredging that compromised fish habitat in Lake Champlain tributaries.

Marinas, ferries, boat tours and other lake-dependent businesses lost revenue from flood damage and the resulting late start to the 2011 season. High water battered the lakeside Burlington Bike Path and severely damaged the Island Line Causeway. It is estimated there are more than 150,000 user visits each year to the Bike Path and Causeway, with 30% of users coming from outside Chittenden and Grand Isle counties. An estimated $2 million in repairs to these waterfront trails will be completed in 2012.

With Lake Champlain's vital role in the formation of the United States and the industrial and agricultural development of the region, the importance of long-term stewardship of the water resources that sustain us is a timely and relevant historical theme. The link between cultural and natural heritage is supported by the management plan for the Champlain Valley National Heritage Partnership (CVNHP), which was approved by the US Department of Interior in 2011. The new national heritage area provides support and funding for projects and programs associated with the interpretive themes "Making of Nations," "Corridor of Commerce," and "Conservation and Community." The latter focuses on the traditional and contemporary human interaction with the landscape and enables the LCBP—the managing entity of the CVNHP—to better integrate the interpretation of environmental issues with cultural heritage.

LCBP

History comes alive on the shores of Lake Champlain at Fort Ticonderoga, whose capture was critical early in the Revolutionary War.

The *State of the Lake 2008* report described the preparations for the Quadricentennial of Samuel de Champlain's 1609 exploration of his namesake lake. The LCBP provided 38 grants totaling $386,803 to support quadricentennial anniversary programs and events. In addition, the LCBP has supported four voyages of the *Lois McClure* since the last report: a journey to Québec City in 2008, a lake-wide Quadricentennial cruise in 2009, a trip along the Erie Canal in 2010, and the "Forest, Farms, and Fisheries" tour in 2011. Operated by the Lake Champlain Maritime Museum, the replica canal schooner serves as an ambassador of Lake Champlain history, providing a floating interpretive display that teaches visitors about the rich history of the Champlain Valley while discussing contemporary environmental concerns.

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LAKE CHAMPLAIN BASIN PROGRAM TECHNICAL ADVISORY COMMITTEE

Bill Ardren, US Fish and Wildlife Service
Kevin Behm, Addison County VT Planning
Breck Bowden, UVM Rubenstein School of Environment and Natural Resources
Bob Brower, NYS Department of Agriculture & Markets
Laura DiPietro, VT Agency of Agriculture
Fred Dunlap, NYS Department of Environmental Conservation
Jon Erickson, UVM Rubenstein School of Environment and Natural Resources
Doug Facey, St. Michael's College/Lake Champlain Research Consortium
David Franzi, SUNY Plattsburgh
Neil Kamman, VT Department of Environmental Conservation, Watershed Management Division
John Kanoza, Clinton County NY Health Department
Mark Malchoff, Lake Champlain Sea Grant
Martin Mimeault, QC Ministère du Développement durable, de l'Environnement et des Parcs
Mario Paula, US Environmental Protection Agency, Region 2
Bernie Pientka, VT Fish and Wildlife Department
Fletcher (Kip) Potter, USDA, Natural Resources Conservation Service
Vic Putman, Essex County Planning
Jamie Shanley, US Geological Survey
Paul Sisson, NOAA/National Weather Service
Eric Smeltzer, VT Department of Environmental Conservation, Watershed Management Division
Ed Snizek, Adirondack Park Agency
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Ann Bove, VT Agency of Natural Resources
Chantal d'Auteuil, Corporation Bassin Versant Baie Missisquoi
Tim Hunt, VT Agency of Natural Resources
Paul Marangelo, The Nature Conservancy
Ellen Marsden, University of Vermont
Angela Shambaugh, VT Agency of Natural Resources
Dave Tilton, US Fish and Wildlife Service
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The *State of the Lake and Ecosystem Indicators* report was compiled by the Lake Champlain Basin Program Steering Committee and staff, with input from the researchers listed on the left and LCBP committees. The report is available online at www.lcbp.org/lcstate.htm.

Lake Champlain Basin Program
54 West Shore Road
Grand Isle, VT 05458
(802) 372-3213
(800) 468-5227 (NY & VT)
www.lcbp.org
lcbp@lcbp.org

Lake Champlain Basin Program

STAFF SUPPORTING THE PROGRAM*

Call (802) 372-3213, unless otherwise noted
Emily Bird - Education & Outreach Intern
Jim Brangan - Cultural Heritage & Recreation Coordinator
Fred Dunlap - NY Coordinator, NYSDEC, (518) 897-1241
Colleen Hickey - Education & Outreach Coordinator
Eric Howe - Technical Coordinator
Bill Howland - Basin Program Manager
Kathy Jarvis - Office Manager
Martin Mimeault - QC Coordinator, Québec MDDEP, (450) 928-7607
Ryan Mitchell - Communications & Publications Coordinator
Meg Modley - Aquatic Nuisance Species Coordinator
Elizabeth Lee Newman - Communications & Publications Associate
Mario Paula - LC Coordinator, USEPA Region 2, (212) 637-3819
Pete Stangel, LTMP Coordinator
Michaela Stickney - VT Coordinator, VTANR/LCBP (802) 241-3619
Stephanie Strouse - Technical Associate
Jeanne Voorhees - LC Coordinator, USEPA New England, (617) 918-1686
Resource Room Staff: Laura Hollowell, Stephanie Larkin, Cynthia Norman (802) 864-1848

*LCBP staff are employees of New England Interstate Water Pollution Control Commission

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Lake Champlain Basin Program
54 West Shore Road
Grand Isle, VT 05458

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