2018

STATE of the LAKE

and

Ecosystem Indicators Report

ABOUT THE LAKE CHAMPLAIN BASIN PROGRAM

The Lake Champlain Basin Program (LCBP) coordinates and funds efforts that benefit the Lake Champlain Basin's water quality, fisheries, wetlands, wildlife, recreation, and cultural resources. The program works in partnership with federal agencies; state and provincial agencies from New York, Vermont, and Québec; local communities; businesses; and citizen groups. These partners lead collaborative, non-partisan actions to address water quality and environmental challenges that cross political boundaries in a multi-national watershed.

The LCBP was created by the Lake Champlain Special Designation Act of 1990, which designated Lake Champlain as a resource of national significance. The LCBP was charged with developing and implementing a comprehensive and coordinated plan for protecting the Lake Champlain Basin. The LCBP works closely with program partners to implement management goals outlined in *Opportunities for Action: An Evolving Plan for the Future of the Lake Champlain Basin.*

The Lake Champlain Steering Committee guides the LCBP's work. Its members include staff from the U.S. Environmental Protection Agency and several other U.S. federal agencies, state and provincial government in Vermont, New York, and Québec, local government, and Lake Champlain Sea Grant. The chairpersons of the LCBP's Technical Advisory Committee, Heritage Area Program Advisory Committee, Education and Outreach Advisory Committee, and Citizen Advisory Committees also serve on the Steering Committee.

The LCBP receives funding from the U.S. Environmental Protection Agency, the Great Lakes Fishery Commission, and the National Park Service. The New England Interstate Water Pollution Control Commission (NEIWPCC) manages the LCBP's financial, contractual, and human resources business operations on behalf of the Lake Champlain Steering Committee. LCBP staff are employees of NEIWPCC.

Visit www.lcbp.org to learn more.

Cover: Middlebury College's R/V David Folger *heads to a research site on Lake Champlain. Photo: Perri Silverhart*

The Lake Champlain Basin

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Photo: Perri Silverhart

Never before has there been so much support from lake users, resource managers, and government entities to improve Lake Champlain and its watershed. Just as the historic flooding of 2011 was a touchstone moment in the history of the management of Lake Champlain, the revised phosphorus Total Maximum Daily Load (TMDL) for Vermont, released by the U.S. Environmental Protection Agency in 2016, has heralded renewed awareness, debate, and action around the health of the Lake Champlain Basin.

Action is underway on many fronts. The governor of Vermont has initiated a phosphorus innovation challenge, the governor of New York has announced a harmful algal bloom reduction effort, and Québec has adopted new legislation to increase protection of wetlands. Federal, state, and provincial government agencies in the United States and Canada are examining and applying tools to reduce phosphorus pollution, mitigate harmful flooding, restore aquatic habitat and native fisheries to the watershed, and interpret the rich culture and heritage of the region. The U.S. congressional delegation representing the jurisdictions within the Lake Champlain Basin continues to enthusiastically support these efforts.

In 2017, the LCBP, with support from the Lake Champlain Steering Committee, released an updated version of *Opportunities for Action,* the management plan for Lake Champlain and its watershed. The plan directs the efforts of the LCBP and its partners in the pursuit of four goals: clean water, healthy ecosystems, thriving communities, and an informed and involved public. These goals serve as the framework for much of the LCBP's work, including this *2018 State of the Lake and Ecosystem Indicators Report.* The report covers the work being done to achieve the four goals and presents the most recent information on the conditions of Lake Champlain and its watershed. It serves as an update to legislators and policymakers and informs citizens and resource managers about threats to the Lake and opportunities to meet present and future challenges.

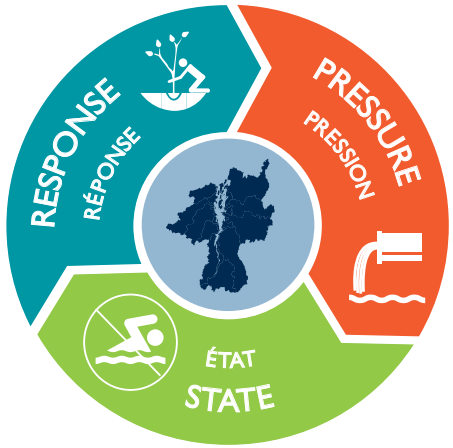
The state, or condition, of the Lake's ecosystem—the focus of this report—is a primary component of the Pressure-State-Response approach adopted by the LCBP for assessing and managing Basin resources. In this approach, the LCBP tracks human activities that can exert "Pressure" that may result in complex, long-term, and cumulative ecosystem impacts—that is, changes in the "State" of the Lake. These changes often elicit a management "Response," such as new environmental policies or management actions. A proper "Response" can reduce sources of "Pressure" to bring about a more desirable "State" of the Lake.

Opportunities for Action identifies several management themes that underlie the strategies aimed at achieving all four goals in the plan. These management themes also are reflected throughout all sections of this *State of the Lake* report. The knowledge of the "State" of the Lake included here and the "Response," which has led to many improvements in water quality and ecosystem health, are the results of science-based, collaborative management that takes a holistic approach to watershed management based on coordinated development of high-quality, objective scientific data.

The *2018 State of the Lake* report highlights the economic integration management theme to a greater degree than previous versions. Management strategies that maintain vibrant local economies while protecting and restoring the ecological and cultural resources of the Basin cut across all four *Opportunities for Action* goals. More than ever, these strategies take into account the inextricable link between innovative and cost-effective approaches to pollution reduction, efficient use of resources through coordinated funding and management actions, and vibrant communities that are able to leverage their natural and cultural heritage assets.

Resilience to climate change is also a common theme in the management efforts of the LCBP and its watershed partners. In an effort to more effectively reflect the far-reaching impact of climate change, the 2018 report includes climate change considerations throughout each section, rather than, as done in the previous two versions of the report, within a dedicated climate change section.

This printed edition of the report includes new information and updated illustrations that summarize the current state of knowledge of the conditions in the Lake Champlain Basin. Additional supplemental materials are available in the online version at sol.lcbp.org.



Partners in Québec, Vermont and New York work to improve the

Jamais auparavant n'a-t'-on vu un tel soutien de la part des usagers du lac, des gestionnaires de ressources et des instances gouvernantes envers l'amélioration du lac Champlain et de son bassin hydrographique. Tout comme la crue historique de 2011 s'est avérée un moment déterminant dans l'histoire de la gestion du lac Champlain, la révision de la TMDL (charge quotidienne maximale totale) de phosphore pour le Vermont, publiée par la « U.S. Environmental Protection Agency » en 2016, a annoncé un renouveau de la sensibilisation, du débat et de l'action autour de la santé du bassin du lac Champlain.

Cette action se déroule sur plusieurs fronts. Le gouverneur du Vermont a lancé un défi à l'innovation concernant le phosphore, le gouverneur de l'État de New York a annoncé une action concertée de réduction de la prolifération d'algues nuisibles, alors que le

health of Missisquoi Bay. Photo: LCBP.

Québec adoptait de nouvelles législations pour améliorer la protection des milieux humides. Des instances gouvernementales fédérales, des États et provinciales aux États-Unis et au Canada examinent et mettent en œuvre des outils visant à réduire la pollution au phosphore, à atténuer les crues destructrices, à restaurer l'habitat aquatique et les pêcheries d'espèces indigènes du bassin versant et à interpréter les richesses culturelles et patrimoniales de la région. Les élus au Congrès des États-Unis qui représentent les juridictions couvertes par le bassin du lac Champlain continuent d'apporter un soutien enthousiaste à ces initiatives.

En 2017, le LCBP, avec l'appui du Comité directeur du lac Champlain, a publié une version mise à jour de *Perspectives d'action,* le plan de gestion du lac Champlain et de son bassin hydrographique. Ce plan oriente les efforts du LCBP et de ses partenaires vers la réalisation de quatre objectifs : propreté de l'eau, bonne santé des écosystèmes, vitalité des collectivités et information et participation du public. Ces objectifs définissent le cadre d'une grande partie de l'action du LCBP, notamment de cette version 2018 du « *State of the Lake and Ecosystems Indicators Report* » (rapport sur l'état du lac et les indicateurs d'écosystèmes). Le rapport rend compte du travail en cours en vue de réaliser ces quatre objectifs et présente l'information la plus courante sur l'état du lac Champlain et de son bassin versant. Il a pour objet de mettre à jour les législateurs et les décideurs et d'informer les citoyens et les gestionnaires de ressources sur les menaces qui pèsent sur le lac, ainsi que sur les moyens de relever les défis actuels et à venir.

L'état de l'écosystème du lac, le sujet principal de ce rapport, est l'une des composantes principales de la méthode Pression-État-Réponse adoptée par le LCBP pour l'évaluation et la gestion des ressources du bassin. Cette méthode prévoit notamment le suivi par le LCBP des activités humaines susceptibles d'exercer une « pression » telle qu'elle peut entraîner des effets complexes, durables et cumulatifs sur l'écosystème, c'est-à-dire provoquer des changements dans l'« état » du lac. Ces changements suscitent souvent une « réponse » de gestion, telle que de nouvelles règles environnementales ou autres mesures d'encadrement. Une « réponse » appropriée peut réduire les sources de « pression » de façon à produire un « état » du lac plus souhaitable.

Perspectives d'action identifie plusieurs thèmes d'action à l'appui des stratégies visant à la réalisation des quatre objectifs du plan. Ces thèmes de gestion sont également reflétés à travers les différentes sections du rapport *État du lac.* La connaissance de l'« état » du lac exposée ici et la « réponse » apportée, qui s'est traduite par de nombreuses améliorations de la qualité de l'eau et de la santé de l'écosystème, sont le résultat d'une gestion collaborative et scientifique qui s'appuie sur une approche globale de la gestion du bassin versant étayée par des données scientifiques objectives et de qualité.

Le rapport État du lac 2018 met l'accent sur le thème de la gestion de l'intégration économique dans une plus grande mesure que les versions précédentes. Les stratégies de gestion visant à préserver la vitalité des économies locales tout en protégeant et en restaurant les ressources écologiques et culturelles du bassin recouvrent chacun des quatre objectifs du plan *Perspectives d'action.* Plus que jamais, ces stratégies prennent en compte le lien inextricable qu'existe entre des méthodes innovantes et économiques de réduction de la pollution, une utilisation efficace des ressources par des actions concertées de financement et de gestion et des collectivités locales dynamiques capables de mettre à profit les atouts de leur patrimoine naturel et culturel.

La capacité à faire face au changement climatique est également l'un des thèmes communs aux initiatives de gestion du LCBP et de ses partenaires dans le bassin versant. Dans un souci de mieux rendre compte de l'incidence profonde du changement climatique, ce rapport 2018 inclut des considérations relatives à ce phénomène à travers chacun des chapitres, contrairement aux deux versions précédentes du rapport, dont un chapitre était dédié spécifiquement au changement climatique.

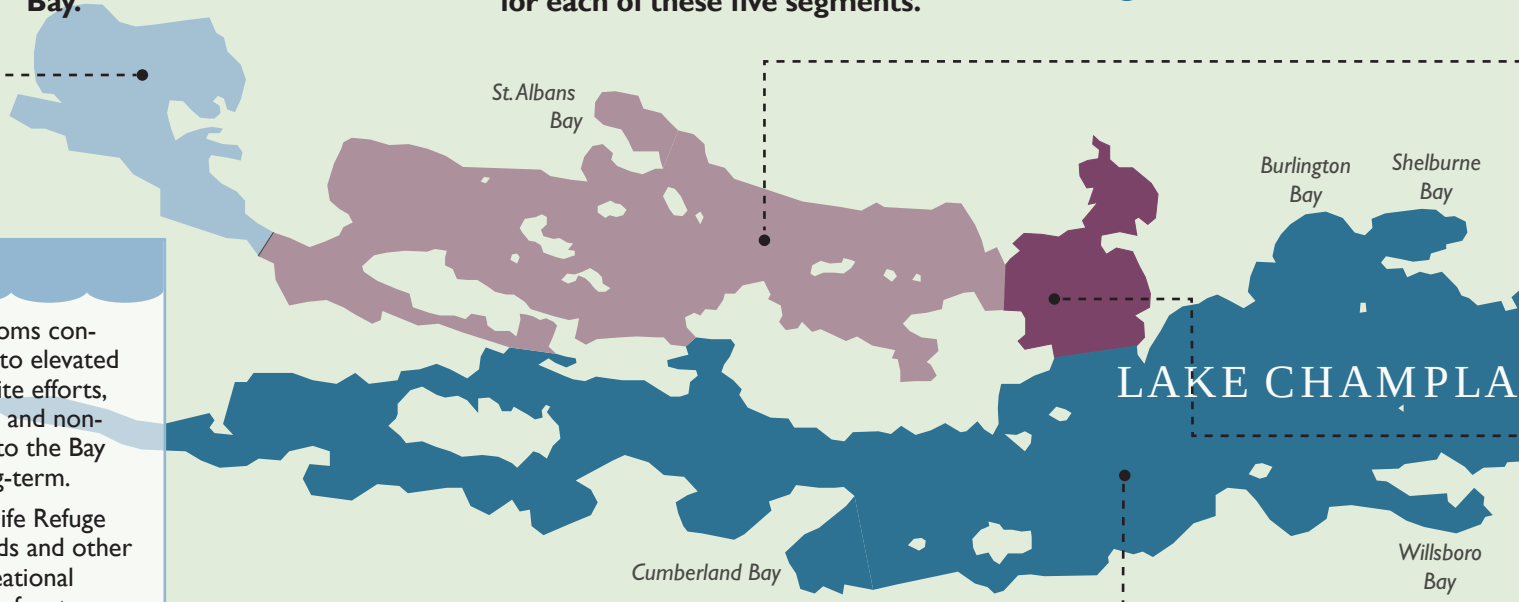
La version papier du rapport contient de nouvelles informations et des illustrations mises à jour qui récapitulent l'état actuel des connaissances sur la situation dans le bassin du lac Champlain. De la documentation supplémentaire est également proposée dans la version en ligne à sol.lcbp.org.

ONE LAKE, OUT OF MANY

It is often said that Lake Champlain is not one lake, but several water bodies joined together. The main segment of the Lake is deep and cold, the northeast areas are shallower and warmer, and the southern end of the Lake resembles a river flowing northward. These differences make it challenging to easily summarize the state of the Lake. Five distinct segments have been used by scientists since the 1970s to describe the major regions of the Lake: Main Lake, Missisquoi Bay, Northeast Arm, South Lake, and Malletts Bay.

This summary highlights key issues related to the LCBP's four management goals for each of the five major lake segments. The Scorecard on page 31 of this document provides information on the current status and trends for nine indicators of lake health for each of these five segments.

Throughout the document, charts and graphs provide information that inform these indicators. The figures that are used to determine the status and trends for indicators are denoted with the following symbol:



MISSISQUOI BAY

- Warm weather cyanobacteria blooms continue to be persistent in part due to elevated phosphorus concentrations. Despite efforts, in-bay phosphorus concentrations and non-point source phosphorus loading to the Bay have not yet decreased in the long-term.
- The Missisquoi Bay National Wildlife Refuge provides habitat for migratory birds and other wildlife, as well as renowned recreational opportunities. A small population of water chestnut in Missisquoi Bay is managed with hand pulling, and is contained to a limited area.
- Communities are working with the Champlain Valley National Heritage Partnership to strengthen connections among themselves and their neighbors through interpretation and new bilingual wayside exhibits.
- Organisme Bassin Versant Baie Missisquoi hosted bilingual boat launch stewards for the first time in summer 2017 and engaged boaters on watershed issues. The stewards conducted voluntary inspections on more than 750 boats launching in Saint-Armand and Venice-en-Québec.

MAIN LAKE

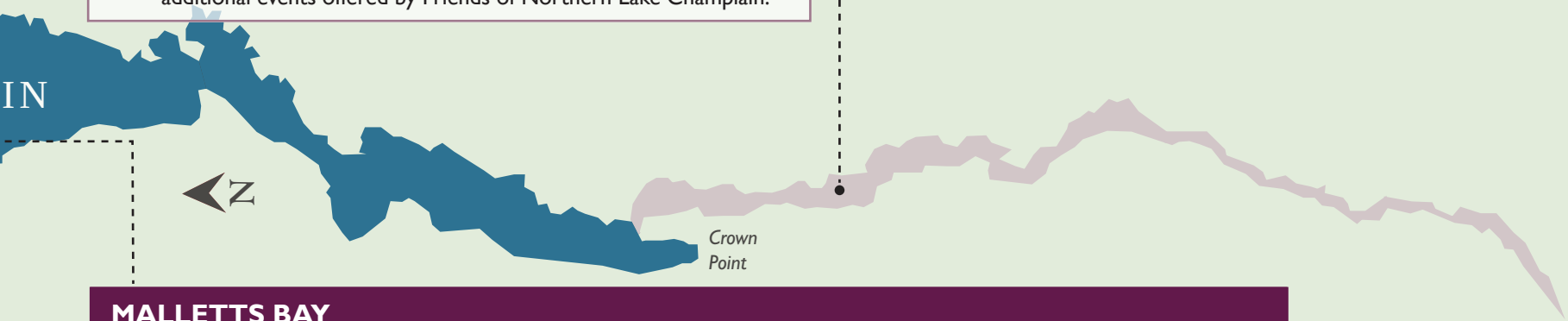
- The water is excellent for recreation at most times and provides high-quality drinking water for many thousands of residents. Nutrient concentrations are relatively low in this segment, particularly in Burlington, Shelburne, and Cumberland Bays.
- Cold- and warm-water fishery reports are very good, and lake trout are reproducing successfully and surviving beyond the fingerling stage. Young Island is recovering from double-crested cormorant degradation and will soon be re-vegetated.
- This segment hosts the most shipwreck sites in the Lake, including the tugboat *U.S. LaVallee*, which was opened to divers in 2017 as the most recent addition to the Lake Champlain Underwater Preserve.
- ECHO at the Leahy Center for Lake Champlain welcomed nearly 500,000 visitors between 2015-2017, and Clinton County Historical Association and NYSDEC ferried more than 200 guests to Valcour Island to celebrate the restoration of the lighthouse in 2016.

NORTHEAST ARM

- Warm weather cyanobacteria blooms continue to be persistent in sections of this segment in part due to elevated phosphorus concentrations. Frequent public beach closures in St. Albans Bay due to bacteria counts and cyanobacteria blooms continue to cause frustration and are the focus of management efforts.
- The cold- and warm-water fishery is very strong in the Northeast Arm, which is a popular area for anglers. A recent invasion of water chestnut in a marsh draining to St. Albans Bay is actively managed and currently contained to a small area.
- Seven state parks provide many opportunities for world-class recreation. Visitors and residents can enjoy the arts at Knight Point State Park, camp on remote islands at Burton, Knights and Woods Islands, and swim at Sandbar State Park. Boaters can now launch at the new public marina in St. Albans Bay.
- Lake partners are sharing information to increase awareness of St. Albans Bay issues. The St. Albans Bay Watershed Association began hosting an annual "Take a Stake in the Lake" event to complement additional events offered by Friends of Northern Lake Champlain.

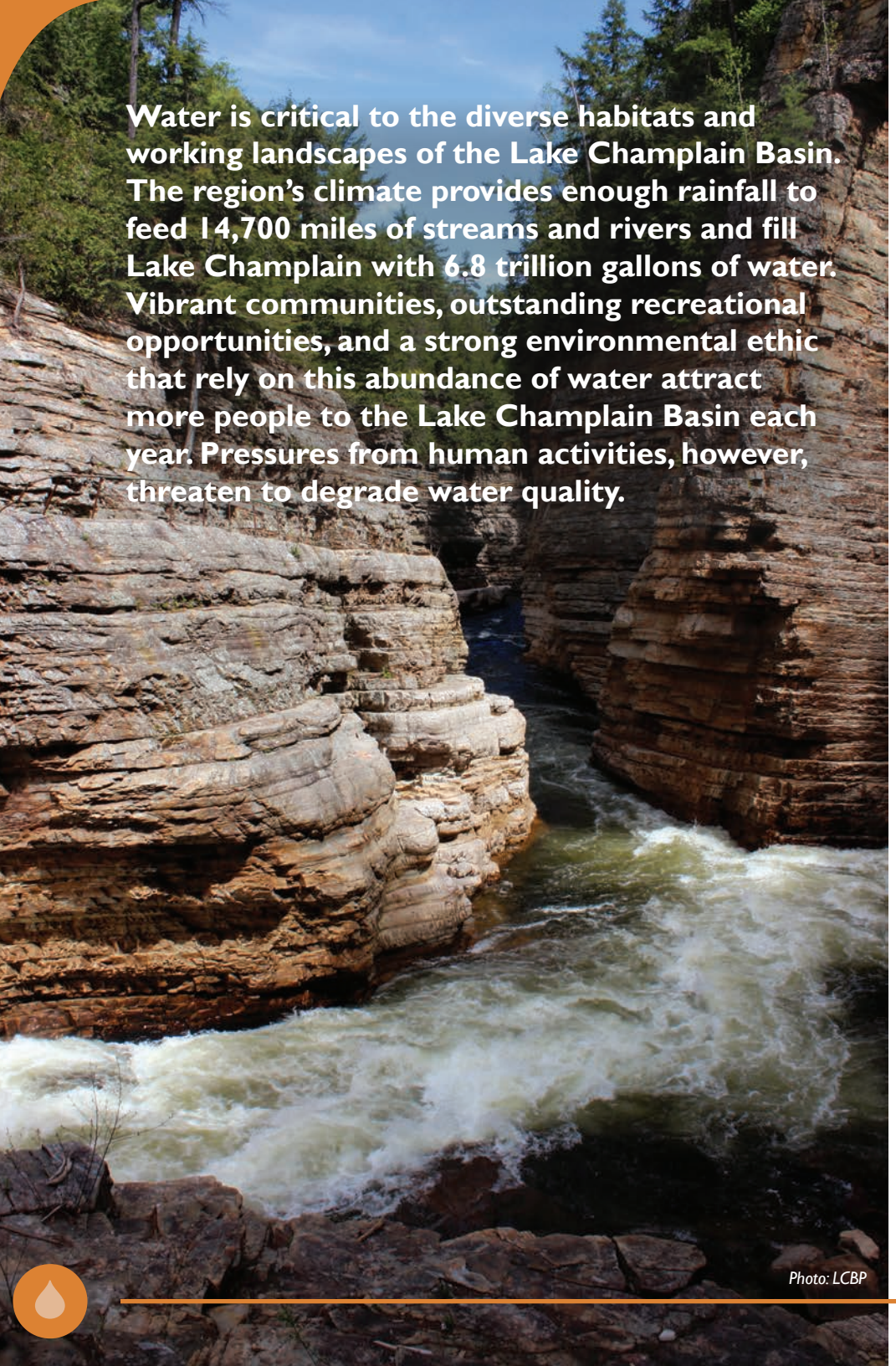
SOUTH LAKE

- Phosphorus concentrations fluctuate annually and are often above the targeted limits. Despite efforts, tributary phosphorus loading to this segment has not improved in the long-term.
- The segment is popular for warm-water fishing, particularly for bass and northern pike. Water chestnut coverage has decreased substantially as a result of mechanical harvesting throughout this lake segment.
- Visitors can learn about the rich history associated with Crown Point, New York, and Chimney Point, Vermont by visiting historic sites and museums, and through a Quest that challenges them to answer riddles about the unique features joined by the Lake Champlain Bridge.
- Public bird banding opportunities are offered by the Vermont Fish and Wildlife Department at Dead Creek Wildlife Management Area and with the Crown Point Banding Association. These groups have banded at least 106 species and over 20,000 birds since 1976.



MALLETTS BAY

- Malletts Bay provides generally clean water with the lowest phosphorus concentrations in the Lake. While cyanobacteria blooms are rare in this segment, occasional elevated bacteria counts have caused public beach closures in recent years.
- The Sandbar Wetlands were recently reclassified as Class I Wetlands, the status of highest importance and protection. The Sandbar Wildlife Management Area supports 29 rare, threatened, and endangered species with over 1,200 acres of high quality habitat. No new aquatic invasive species have arrived in this segment since spiny waterflea in 2014.
- Known for its recreational value, Malletts Bay is home to swimming, sailing, and boating in the summer as well as winter activities like ice-boating and the Vermont Pond Hockey Classic tournament each year. The Local Motion Bike Ferry has taken 44,000 riders across "the cut" on the three-mile Colchester Causeway since 2015.
- Marina operators from Malletts Bay, like their counterparts lakewide, attend an annual training about current lake and navigation issues so they can share this information with the boating public.



Water is critical to the diverse habitats and working landscapes of the Lake Champlain Basin. The region's climate provides enough rainfall to feed 14,700 miles of streams and rivers and fill Lake Champlain with 6.8 trillion gallons of water. Vibrant communities, outstanding recreational opportunities, and a strong environmental ethic that rely on this abundance of water attract more people to the Lake Champlain Basin each year. Pressures from human activities, however, threaten to degrade water quality.

Photo: LCBP

DRINKABLE, FISHABLE, AND SWIMMABLE WATER

Lake Champlain continues to provide high-quality and great-tasting drinking water to surrounding communities.

More than 145,000 people rely on Lake Champlain as their source of safe and reliable drinking water—approximately 24% of the Basin's population. There are 100 public water suppliers in the Lake Champlain Basin (73 in Vermont, 26 in New York, and one in Québec). Most of the drinking water from these sources comes from 35 monitored and regulated public water utilities; motels, mobile home parks, restaurants, and other businesses also treat and use the Lake's water. A number of seasonal camps and cabins draw untreated water directly from the Lake, but consuming untreated water is unsafe and not recommended.

The U.S. Safe Water Drinking Act requires all public water utilities to monitor for 86 potential contaminants in drinking water. Lake Champlain's drinking water rarely exceeds limits for any of these 86 contaminants. The Lake's water is not only safe and reliable, it is award-winning. The 2015 "Best of the Best" People's Choice Taste Award for North America went to Champlain Water District, which draws water from Shelburne Bay and is the largest supplier of drinking water in Vermont.

Lake Champlain fish can be a safe and delicious part of a healthy diet when consumption advisories are followed.

Fishing is a longstanding tradition on Lake Champlain and continues to be an important way in which people connect with the Lake's ecosystem. New York, Québec, and Vermont have each determined safe fish consumption levels for their jurisdictions to provide guidance to consumers.

Most of these fish consumption advisories are a result of the presence in fish tissue of mercury, a toxic heavy metal that can cause severe illness, even at low doses. Mercury biomagnifies through the food chain, which means that older, larger fish farther up the food chain typically contain more mercury than small fish. Therefore, a small species such as yellow perch will generally contain lower levels of mercury than lake trout, a large, predatory fish.

Historically, the biggest source of mercury in Lake Champlain is deposition from air pollution, primarily from coal-burning plants and industries in the Midwest. Some common household items, such as old thermometers and compact fluorescent light bulbs, also contain small amounts of mercury that can enter waterways if the items are not

disposed of properly as hazardous materials.

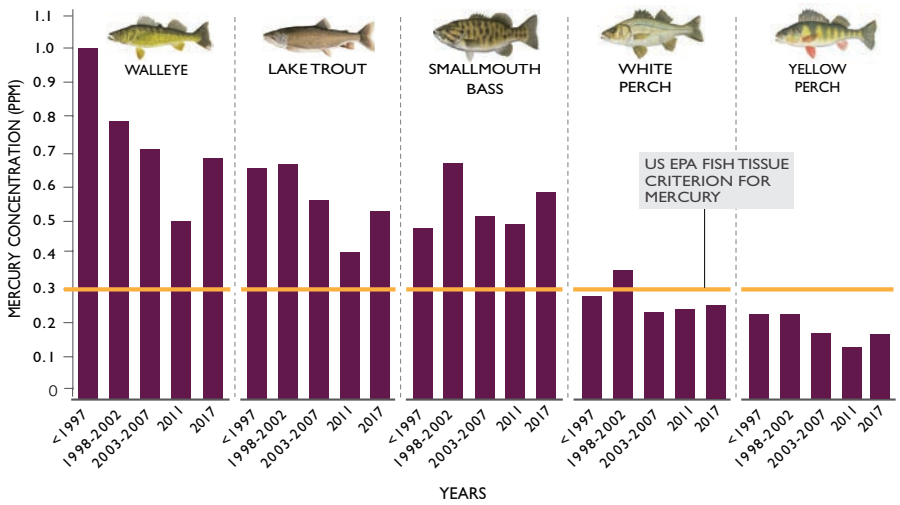
Local and national efforts have resulted in decreases in mercury concentration in several Lake Champlain fish species. This was particularly true from the 1990s until 2011, when mercury decreased in nearly all fish species sampled (Figure 1). Between 2011 and 2017, however, the trend reversed, and mercury was found to have increased in all species sampled. The reason for this reversal is unclear, and researchers continue to investigate potential causes for the change. A similar trend has been observed in the Great Lakes region.

The Lake Champlain Basin's rivers and lakes are safe for swimming at most times.

Thousands of residents and visitors enjoy swimming in Lake Champlain and its tributaries each year. With 587 miles of shoreline, 54 public beaches on the Lake, and hundreds of swimming holes on rivers in the Basin, there are countless ways to cool off in the summer months. For most of the swimming season, beaches in most places on the Lake are safe and open to the public.

When a public beach is closed for health concerns, it is usually a result of elevated levels of coliform bacteria or presence of cyanobacteria (also known as blue-green algae; Figure 2). Coliform bacteria are usually harmless and are naturally present in all animals, including humans. Elevated coliform levels in water, however, can be an indicator of the presence of harmful disease-causing pathogens. Elevated coliform levels typically occur following rainstorms that wash sediment, pollutants, and bacteria into the Lake.

While Lake Champlain and its tributaries provide a fine way to cool off



NOTE: The values are mean mercury concentrations, normalized to the average length of the fish.
DATA SOURCES: Vermont Agency of Natural Resources; Biodiversity Research Institute, 2011; Darrin Fresh Water Institute, 2018
Fish illustrations © Flick Ford.

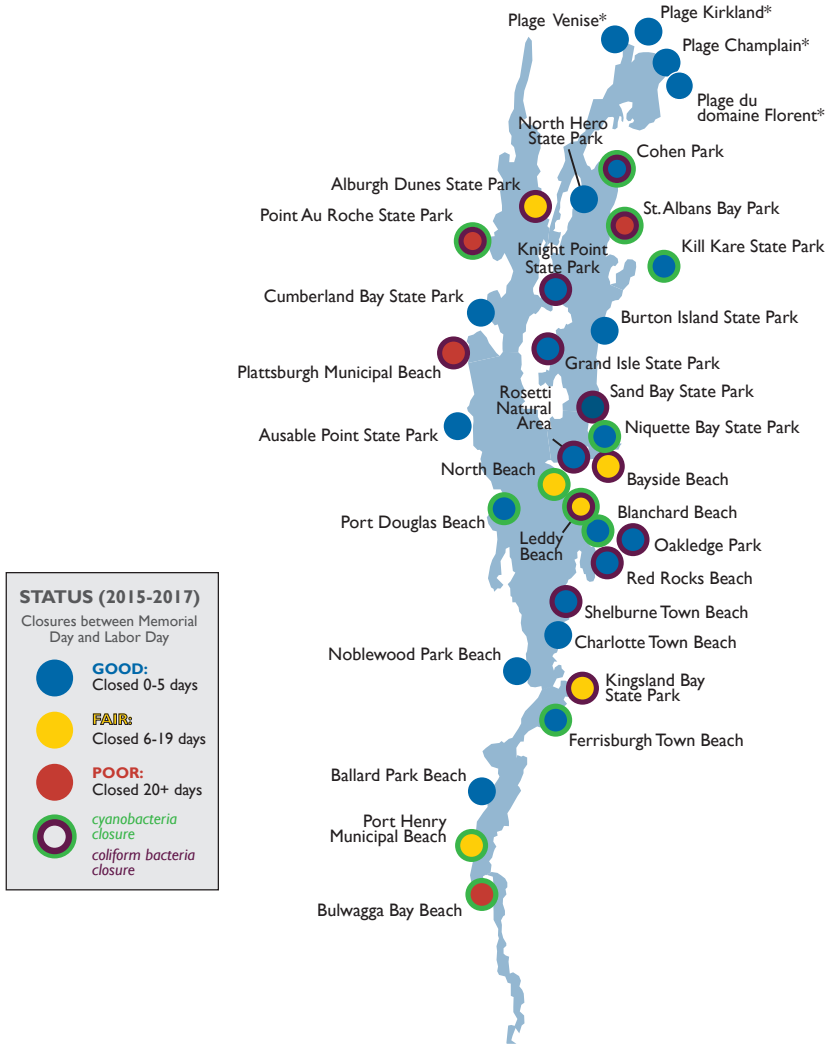
Figure 1 | Mercury concentration in Lake Champlain fish tissue

A young swimmer contemplates a plunge. Photo: LCBP.

PFOA in the Basin?

Following the detection of high concentrations of perfluorooctanoic acid (PFOA) in groundwater just outside the Lake Champlain Basin in 2016, the State of Vermont initiated a statewide program to identify contamination from these chemicals. PFOA first was detected in wells in Hoosick Falls in New York and in the Vermont towns of Bennington, North Bennington, and Shaftsbury. The subsequent testing found high levels of PFOS—a related substance in the same family of chemicals—within the Basin at the Rutland Airport Business Park. Both PFOA and PFOS are human-made compounds used in many products that resist sticking, staining, and water damage. They also are used commonly in firefighting foams. These potential carcinogens can cause liver and kidney damage and can have developmental effects on fetuses during pregnancy.

on a hot day, health officials recommend that swimmers check in with their local municipality about public beach water quality and safety before jumping in. Experts advise waiting 24 hours after a heavy rainfall before entering a water body to reduce the risks associated with exposure to unsafe levels of coliform bacteria or high river flows.



NOTE: Non-water quality-related closures are not represented on this map.
* Québec beaches are no longer officially monitored for cyanobacteria. Though a bloom may occur, closures are voluntary.
DATA SOURCES: Town Offices, VT ANR, UVM, NYS DOH, QC MDDELCC

Figure 2 | Public beach closures on Lake Champlain, 2015–2017

PATHOGENS AND CYANOBACTERIA

Pathogens continue to impair water quality and are costly to eliminate, but recent efforts have helped to identify and eliminate some threats.

It is usually best for cities and towns to maintain separate pipe networks for stormwater and sanitary sewage. In cases where there is just one pipe network—a combined sewer system—both flows are combined as they are conveyed to a wastewater treatment facility. When heavy rainfall generates more stormwater runoff than can be accommodated by these combined systems, treatment facilities can be overwhelmed by the high volume of water; untreated or partially treated sewage may then enter the tributary network and eventually the Lake through overflow pipes. These events, known as combined sewer overflows (CSOs), are sources of coliform bacteria and nutrients to the Lake.

Substantial efforts have been made to reduce the number of CSO events in the Basin. Since 1990, the number of CSO discharge points, or outfalls, in Vermont has decreased from 178 to 53. That number is expected to drop even further as a result of a CSO Rule adopted by Vermont Department of Environmental Conservation in 2016. CSOs in the New York portion of the Basin also have declined, with the City of Plattsburgh alone eliminating fifteen CSO outfalls since the 1970s. Long Term Control Plans are in

Combined sewer overflows remain a particularly difficult water quality challenge because of the high cost of separating storm and sanitary sewers. Photo: City of Plattsburgh.

place to address the remaining eleven discharge points in Plattsburgh to mitigate their impact.

Additional efforts are underway to better understand and address the sources of coliform bacteria in the Basin's waterways, including waste from farm animals, wildlife, pets, and humans. The City of Plattsburgh, for example, used DNA tracking technology to determine the source of coliform bacteria that led to public beach closures along the city's Lake Champlain shoreline. The study found that gulls and cows were the most common sources of coliform bacteria during dry weather conditions and after rainstorms that did not result in CSOs. After storms that caused CSOs, the most common sources were gulls, humans, and dogs.

Cyanobacteria blooms are not present most days in the Lake Champlain Basin, but warm weather blooms continue to present a challenge.

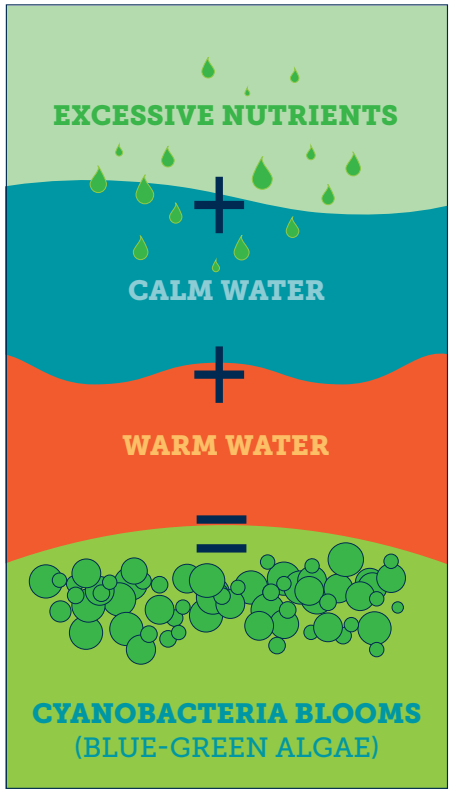
Cyanobacteria are a group of primitive bacteria that are native to nearly every ecosystem on Earth. Several species of cyanobacteria are found in Lake Champlain, and most of the time they do not cause harm. Cyanobacteria can become a nuisance when growth is accelerated by calm, warm weather and excessive levels of nutrients such as nitrogen and phosphorus. A cyanobacteria bloom occurs when colonies of cyanobacteria become large enough to see with the naked eye. These colonies typically look like small green pinhead-sized balls and can form a layer (or bloom) on the surface of the water that sometimes resembles thick pea soup.

Severe cyanobacteria blooms sometimes produce toxins that are harmful to humans, pets, and wildlife and can have adverse effects on the Lake Champlain ecosystem, such as reduced oxygen levels in the water and noxious odors. A recent LCBP-supported study that collected fish during blooms did not detect cyanotoxins in Lake Champlain fish tissue, though scientists are still investigating potential impacts to the Lake's fishery. In addition, tests of drinking water in Vermont public treatment facilities found no detectable presence of cyanotoxins in raw or treated drinking water in summer of 2017.

Toxins produced by cyanobacteria blooms can make the Lake's water near blooms unsafe for swimming. The LCBP works in partnership with the Lake Champlain Committee, Vermont Department of Environmental Conservation, and Vermont Department of Health (DOH) to support the Lake Champlain Volunteer Cyanobacteria Monitoring Program. During the warm months, more than a hundred volunteers report each week on water conditions along the shoreline. If a cyanobacteria bloom is visible, an alert is posted online to the Lake Champlain Cyanobacteria Tracking Map hosted by Vermont DOH. If the bloom is at a public beach, water samples are tested to determine whether the beach is safe for swimming. Local authorities are notified if test results merit closure of the beach.

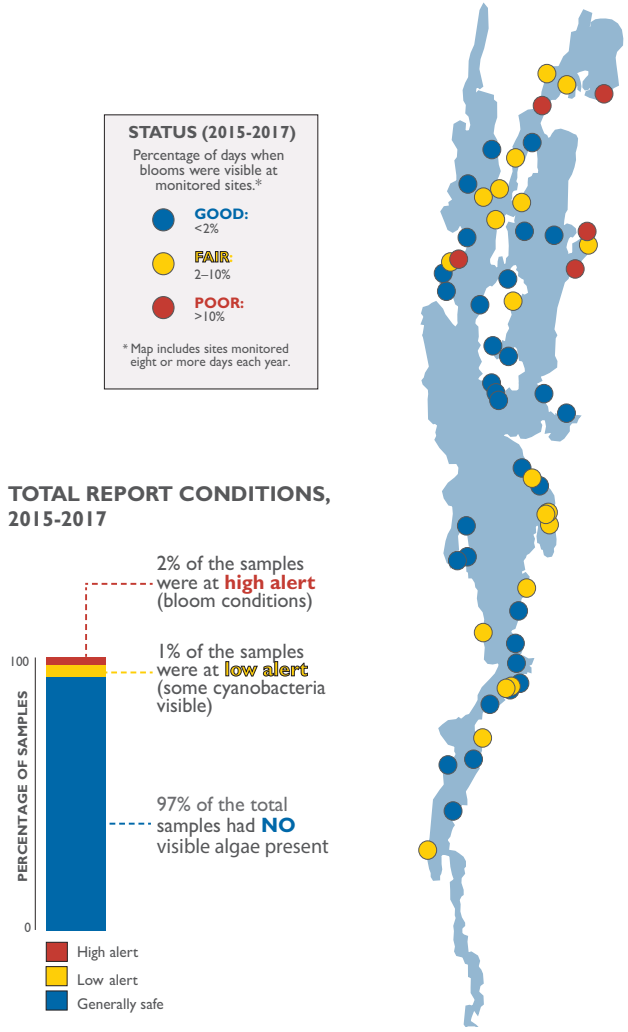
Cyanobacteria blooms are not present most days in Lake Champlain (Figure 3). Blooms occur most frequently from July to August and in shallower, warmer bays of the Lake, such as Missisquoi and St. Albans Bays. When exceptions occur, it is generally due to unusual circumstances. In the fall of 2017, unseasonably warm temperatures, low wind speeds, and excessive nutrients resulted in localized cyanobacteria blooms in many parts of the Lake and in other smaller lakes in the

Cyanobacteria blooms can limit the use of beaches on Lake Champlain. Photo: LCBP.



Basin. A bloom in Lake Carmi, Vermont, was especially persistent and intense during this time and continued late into the fall. In addition, *Scytonema*, a type of cyanobacteria that is rarely observed, was identified in a portion of Burlington Bay for the first time and persisted for several weeks in September and October 2017.

Limiting the levels of nutrients such as phosphorus is critical in combating cyanobacteria blooms in Lake Champlain, and the LCBP and its partners are working to address this root cause.



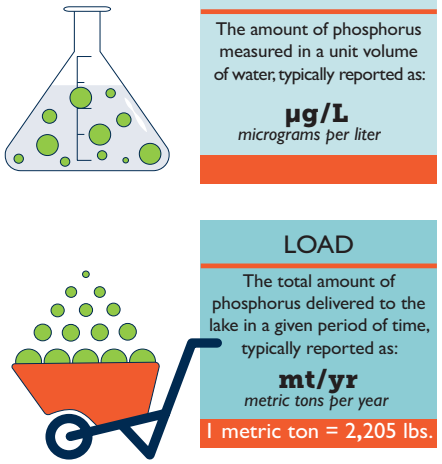
DATA SOURCES: US-only monitoring programs, VT ANR, LCC, LCBP

Figure 3 | Cyanobacteria alerts, 2015–2017

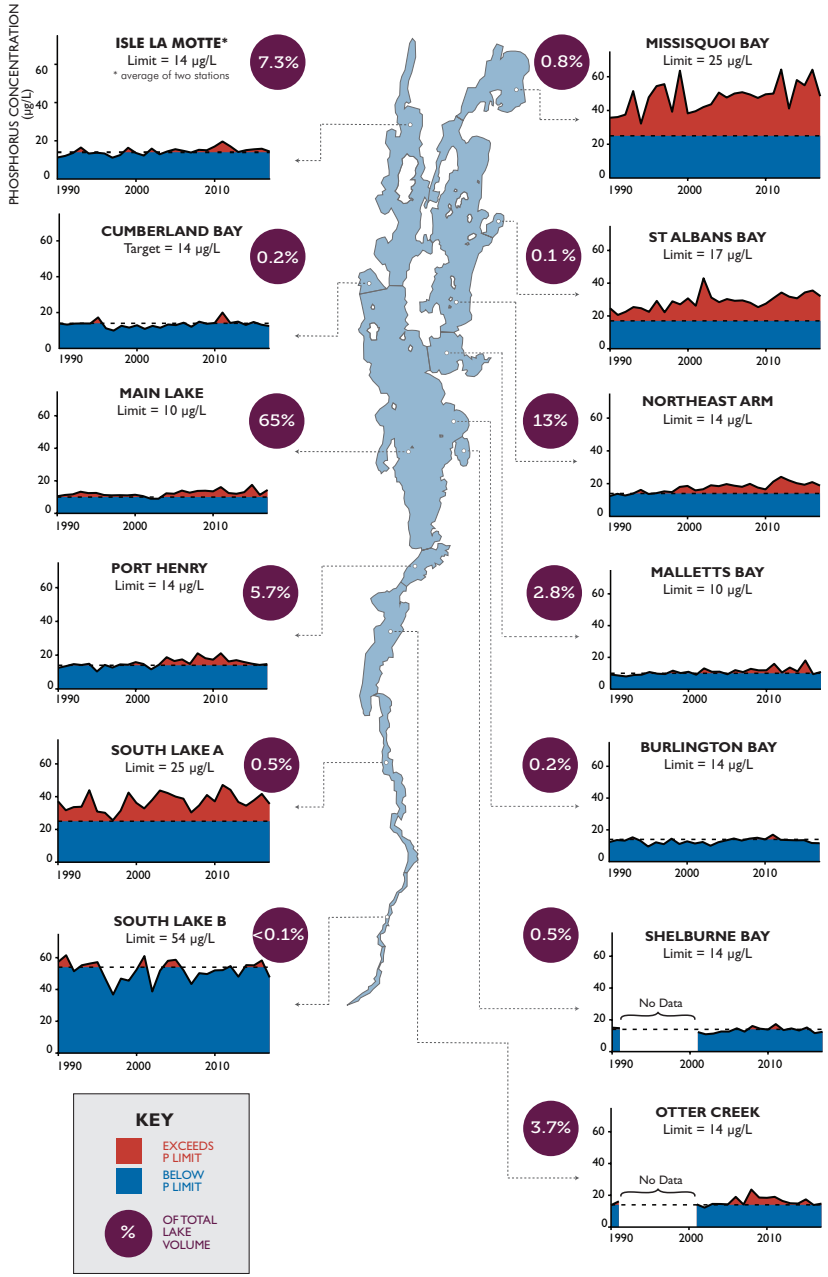
PHOSPHORUS

Phosphorus is a nutrient that influences lake health and cyanobacteria blooms.
Nutrients are the food that fuels cyanobacteria growth and, when present in excess, nutrients can be a contributing factor to cyanobacteria blooms. Phosphorus is thought to often be a "limiting" nutrient for cyanobacteria growth. This means that cyanobacteria often have enough of other nutrients to grow, so when more phosphorus is available, they grow more readily.

Some forms of phosphorus fuel cyanobacteria more easily than others. For example, phosphorus can be bound to soil particles that erode from streambanks. When in this "particulate" form, the phosphorus is inaccessible to cyanobacteria; it may take months or years for this phosphorus to be released in the Lake in a form that can be used for cyanobacteria growth. In contrast, dissolved forms of phosphorus in fertilizer and wastewater treatment effluent are more readily available for cyanobacteria growth. Targeted efforts to reduce phosphorus loading to Lake Champlain should address all forms of phosphorus.



Many lake segments have phosphorus concentrations that are often near or below targeted limits. However, phosphorus concentrations in Lake Champlain's shallow bays are often above these limits and generally have not decreased in recent decades.
Excessive phosphorus concentration can have a significant impact on a lake's ecosystem and is a contributing cause of cyanobacteria blooms. Targeted phosphorus concentration limits for thirteen segments of Lake Champlain (Figure 4) were established in 1991, and the LCBP has supported monitoring efforts for phosphorus concentrations in the Lake since 1990. From 1990 to 2017, most segments did not show long-term trends in phosphorus concentration, though the Northeast Arm showed an increasing trend over this time period. Annual average concentrations often have been near or below targeted limits since 1990 in the Main Lake, Isle La Motte segment, Cumberland Bay, Port Henry, South Lake B segment, Malletts Bay,



DATA SOURCES: Long Term Monitoring Program (LCBP, VT ANR, NYSDEC)

Figure 4 | Annual mean phosphorus concentration by lake segment, 1990–2017

Burlington Bay, and Shelburne Bay, which make up approximately 82% of the Lake's volume.

Phosphorus concentrations above targeted limits have been observed in the shallow waters of Missisquoi and St. Albans Bays, the Northeast Arm, and the South Lake A segment. Some of these areas have high phosphorus loads from their contributing sub-watersheds. Also, because there is less water to dilute incoming nutrients, shallow bays are more susceptible to problems associated with excess phosphorus than the deeper bays and Main Lake. Shallow bays are also more affected by phosphorus moving up the water column from sediment at the bottom of the Lake.

Phosphorus comes from a variety of sources in the watershed and from lake sediments.

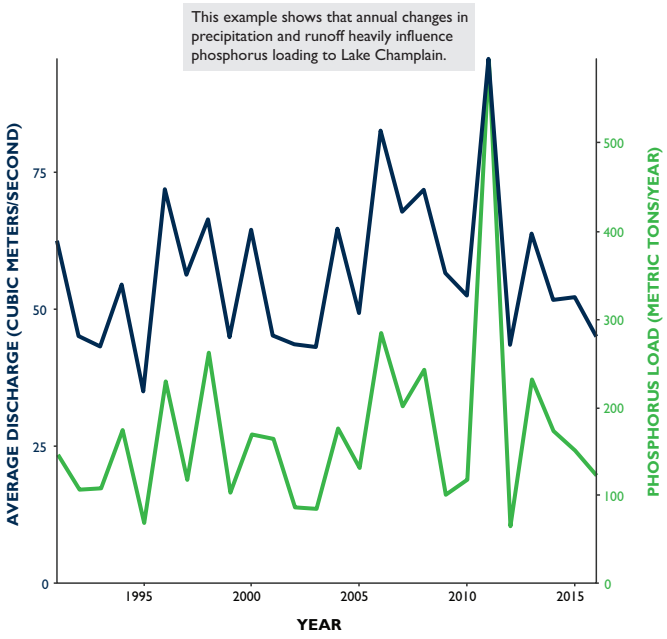
For every square mile of water on Lake Champlain, eighteen square miles of land in the Lake Champlain Basin deliver water to the Lake and contribute sediment, nutrients, and other potential pollutants. For the Great Lakes, this ratio is much lower: there is only 1.5 to 3.4 times as much land as lake surface area in those watersheds. Most nutrients come from sources on the land, so the relatively high land-to-lake area ratio for Lake Champlain poses a significant challenge in limiting nutrient pollution.

Rivers are the pathways for water, sediment, and nutrients to move into the Lake. Each year the Basin's rivers deliver about 921 metric tons (2 million pounds) of phosphorus. Annual changes in load depend upon the amount of rain and runoff in the watershed (Figure 5). This variability due to precipitation and temperature may confound efforts to reduce phosphorus loading. While management practices may help to reduce inputs, the increasingly intense rainstorms associated with climate change may release more phosphorus, possibly cancelling out some gains made through pollution reduction efforts.

Long-term phosphorus loading trends have not improved in most Lake Champlain tributaries. While long-term decreases have been documented in the LaPlatte and Little Ausable Rivers, long-term increases in phosphorus loading have been documented in Lewis and Little Otter Creeks, and in the Poultney River. All other monitored tributaries show no significant long-term trends in phosphorus loading (Figure 6).

Phosphorus from developed land

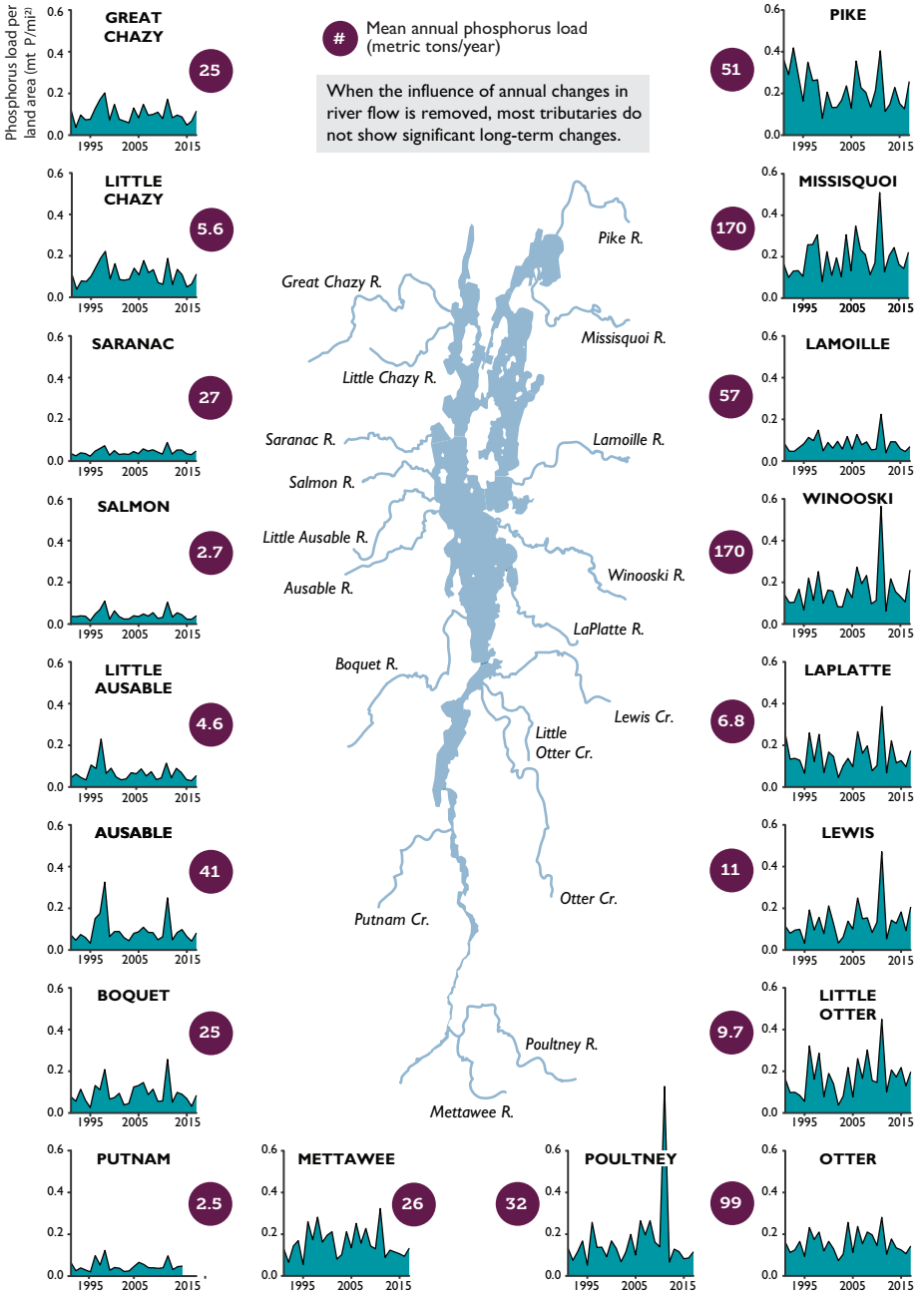
A variety of land uses contribute phosphorus to Lake Champlain. Addressing each input is critical to achieving long-term reductions in phosphorus load. Developed land can be a substantial source of nutrients and other pollutants to the Lake and can contribute substantially more phosphorus per land area than other land uses (Figure 7). Impervious surfaces, such as parking lots and rooftops, shed rainwater



DATA SOURCES: Long Term Monitoring Program (LCBP, VT ANR, NYSDEC)

Figure 5 | Mean annual water discharge and phosphorus load for the Winooski River, 1990–2016

Tributaries deliver water, sediment, nutrients, and other pollutants to Lake Champlain tributaries. Photo: LCBP.



NOTE: Results for 2017 are provisional.
DATA SOURCES: Long Term Monitoring Program (LCBP, VT ANR, NYSDEC)

Figure 6 | Annual tributary phosphorus loading, 1990–2017

quickly and do not allow stormwater to soak into the ground. High storm flows increase erosion of streambanks, sending more sediment and nutrients downstream to the Lake. Large surges of runoff from developed land can increase the severity of downstream flooding, causing property damage. Green infrastructure designs can reduce these high storm flows by slowing down and storing runoff, thereby reducing the amount of water and nutrients delivered to the Lake.

Phosphorus from developed lands accounts for approximately 16% (147 metric tons or 323,600 pounds) of the total phosphorus load to Lake Champlain each year. Most of this phosphorus comes from nonpoint sources in the built environment, such as impervious pavement, lawns, and rooftops. In contrast, wastewater treatment facilities, an example of point source phosphorus, contribute 6% of the annual phosphorus load to the Lake.

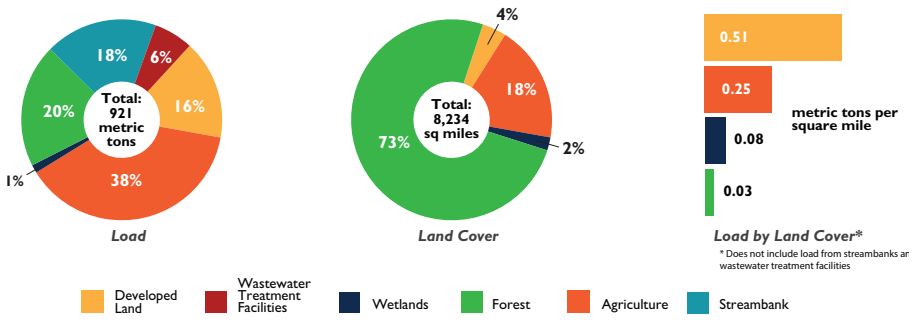
Regulations banning phosphorus from laundry detergents in 1976 greatly reduced the amount of phosphorus entering wastewater treatment facilities, and technology upgrades since then have increased the amount of phosphorus removal before discharge to the Lake (Figure 8).

Phosphorus from agricultural land

Farming has long been a way of life for many in the Lake Champlain region, but agriculture can have a significant impact on water quality. Runoff and erosion from barnyards, laneways to pastures, and animal congregation areas can carry excessive pollution to nearby waterways and eventually to Lake Champlain. Most conventional farms rely in part on commercial fertilizers and feed additives, and organic agricultural practices also can involve the application of fertilizer to increase crop productivity. Cattle farms and other animal-based operations generate large amounts of manure that must be disposed of or used carefully; farmers frequently spread manure on their fields to recycle nutrients back into crops and pastures. A portion of the nutrients within fertilizers, additives, and manure is washed off the land and into a waterway before it can soak into the ground.

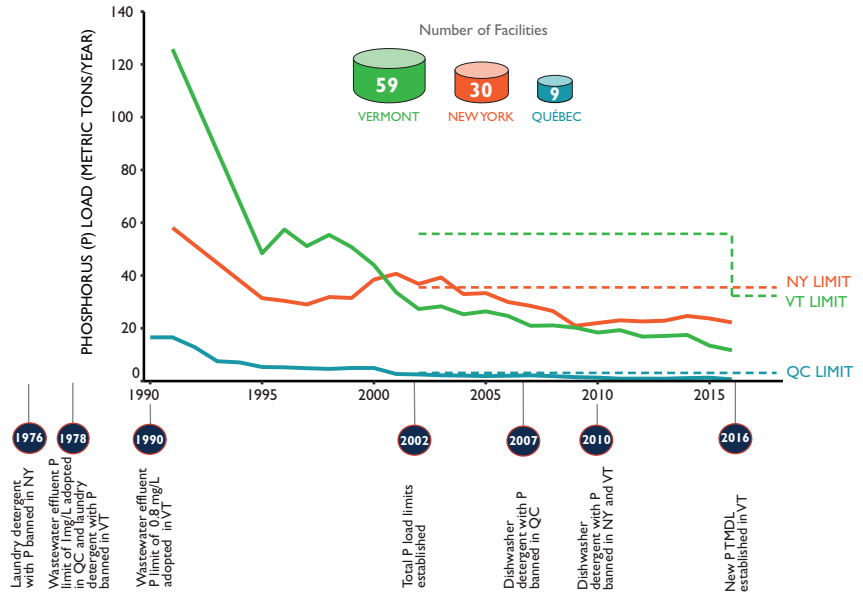
Approximately 38% of the phosphorus load to the Lake comes from agriculture (352 metric tons or 775,000 pounds each year). One key challenge in addressing this long-term problem is that part of the load comes from legacy phosphorus—that is, phosphorus that

Runoff from agricultural fields is a significant source of sediment and nutrients that enter the Lake. Photo: LCBP.



DATA SOURCES: Long Term Monitoring Program (LCBP, VT ANR, NYSDEC)

Figure 7 | Annual phosphorus loading and land cover in the Lake Champlain Basin



NOTE: The Québec target is an estimate based on the 2002 VT/QC agreement for Missisquoi Bay. The New York target is based on the 2002 TMDL. Vermont's target is based on the 2016 TMDL.
DATA SOURCES: NYSDEC, VTDEC, QC MDDELCC

Figure 8 | Phosphorus load from wastewater treatment facilities, 1990–2016

has been added to soils over decades of farming. Such legacy phosphorus will continue to be released into the Basin's waterways even as efforts to reduce future loading are underway.

Phosphorus from streambank sediments

The erosion of streambanks accounts for approximately 18% (165 metric tons or 365,000 pounds) of the annual phosphorus load to the Lake. Streambanks that lack significant woody plant growth can be susceptible to erosion during floods. Streambank erosion often occurs when lands near a river are altered to accommodate land use activity such as construction of a road, cultivation of farmlands, or any activity that removes or prevents a vegetated woody buffer. When streambanks erode and collapse into a stream, the change in flow patterns can cause increased erosion and the release of phosphorus in the future. Collapsed streambanks at the edge of agricultural fields may be especially high in legacy phosphorus.

Phosphorus from lake sediments

Stores of phosphorus are locked up in lake-bottom sediments as materials delivered from the watershed have settled to the bottom over many decades. Chemical reactions associated with low oxygen levels can cause this phosphorus to be released into the water. This phosphorus can fuel cyanobacteria growth in the shallow bays where sunlight penetrates closer to the bottom sediments. Hot, calm weather not only creates the conditions for this release of phosphorus, it is the type of weather that cyanobacteria prefer for growth.

Dive In: What You Can Do

Test your turf. Before fertilizing, test lawns and gardens to determine the actual need. It may be possible to use less fertilizer than anticipated or even none at all.

Healthy soil, healthy lawn. Foster soil health in your lawn and garden rather than relying on lawn care products that import more nutrients into the Basin.

Let it grow. Set your lawn mower blades to 3" and leave grass clippings. Tall grass is healthier and has deeper roots that hold more water and reduce runoff.

Rein in the rain. Redirect your gutter downspouts to a lawn, plant a rain garden, or install a rain barrel.

Wash vehicles on grass. Wash your vehicle on a lawn instead of a driveway to prevent detergents from running into the Lake. Alternatively, use a carwash where the water is treated after use.

Shore up the water's edge. Plant native vegetation along shorelines and riverbanks to hold soil in place and reduce erosion.

Many efforts are underway to reduce phosphorus loading and ultimately reduce phosphorus concentrations in Lake Champlain.

Lake Champlain has been the focus of renewed investments in watershed management practices by the U.S. federal government, state and provincial agencies, and municipalities. In 2015, the Vermont legislature passed the Clean Water Act (Act 64), which created the Clean Water Fund to reduce the amount of phosphorus and other pollution entering the state's waterways. In 2016, the U.S. Environmental Protection Agency produced an updated Vermont Total Maximum Daily Load (TMDL) for phosphorus loading into twelve Vermont segments of Lake Champlain, while New York continues to work toward the TMDL set in 2002 for New York segments of the watershed. Vermont and Québec adopted an agreement concerning phosphorus reduction in Missisquoi Bay in 2002. The agreement reaffirmed the phosphorus concentration limit for the bay and established a phosphorus loading limit for the bay's watershed. The two jurisdictions currently are working toward a renewed agreement and shared common goals for the restoration of Missisquoi Bay.

Farmers, resource management agencies, and local watershed organizations have long recognized that farms in the Basin play a major role in the nutrient pollution problem. Several initiatives are underway to help the agricultural sector do its part in meeting targeted phosphorus loading limits and ultimately reducing in-lake phosphorus concentrations. Ongoing grant programs, wastewater treatment upgrades, agricultural support to implement best management practices, and outreach programs all work together to meet the critical need to reduce phosphorus loading.

A variety of research studies are examining ways to reduce phosphorus loading. Photo: Stone Environmental, Inc.

TOXICS

Some toxic substances and contaminants are present in Lake Champlain, but their effects and prevalence are not well understood.

A number of pollutants and contaminants found in the Lake are of potential concern, including microplastics, pharmaceuticals, road salt, pesticides, PCBs, mercury, and other bioaccumulating toxic substances. These substances are generally found at low concentration levels. The long-term effects of low-concentration toxic substances on ecosystem and human health are not well understood.

Law Island is a recent toxic clean-up success story. This 8.5-acre island, located north of Burlington, Vermont, off Colchester Point, was the site of five dilapidated and abandoned structures, two abandoned cars, and associated refuse that left a legacy of toxic contaminants. Tests conducted in 2007 demonstrated lead and asbestos contamination from materials on the island. In partnership with the Vermont Agency of Natural Resources, the Town of Colchester undertook environmental remediation. By the summer of 2012, the site was determined to no longer be an environmental hazard. It is hoped that Law Island will serve as both wildlife habitat and a public recreation site.

Microplastics, small pieces of plastic less than 5 mm in diameter, are a growing concern in Lake Champlain. Microplastics come from a variety of sources and come in different forms; microbeads are found in some personal care products, microfibers from synthetic clothing, and eroded pieces of material from litter and other human sources. These materials often pass through wastewater treatment systems. A recent study conducted by SUNY Plattsburgh found between 10,000 to 15,000 microplastic particles were discharged every day at monitored treatment facilities in the Basin.

Microplastics can be ingested by fish and other wildlife and can cause digestive blockage and altered feeding behavior, which can in turn affect reproduction and overall health. Harmful bioaccumulating chemicals have been found in microplastics around the world; heavy metals and PCBs have been found in microplastics in Lake Champlain. The SUNY Plattsburgh study found fibers to be the most common plastics ingested by the bird and fish species upon which the research focused. The study also found greater amounts of plastics in organisms higher in the food chain, particularly cormorants, bowfin, and lake trout.

As seen in many lakes across the Northeast, the amount of chloride in Lake Champlain is increasing. Chlorides are the primary active ingredient in most winter deicing solutions and are carried to the Lake in spring runoff. Also, water softeners add chloride to water systems, and chlorides typically are not removed by wastewater treatment facilities. High chloride levels can interfere with the survival and reproduction of certain aquatic species, such as plankton and some types of bacteria, and can also indicate the presence of harmful toxic substances like heavy metals. Some invasive species, such as Eurasian watermilfoil, are tolerant of chlorides and can displace native species affected by this form of water pollution.

Plastic debris in Lake Champlain can break down to small sizes that can be ingested by fish and wildlife. Photo: Rozalia Project.

Dive In: What You Can Do

Don't trash toxics. Take toxic waste and hazardous items to designated waste drop-off centers. This includes electronics, paint, pesticides, herbicides, motor oil, and items that contain mercury, such as non-digital thermometers and compact fluorescent light bulbs (CFLs).

Look for leaks. Check cars, trucks, boats, and other machinery for leaking oil and other fluids.

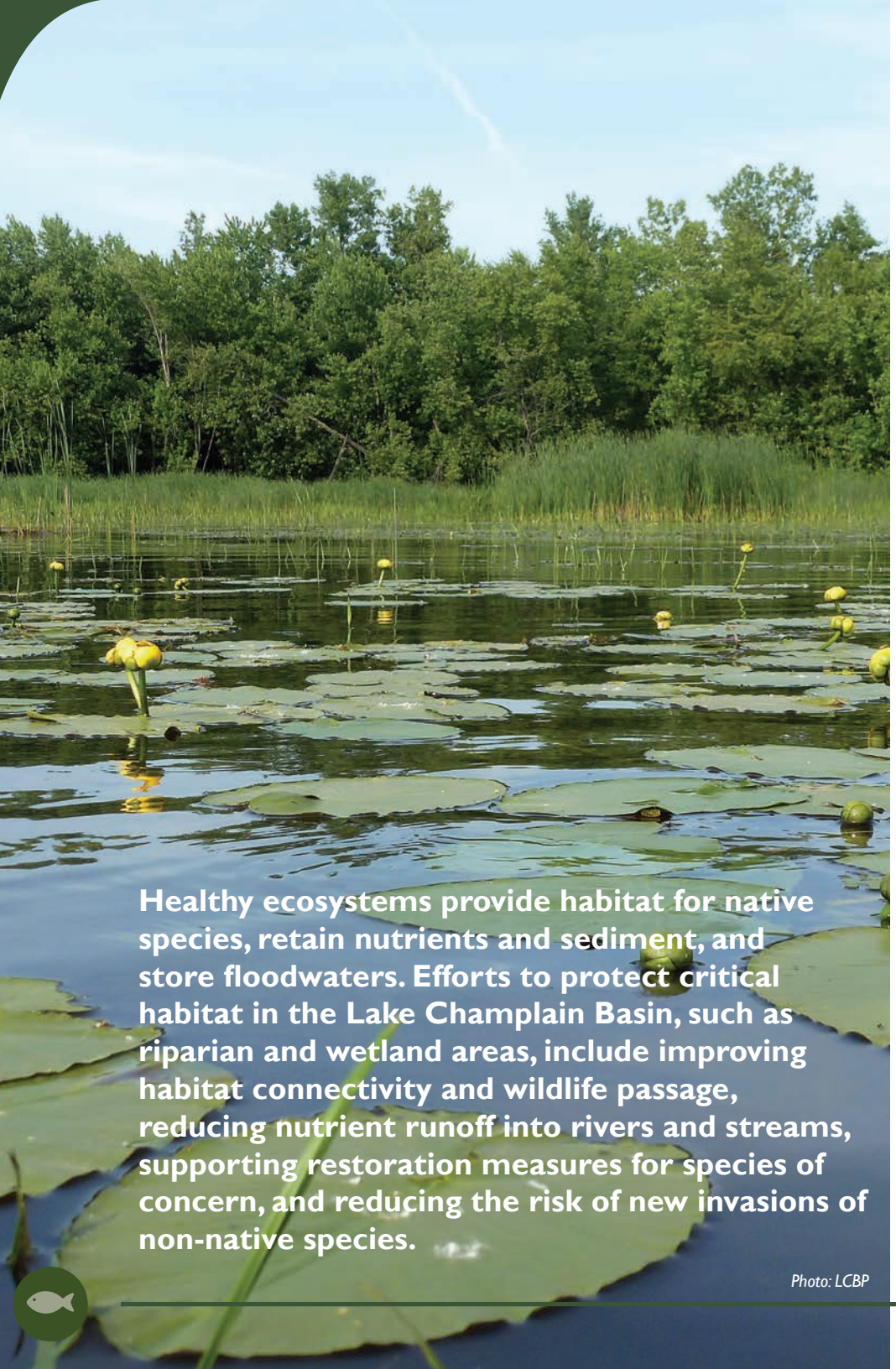
Don't flush unused medications. Return them to a pharmacy or an authorized drug collection site.

Go natural. Reduce or eliminate the application of pesticides and herbicides on your property. Choose less toxic options for pest control.

Clean greener. Use less toxic household cleaners. Not all chemicals can be removed in the wastewater treatment process.

Avoid plastic microbeads. Don't use personal care products that contain tiny pieces of polyethylene plastic used as exfoliants.

Use reusable. Drink from reusable coffee mugs or water bottles instead of buying disposable plastic versions. Bring reusable bags to the grocery store rather than using plastic or paper bags.



Healthy ecosystems provide habitat for native species, retain nutrients and sediment, and store floodwaters. Efforts to protect critical habitat in the Lake Champlain Basin, such as riparian and wetland areas, include improving habitat connectivity and wildlife passage, reducing nutrient runoff into rivers and streams, supporting restoration measures for species of concern, and reducing the risk of new invasions of non-native species.

Photo: LCBP

BIODIVERSITY

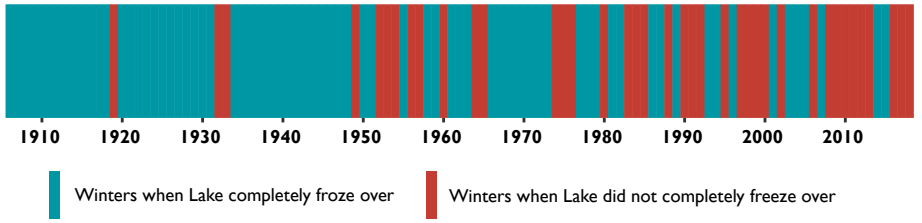
Several pressures pose threats to the Basin's biodiversity but efforts to protect habitat are helping to improve the health of the ecosystem.

The Lake Champlain ecosystem includes both the plants, animals, and microorganisms and the habitats that support them. The watershed's biodiversity refers to the large number and variety of life forms in a broad range of habitats within the Basin's ecosystem. The Basin's biodiversity is threatened primarily by loss of habitat, the changing climate, and the introduction of invasive species.

Certain types of habitat are critically important to protecting water quality and ecosystem functions. Wetland and riparian areas provide flood water storage, nutrient retention, erosion control, and food and nursery habitat for fish and other wildlife. These areas also are especially vulnerable to development, pollution, and climate change. Protection and restoration of wetland and riparian habitats is a focus of federal, provincial, and local partners. Projects such as culvert replacements to accommodate passage of aquatic organisms can improve connectivity of ecosystems and provide flood protection measures.

Scientists are documenting the effects of the changing climate throughout Lake Champlain and its watershed. Seasonal temperatures and precipitation patterns are changing toward warmer and wetter conditions. Average surface water temperatures in Lake Champlain have increased in recent decades, and the Lake has frozen over less frequently in the last 50 years than in the previous half century (Figure 9).

These changes in climate affect both aquatic and terrestrial habitat. Across New England, milder winters and increased precipitation in the form of rain negatively impact many economically important tree and forest species, according to a new assessment led by the U.S. Department of Agriculture (USDA) Forest Service



DATA SOURCE: National Weather Service/US Weather Bureau

Figure 9 | Freeze-over of Lake Champlain, 1906–2018

Northern Research Station. Forests in the upper reaches of the Lake Champlain Basin are important to the Lake's water quality, as they store and filter water that eventually travels to the Lake. If the composition or extent of these forests are degraded, the impact on the Lake's water quality could be significant.

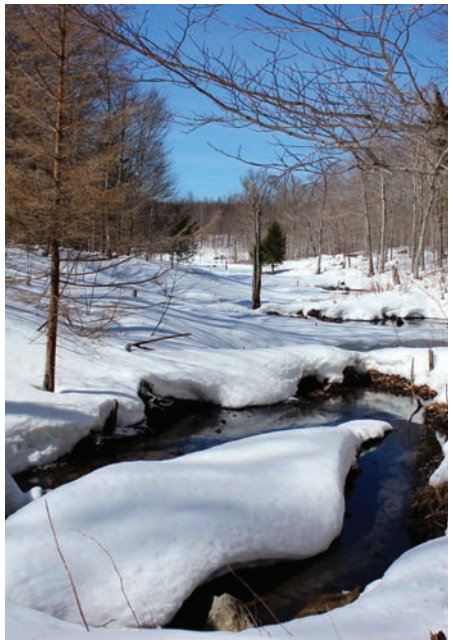
In response to the biodiversity challenges, various efforts have been undertaken. In 2016, the USDA Natural Resources Conservation Service worked with local landowners to conserve additional wetland parcels in the Otter Creek Swamp, increasing the total amount of conserved wetlands in this system to 2,148 acres. The Nature Conservancy considers Otter Creek Swamp to be the largest and most biologically diverse swamp complex in New England. It is a haven for bird species, a foraging area for endangered Indiana bats, and a home to large mammals such as moose and bear. Otter Creek Swamp also provides flood protection to the downstream town of Middlebury. During Tropical Storm Irene, the wetlands and floodplains reduced flood damage to the town by as much as $1.8 million. This flood protection likely will become more valuable if the frequency of extreme events in the watershed increases as predicted by climate models.

In 2016, Vermont approved the reclassification of the 1,359-acre Sandbar wetlands, the large delta wetland complex between the Lamoille River and Lake Champlain, as Class 1, the highest level of protection. The designation more than doubled the state's total acreage of Class 1 wetlands. The Sandbar complex is home to 29 rare, threatened, and endangered species and provides water storage, nutrient retention, and erosion control.

Early in 2018, New York's Adirondack Park Agency classified the 20,543-acre Boreas Ponds Tract as a mix of limited use wild forest and wilderness. This area is home to rare plant and animal habitat and will provide low-impact recreation opportunities for residents and visitors. The tract's namesake ponds account for 320 acres of water themselves, but the tract also includes the Boreas River and various streams; all the water ultimately ends up in either Lake Champlain or the Hudson River. The classification of the Boreas Ponds Tract increases the size of the Adirondack Park's High Peaks Wilderness Area to more than 250,000 acres.

Work continues on the restoration of some critical native species in Lake Champlain. New technology is allowing researchers to acoustically track tagged lake sturgeon, which will help fisheries biologists better understand the movement, habitat use, and migratory patterns of the fish. The bald eagle has made a remarkable comeback from years of decline after the use in the mid-20th century of DDT, a pesticide that caused the eagles to produce eggs with thin, unviable shells. The number of nesting pairs of bald eagles in Vermont has grown from one in 2003 to twenty-one in 2017. Audubon Vermont and the Vermont Fish and Wildlife Department are considering upgrading the state status of the bald eagle from endangered to threatened.

The removal of the Willsboro Dam on the Boquet River opened up miles of habitat for Atlantic salmon and other key fish species. Photos: Vic Putman.



Changing snowpack and timing of spring melt affects habitat from mountain streams to Lake Champlain. Photo: LCBP.

FISH HEALTH

Anglers find that fishing in Lake Champlain is good in every season, whether fishing for walleye, pike, bass, Atlantic salmon, lake trout, or perch.

The Lake is home to more than 80 species of fish, including key sport fish species that attract fishing tournaments of all sizes, from local fishing club derbies to large national competitions. In 2016 and 2017, anglers caught state record-sized carp, cisco, freshwater drum, and redhorse sucker in Lake Champlain and its tributaries.

Lake trout, Atlantic salmon, and other high-priority game fish species continue to be stocked in Lake Champlain by state and federal fish and wildlife agencies in Vermont and New York to support the Lake Champlain sport fishery. In the summer of 2017, the U.S. Fish and Wildlife Service (USFWS) celebrated the reopening of the White River National Fish Hatchery in Bethel, Vermont. The hatchery, which was severely damaged by Tropical Storm Irene in 2011 and subsequently decommissioned, is once again an important source of broodstock of Atlantic salmon and lake trout for the Lake Champlain Basin.

The 40-year effort to restore lake trout in Lake Champlain has shown recent promise. Scientists from the University of Vermont have found that the percentage of wild juvenile lake trout in Lake Champlain (the offspring of stocked fish) increased from 24% of lake trout collected in 2015 to nearly 50% in 2017. The surge is likely a result of changes in the diet of recently hatched trout, reduction in predation, improved sea lamprey control, and changes in the use of spawning sites.

Non-native and invasive fish species continue to be a challenge in Lake Champlain. Populations of alewife, tench, rudd, and some of the more popular introduced species, such as rainbow and brown trout, have increased in number and size. Invasive alewife continue to disrupt the Lake Champlain food chain by outcompeting and displacing native rainbow smelt, the primary food source for lake trout and Atlantic salmon. Some sport fish will prey on alewife, but a diet rich in alewife can lead to elevated ingestion of the enzyme thiaminase in lake trout and Atlantic salmon. This enzyme can prevent the uptake of thiamine in some salmonid eggs, leading to early mortality in hatchlings.

The wounding rate of Atlantic salmon by sea lamprey is near target limits established by fisheries managers, though challenges remain for lake trout.

Sea lamprey are eel-like parasitic fish that have had devastating impacts on Atlantic salmon, lake trout, and other sport fish in Lake Champlain. The fish are native to the Atlantic Ocean, and debate continues as to whether they are a native nuisance or an invasive species in Lake Champlain. Sea lamprey spend the first four years of their lives as larvae in tributaries to the Lake. In their fifth year, most lamprey become parasitic and enter the Lake, where they attach to host fish and feed on the host's blood and body fluids.

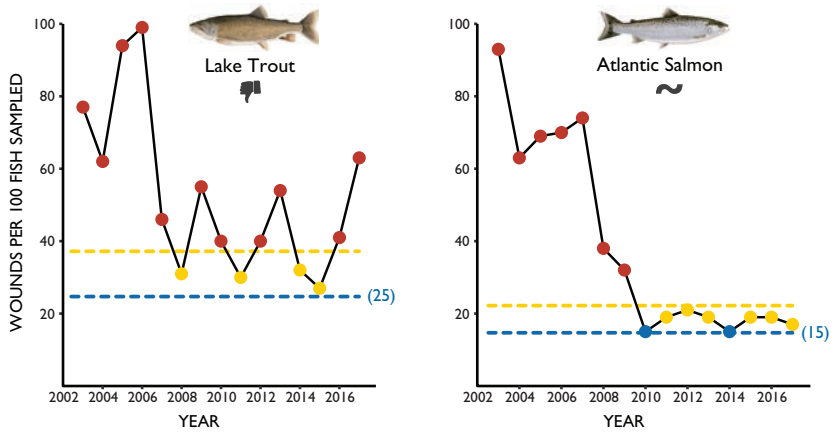
A long-term management program, operated since 2002 by the Lake Champlain Fish and Wildlife Management Cooperative in partnership with Vermont Fish and Wildlife Department and New York State Department of Environmental Conservation, has helped to reduce sea lamprey impacts on native fish. In this collaborative effort, researchers prioritize and treat tributaries by evaluating lamprey larval density in rivers, streams, and deltas; monitor trends in lamprey populations; and study the effectiveness of chemical treatments. Methods of control include installing barriers to prevent spawning, using traps, and applying chemical pesticides called lampricides in rivers and deltas. These efforts have had some success. A seasonally-operated barrier on the Morpion Stream in Québec, for example, has eliminated reproduction in upstream sections. And the first-time use of lampricide in the LaPlatte River in Shelburne, Vermont, has reduced a previously uncontrolled source of sea lamprey.

All of these methods are designed to have their effect during the sea lamprey's larval stage, before they become parasitic and prey on fish in Lake Champlain. The ultimate goal is to reduce the amount of chemicals

USFWS and its partners work to ensure that anglers enjoy a healthy fishery in Lake Champlain. Photo: USFWS.

required to control the species, but in the meantime, the USFWS ensures that treatments have limited impacts on non-target species, especially threatened and endangered species. Lake sturgeon, channel and eastern sand darters, stonecats, mudpuppies, mussels, and native lamprey species may be susceptible to lampricides. Lampricides are non-toxic to humans and mammals at the levels in which they are applied in the Lake Champlain Basin. However, residents within treatment areas are notified before treatment occurs and advised of a temporary limit on fishing and recreation and on using water for human consumption, domestic use, irrigation, or livestock watering.

In the last few years, the number of sea lamprey wounds observed on Atlantic salmon has remained near the established limit, while the wounding rate of lake trout has increased (Figure 10). A number of factors may affect wounding rates, including sample collection and reproduction success of both lamprey and salmonids.



NOTE: Lake trout sampled were 533-633mm (21-25 in) in length. Salmon were 432-533 mm (17-21 in) in length. This graphic contains Lake-wide data.
DATA SOURCE: USFWS
Fish illustrations © Flick Ford

Figure 10 | Sea lamprey wounding rates in Lake Champlain, 2002–2017

AQUATIC INVASIVE SPECIES

A number of aquatic invasive species have arrived in Lake Champlain, but no new species have been detected since the discovery of spiny waterflea in 2014. Non-native species are plants, animals, and pathogens that are introduced to the Lake Champlain Basin from outside the watershed. The list of non-natives currently present in the Basin includes those whose impact has been difficult to quantify, including well-liked species such as rainbow trout, brown trout, and largemouth bass as well as the lesser known faucet snail or European fingernail clam. Some of these non-native species are designated as invasive species, meaning they are known to cause economic or environmental harm or have an adverse effect on human health.

Of the 50 known aquatic non-native species in Lake Champlain, just over a dozen are invasive (Figure 11). Commonly known aquatic invasive species (AIS) include plants such as Eurasian watermilfoil, purple loosestrife, and water chestnut; crustaceans and mollusks such as spiny waterflea, rusty crayfish, and zebra mussel; and harmful pathogens such as largemouth bass virus.

The spiny waterflea is the most recent aquatic invasive species to be detected in Lake Champlain and poses the greatest risk of spread to other water bodies. This crustacean, which is native to northern Europe and Asia, likely was introduced with released ballast water into the Great Lakes, after which it spread rapidly to the inland lakes of the Adirondacks and then to

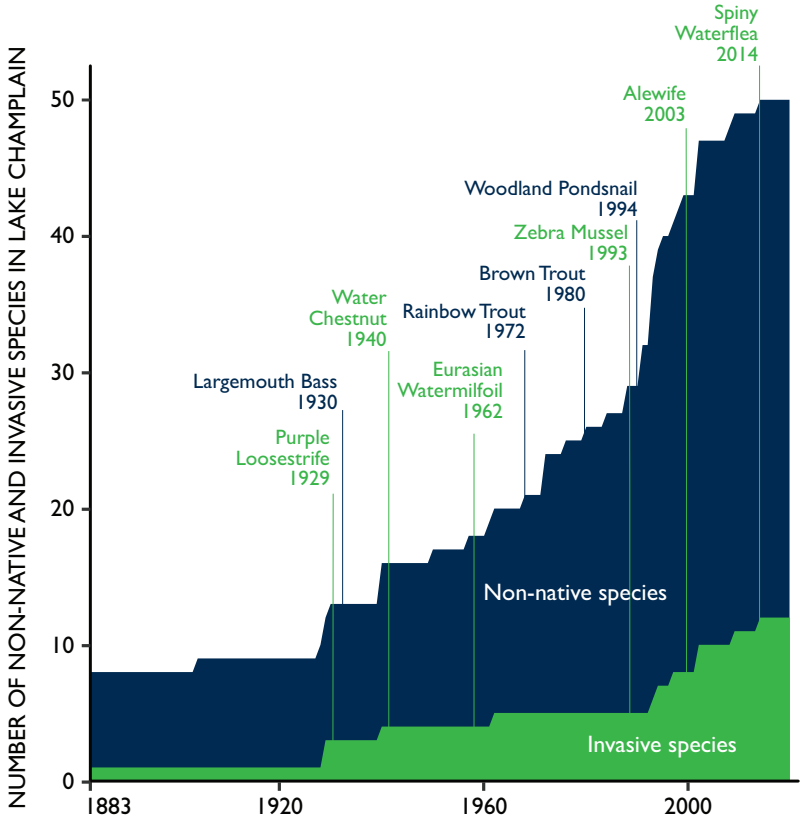
Treatment of high-risk boats with a hot-water high-pressure wash can help to prevent the spread of aquatic invasive species. Photo: LCBP.

Lake Champlain. The Lake Champlain Long-Term Water Quality and Biological Monitoring Program first detected spiny waterflea in the Lake in 2014. In addition to its negative impact on the Lake's plankton communities, the species' long, barbed tail fouls the lines and downriggers of anglers. That fishing equipment, along with bilge water, provides a key means for the spiny waterflea to further its spread in the Basin.

Asian clams have been present in the Champlain Canal and Lake George for several years, but it was not until 2016 that they were found by an angler in Lake Bomoseen. Asian clams are small bivalves that can clog water intake pipes and irrigation systems and can carpet sandy areas on a lake bottom. They are hermaphrodites, meaning each individual can reproduce without a mate, a trait that allows them to spread rapidly. The Lake Champlain AIS Rapid Response Task Force evaluated the detection of Asian clam in Lake Bomoseen for potential management action. Because the population was spread over a large area (making in-lake control of the species nearly impossible), the task force suggested increased boat launch stewardship and installation of a decontamination station.

The Basin's ecosystem likely is affected by some non-native species that have not yet been documented to cause harm in water bodies. Local watershed organizations actively manage species such as European frogbit and yellow flag iris. Species on the doorstep of Lake Champlain that present the greatest threat from outside the Basin include round goby, quagga mussel, hydrilla, and starry stonewort.

The Basin is also threatened by a number of terrestrial invasive species and forest pests and pathogens that can cause significant economic damage. Emerald ash borer, a devastating invasive forest pest species, was detected for the first time in Vermont in February 2018, and hemlock woolly adelgid, another forest pest, was discovered in the Lake George region in 2017.



NOTE: Data reflects the year of first reported sighting of species.
DATA SOURCE: Ellen Marsden, University of Vermont

Figure 11 | Aquatic non-native and invasive species in Lake Champlain, 1883–2017

Hydrilla, quagga mussel, round goby, and starry stonewort (clockwise from top left) are the most threatening invasive species "on the doorstep" of Lake Champlain. Photos: University of Florida, Ellen Marsden, USFWS, Minnesota DNR.

Some of the most significant impacts to Lake Champlain ecology are caused by aquatic invasive species, which have altered the plankton community at the base of the food web. Zooplankton are the food source that drives the fishery of Lake Champlain, supporting Atlantic salmon, lake trout, and other key species. Scientists at SUNY Plattsburgh documented declines in native plankton called rotifers after the invasive zebra mussel was first detected in southern Lake Champlain in 1993. Zebra mussels established themselves throughout the Lake in less than a decade. Their impact on plankton is just one of this invasive species's far-reaching effects. Zebra mussels also smother and displace native mussels, clog water intake pipes, cut the feet of swimmers, and encrust submerged historic shipwrecks.

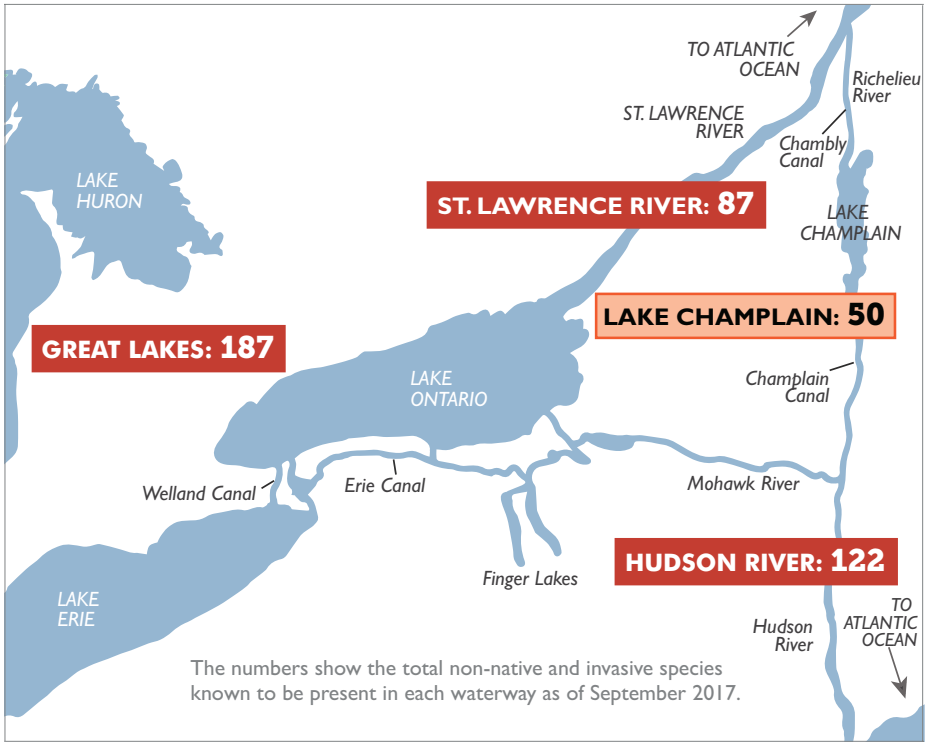
After the detection of invasive alewives, populations of native water fleas known as copepods and cladocera shifted, suggesting that alewives not only out-compete native rainbow smelt but also may impact the native group of water fleas, which serve as part of the base of the Lake Champlain food chain. The invasive spiny waterflea, which arrived in 2014, may also affect the Lake's ecosystem. Samples collected in summer 2014 showed a sharp spike in densities of spiny waterflea during the initial invasion of this species. Spiny waterflea densities declined in the following years, but a decline in the abundance of several planktonic species of rotifers and some common crustaceans has been attributed to spiny waterflea predation.

Aquatic invasive species can hitch a ride on recreational vessels passing through the Chambly Canal on the Richelieu River and other canals that connect Lake Champlain to other water bodies in the region. Photo: LCBP.

While some invasive species migrate, human activity is the most common cause of aquatic invasive species spread. The primary source of new aquatic species in the Northeast is ballast water taken in by ships at sea and released into the Great Lakes. Once in the Great Lakes, a species can spread through the canals that connect Northeast water bodies and that provide a leading pathway for introduction to Lake Champlain (Figure 12).

The Champlain Canal, which connects the Lake to the Hudson River, has been the most significant pathway for AIS spread. A feasibility study has recently begun to examine options for a barrier on the Champlain Canal to prevent the movement of aquatic non-native and invasive species.

Other pathways of introduction and spread include baitfish release, aquarium and pet dumping, water garden escapes, and overland transport on watercraft, trailers, and recreational



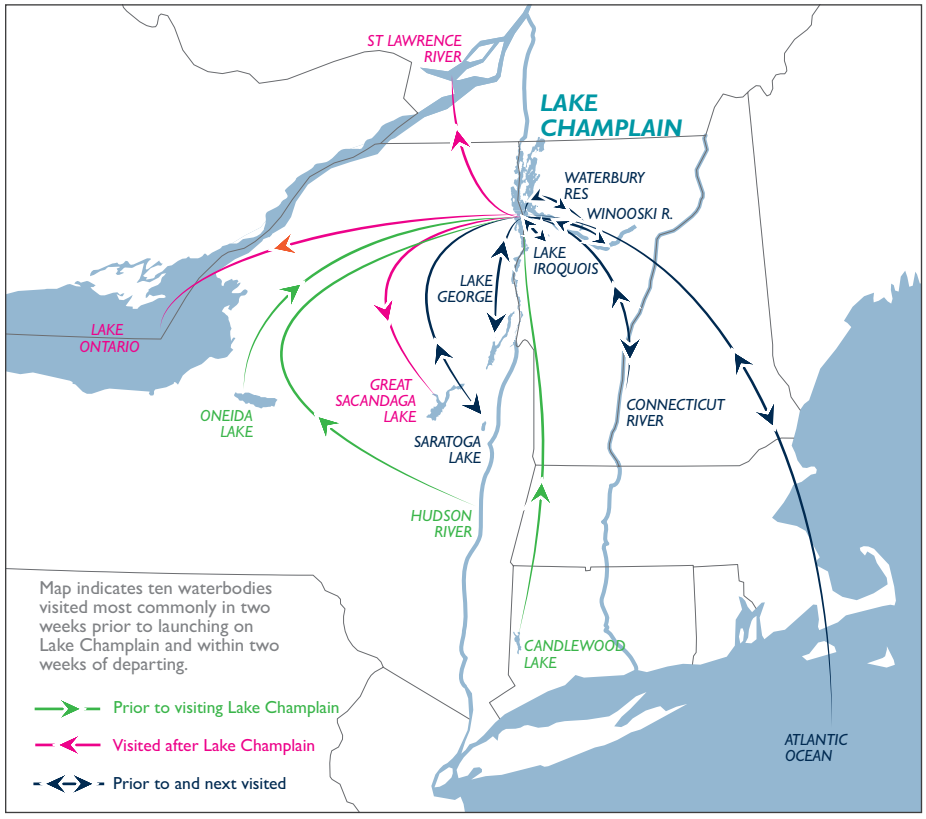
NOTE: All the waterways contain some overlap of species
DATA SOURCES: UVM, LCBP, Lake Champlain Sea Grant, Great Lakes Environmental Research Laboratory, Lafontaine and Costan 2002, Strayer 2012 and Egan 2017. Lake Champlain data current as of September 2017.

Figure 12 | Non-native threats to Lake Champlain Basin from connected waterways

equipment. The LCBP and many partners support boat launch steward and greeter programs on Lake Champlain and other water bodies throughout the Basin. The stewards inspect boats as they launch and depart from lakes to intercept invasive species before they are spread. Watercraft decontamination stations have been strategically placed across the Adirondack region, on the shorelines of Lake George and Lake Champlain, and at various locations throughout Vermont. Stewards treat high-risk boats with high-pressure hot water to flush any potential non-native and invasive species from boat exteriors, engines, and other compartments. Vermont and New York have recently strengthened rules and regulations requiring boaters to clean and drain their boats and trailers when moving between waterways to help prevent the spread of AIS. In another prevention step, Québec has implemented new baitfish regulations.

Steward programs also collect important information about the overland transport of boats. Surveys show that vessels entering Lake Champlain come from as far away as Texas and Colorado and that certain water bodies in the Northeast are commonly visited in a short period of time immediately before arriving on Lake Champlain or after departing (Figure 13). An understanding of boat movement helps to prioritize AIS-infested water bodies for boat inspections and decontamination stations. Partners in the Basin take a regional approach to risk assessment and spread prevention by sharing techniques and data from their programs.

Early detection and rapid response are key elements of spread prevention efforts. Containing and managing new introductions of species before they become established helps to lower the potential long-term management burden that falls on the states and non-profit organizations, all of which have limited resources and funding. Trained volunteers serve a critical role as early detectors of new species and the spread of existing invasive species in the Basin.



DATA SOURCE: Lake Champlain Basin Program Boat Launch Steward Program

Figure 13 | Potential spread of aquatic invasive hitchhikers by trailered boats in the Northeast

Dive In: What You Can Do

Become a volunteer citizen scientist. Contact your local watershed organization or state agency and learn how to look for and identify invasive species.
Clean, drain, and dry. Take steps to stop aquatic hitchhikers.
Dispose of bait properly. Don't dump in water bodies.
Use only native species. Don't plant invasives in lawns or gardens.
Use local firewood. Never move firewood between locations.

The LCBP boat launch steward program expanded to Québec for the first time in 2017. Photo: OBVBM.

Invasive water chestnut continues to require intensive control measures each year, but coordinated management efforts have greatly reduced the extent of infestations.

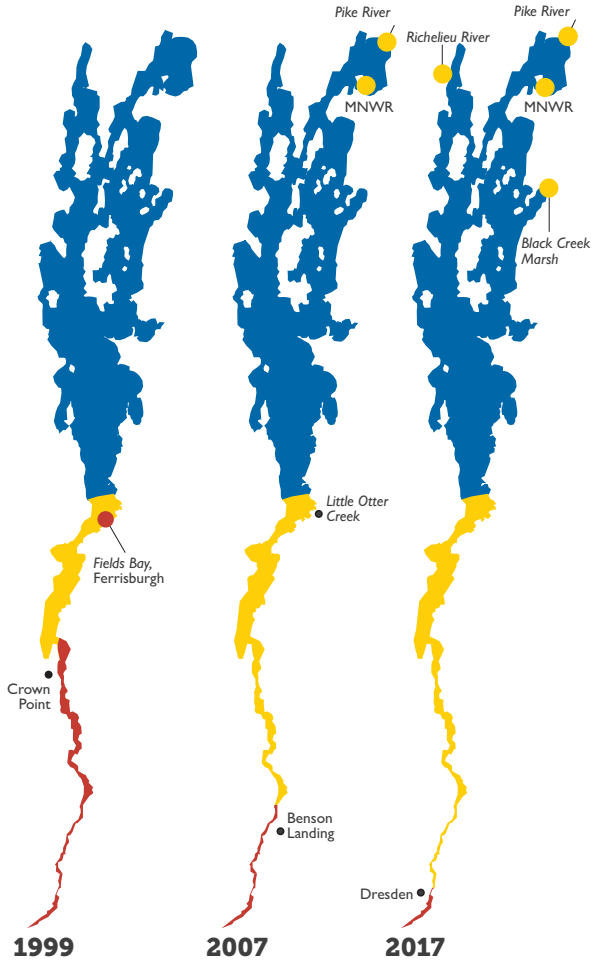
The water chestnut is an invasive plant that forms dense leafy mats that float on the water surface. In the southern end of Lake Champlain, water chestnut limits boat traffic and recreational use, crowds out native plants, and creates oxygen-depleted zones uninhabitable for fish and other organisms. It was first documented in southern Lake Champlain in the 1940s and was likely introduced through the Champlain Canal from a water garden escape. The Hudson River also contains significant populations of water chestnut.

Lake Champlain's water chestnut control program is a long-standing success story. Nearly a dozen U.S. federal, state, provincial, and non-government organizations provide support to harvest water chestnut mechanically and by hand in Lake Champlain and other inland waters in the Basin. Since 1999, these efforts have pushed areas of dense population from Crown Point southward to the Dresden Narrows. Substantial progress by hand harvesting has been made at a few satellite populations in the Richelieu River, Pike River, and Missisquoi National Wildlife Refuge (Figure 14).

Mechanical and hand harvesting efforts to control water chestnut over the past few years have been challenging due to fluctuating water levels in the Lake. Low water levels in 2016 limited management staff and volunteers in their ability to access shallow areas for harvesting plants; fortunately, higher water in 2017 allowed teams to make up for the lost progress. In 2017, after water levels recovered, teams harvested more than 2,000 rosettes in Black Creek Marsh in St. Albans Bay that were discovered the previous year.

The effort to control this invasive plant could soon be augmented by a new technological tool. The Lake Champlain Committee and Vermont Department of Environmental Conservation are evaluating the possibility of using drones to increase the efficiency of water chestnut management in the Lake. Drones are being evaluated for use in detection, surveying, documentation, and monitoring water chestnut beginning in 2018.

Water chestnut rosette. Photo: Martin Mimeault.



MISSISQUOI BAY

Hand-pulling efforts in MNWR continue to reduce the population, which fell from just under 6,000 rosettes in 2007 to 447 in 2017. The Pike River population has declined from 1,487 rosettes in 2015 to zero detections in 2016 and 2017.

NORTHEAST ARM

A new population of water chestnut was discovered in Black Creek Marsh in late 2016 and about 2,000 rosettes were harvested in 2017.

MAIN LAKE

Hand-pulling is necessary between Little Otter Creek in Ferrisburgh, VT and Crown Point, NY. 591 rosettes were found in the Richelieu River in 2015; no plants detected in 2016 or 2017.

SOUTH LAKE

Water chestnut is mechanically harvested by VTDEC and NYSDEC in the red-shaded area, which has been steadily reduced over the past two decades.

STATUS

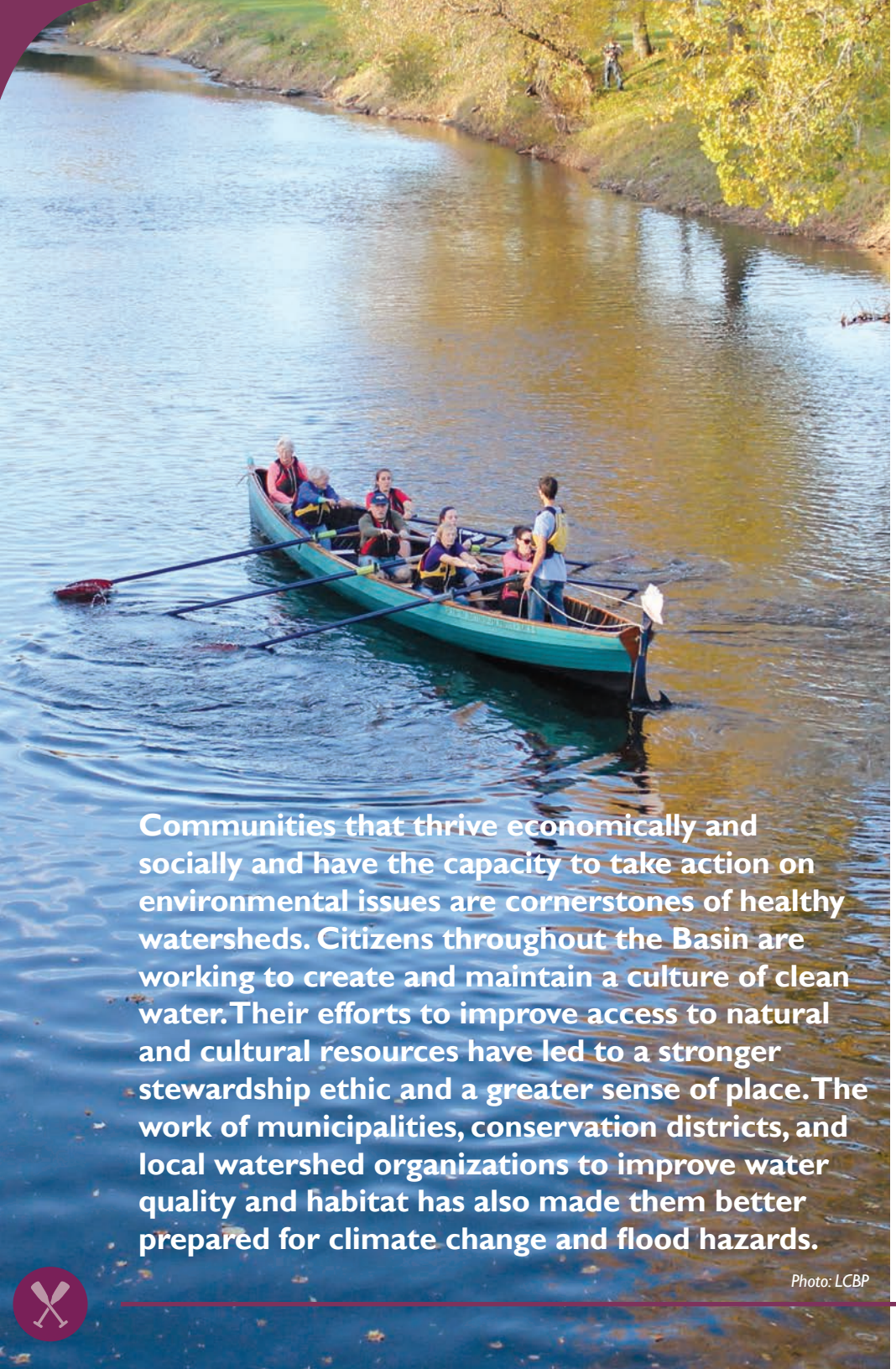
GOOD — No water chestnut present; monitoring on-going

FAIR — Water chestnut is present with less than 25% coverage (typically managed by hand-pulling)

POOR — Water chestnut is present with greater than 25% coverage (typically managed by mechanical harvesting)

DATA SOURCES: VT DEC, NYSDEC, QC MDDELCC, USFWS

Figure 14 | Extent of water chestnut coverage in Lake Champlain, 1999, 2007, 2017



Communities that thrive economically and socially and have the capacity to take action on environmental issues are cornerstones of healthy watersheds. Citizens throughout the Basin are working to create and maintain a culture of clean water. Their efforts to improve access to natural and cultural resources have led to a stronger stewardship ethic and a greater sense of place. The work of municipalities, conservation districts, and local watershed organizations to improve water quality and habitat has also made them better prepared for climate change and flood hazards.

Photo: LCBP

COMMUNITY ENGAGEMENT

In addition to contributing to healthy ecosystems and improved human health, clean water also provides economic benefits.

As threats to water quality and habitat—particularly those magnified by a changing climate—have become more acute, local leaders are intensifying their focus on efforts to minimize the threats and adapt to climate change and its effects. Undesirable lake conditions such as cyanobacteria (also known as blue-green algae) blooms have caught the public's attention. Catastrophic events also shape attitudes and actions at the local level. In 2011, spring lake flooding and Tropical Storm Irene together damaged several thousand homes in New York, Québec, and Vermont, and caused millions of dollars in other damages.

In 2016, a University of Vermont (UVM) study supported with LCBP funding examined property values, tourism expenditures, and regional economic data to assess the economic impacts of clean water. The researchers predicted that a decline in water quality could result in a $16.8 million decrease in summertime economic activity. They also found that deterioration in water clarity could cause home values to drop as much as 37%. This scenario was borne out in the same year as the study was released, when assessed property values for several shoreline homes in Georgia, Vermont, decreased after cyanobacteria blooms reduced lake use for these properties. Unsurprisingly, improvements in water quality have the opposite influence on property values: the UVM study found that if the new phosphorus standards in Vermont are met and water clarity increases, the values of homes in lakeshore areas could increase by more than $15,000.

Throughout the watershed, local communities are seizing opportunities to address water quality challenges in ways that also save money.

Grant programs from the LCBP and our state and provincial partners support many projects that improve water quality and ecosystem health and foster climate change adaptation and flood resilience. Watershed groups, municipalities, conservation districts, and other organizations have implemented projects that increase the efficiency of road salt application, update road maintenance programs to prevent erosion and reduce repair costs, and install green infrastructure that reduces investment in more expensive traditional infrastructure.

A 2016 state municipal grant program helped 186 Vermont towns get a jump on a new general stormwater permit for roads by bringing forty miles of roads up to current standards. In New York, state water quality improvement program grants

have allowed the Clinton and Franklin County Soil and Water Conservation Districts to implement best management practices throughout New York's portion of the Basin as part of a roadside erosion plan. In Québec, the Memphremagog and Brome-Missisquoi regional county municipalities have implemented programs to train road crews and other municipal staff on erosion control and stormwater management techniques.

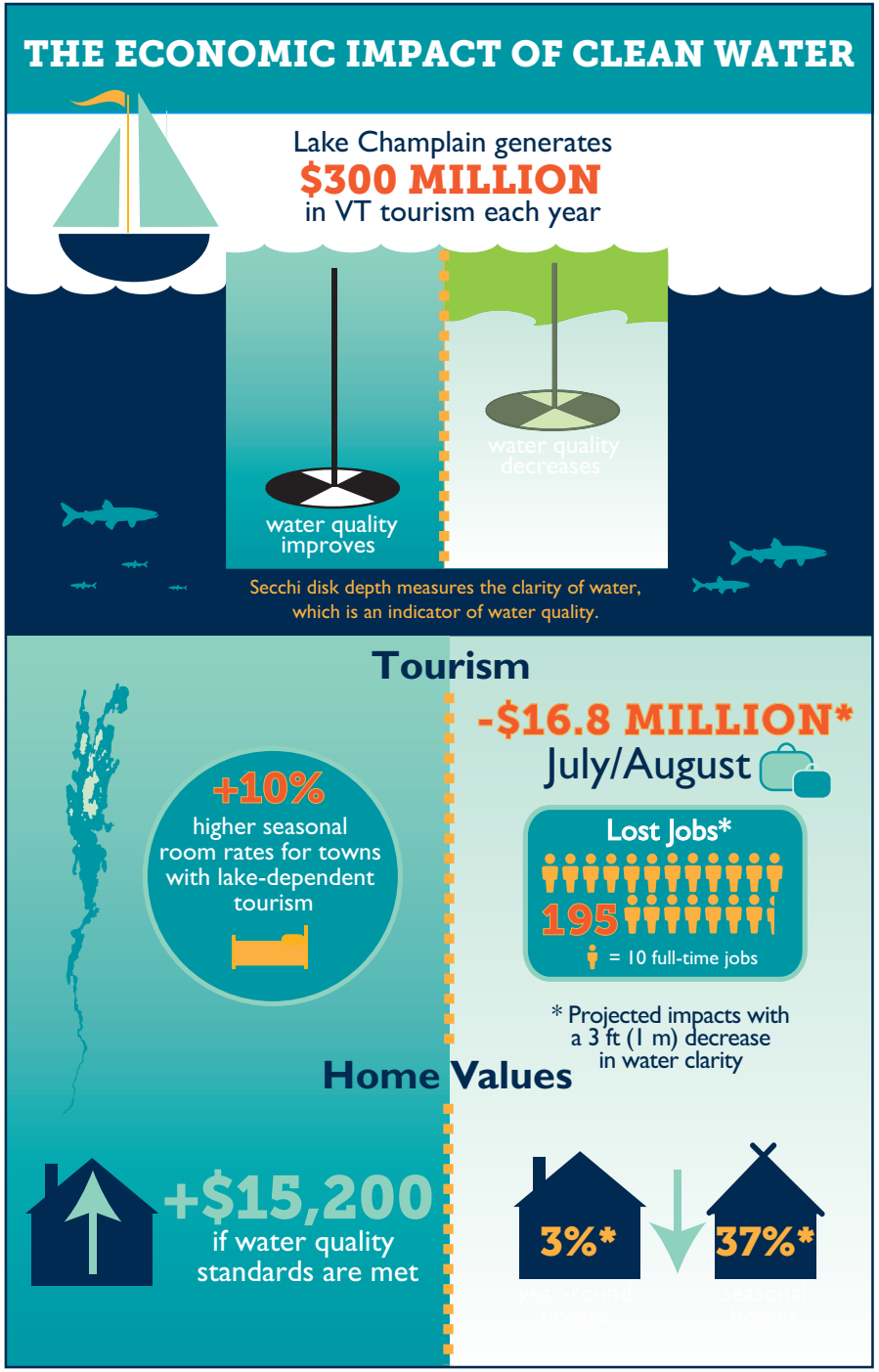
Communities in the watershed are taking important steps to enhance resilience to severe flood events.

In 2015 and 2017, the LCBP's local grant program included a focus on flood resilience. These grants targeted projects that enhance the ability of communities to adapt to climate change and to withstand and recover from the impacts of severe events. The projects included community outreach, design and implementation of streambank stabilization and other stormwater mitigation projects, and establishment of river corridor easements.

Since 2011, many communities across the Lake Champlain Basin have taken important steps to become more flood resilient. A third of the communities in Vermont have protected river corridors or floodplains from further losses. More than half have adopted Local Hazard Mitigation Plans or are in the process of doing so (up from 35% in 2014), and 80% have Emergency Operations Plans in place (up from 36% in 2014).

The New York Rising Community Reconstruction Plan for the Towns of Jay and Keene identified a suite of projects to rebuild and implement flood resilience strategies in the wake of Tropical Storm Irene and Tropical Storm Lee. And in the upper reaches of the Missisquoi River in Québec, the Memphremagog Regional County Municipality has launched an initiative to examine the consequences of climate change and conduct a vulnerability analysis that will be used to help municipalities develop adaptation strategies.

Riparian plantings help communities become more resilient to flooding events. Photo: Wildlife Management Institute.



DATA SOURCE: *An Assessment of the Economic Value of Clean Water in Lake Champlain*. Brian Voigt, Julia Lees, Jon Erickson, University of Vermont, Gund Institute for Ecological Economics. September 2015.

RECREATION

Ample recreational opportunities continue to foster stewardship of the Basin's natural and cultural heritage.

People connect to the land and waters of the Lake Champlain Basin in a variety of ways. Swimming, fishing, and boating continue to be popular in all seasons. Residents and visitors flock to the Lake's beaches in summer. Anglers fish favorite local spots and participate in fishing tournaments and derbies year-round. State agencies increase interest in fishing, and access to it, by hosting free fishing days. In the spring of 2018, *BoatUS* magazine affirmed what many local residents know when it recognized Lake Champlain as one of eight premier freshwater boating destinations in the United States.

Communities throughout the watershed have recognized the importance of recreation to their identity and their local economies. Watershed groups, recreation organizations, museums, historical associations, and municipalities have implemented projects to foster the appreciation of the Basin's history and to enhance recreation opportunities.

In recent years, a number of designated recreation paths on both land and water have been established or enhanced. The Western New England Greenway, a multi-state bike route that links New York City and Montreal, traverses Vermont from the Massachusetts state line to the border with Québec, was established in 2015. Work continues on the North Country National Scenic Trail, a 4,600-mile

The Island Line Trail provides a spectacular way for cyclists to experience Lake Champlain. Photo: LCBP.

DATA SOURCE: NYSDEC, Northern Forest Canoe Trail, Vermont River Conservancy, Lake George Park Commission, NYSDEC.

Figure 15 | New and improved cartop boat access sites, 2015–2018

footpath that begins in Crown Point, New York, and meanders through seven states, ending at Lake Sakakawea State Park in North Dakota. An effort is underway to extend the trail eastward to the Long Trail in Vermont.

The improvement and creation of new water trails and access points has helped get more people out on rivers and lakes (Figure 15). The Lamoille River Paddlers Trail in Vermont was established in 2015, with the goal of providing new opportunities for low-impact water-based recreation. Managers of the Northern Forest Canoe Trail, which extends from Old Forge, New York, to Fort Kent, Maine, continually work to adapt to constantly changing river conditions and provide the best experience for paddlers. In Québec, a paddlers trail on the Pike River was expanded with a number of new sites and upgrades.

Many other important connections have been made between Basin communities and their waterways. The Vermont Fish & Wildlife Department completed the reconstruction of the John Guilmette Fishing Access Area in South Hero. The Community Sailing Center on the Burlington waterfront opened a new facility that will enhance camp and school programs that include important environmental education components. In Plattsburgh, New York, a new municipal marina opened in 2015.

Cultural heritage tourism continues to have a growing impact on the Champlain Valley economy. A 2017 study released by Fort Ticonderoga found that guest spending at the 18th century fort in New York generated $12.1 million for the local economy. While military history is still often the focus of heritage tourism, several regional efforts have recognized the importance of diverse cultural components that have shaped the making of the two nations in which the Basin sits. In 2016, the Vermont Department of Marketing and Tourism published the African American Heritage Guide. Developed in collaboration with the Vermont Partnership for Fairness and Diversity, the guide directs visitors to 22 sites that interpret African American heritage in Vermont; thirteen stops on the trail are in the Lake Champlain Basin. In 2017, communities in New York kicked off the 100th anniversary of women's suffrage with lectures, programs, and special events.

In the heart of the Champlain Valley, the Lake Champlain Bridge Quest links historic sites on the New York and Vermont shores of the Lake. Visitors search for clues at the sites to answer seven riddles in order to collect a commemorative coin. The Bridge Quest is a collaborative effort of the Champlain Valley National Heritage Partnership, Chimney Point State Historic Site, Crown Point State Historic Site, Lake Champlain Visitors Center, and Crown Point State Campground. This bi-state effort to offer a cohesive perspective on the region's history encourages visitors to walk the sites and enjoy the scenic beauty, all while learning about the area's history and archaeology.

New water trails and projects that improve access to rivers throughout the Basin have enhanced recreational opportunities for paddlers of all types. Photo: Scott Staples.

A Fort Ticonderoga craftsman threads the region's history into visitors' lives. Photo: LCBP.

A public that understands the Basin's water quality and resource management challenges as well as possible solutions can make informed choices about protection and restoration. Organizations and institutions throughout the Basin are working on many fronts to educate citizens of all ages. Through formal education programs in classrooms and camps and with outreach efforts at public events, partners are equipping citizens to take action and change behavior to improve water quality.

Photo: LCBP

EDUCATION AND OUTREACH

School programs that educate young learners about watershed issues play an important role in addressing the Basin's challenges.

Developing an understanding of watershed science at an early age is critical to fostering stewardship of natural and cultural resources. Instruction in classrooms and field settings that is centered around rich watershed content equips young citizens to make informed choices about their personal actions. Educating these young learners creates a powerful multiplier effect as they share information and values with family and friends.

The Champlain Basin Education Initiative (CBEI) continues to train teachers in place-based watershed education. Thirty-three educators have taken the year-long Watershed for Every Classroom professional development program since 2015. This comprehensive course offers in-depth exploration of the Basin's natural and cultural resources. Hundreds more educators have attended one- or multi-day sessions with CBEI partners and teaching institutions. After actively engaging with scientists and other specialists during these programs, each teacher shares the newly acquired knowledge with as many as 200 students each year.

Students also learn while participating directly in projects that benefit the watershed. More than 20 New York schools and 40 Vermont schools in the Basin have worked with the Lake Champlain Chapter of Trout Unlimited and the Vermont Trout Unlimited Chapter on the Adopt-A-Salmon and Adopt-A-Trout programs. Through these programs, fish eggs provided by New York State Department of Environmental Conservation (DEC) and the U.S. Fish & Wildlife Service are delivered to classrooms in January. Students care for the fish through the winter and release them in local streams in late spring. Collectively, volunteers from Trout Unlimited teach more than a thousand middle and high school students about watersheds, river habitat, water quality, and fishing.

Watershed Alliance, a program of the University of Vermont Extension and Lake Champlain Sea Grant, offers programs that educate students and provide citizen science opportunities. More than 2,700 students participated in a water quality monitoring program since 2015. The program begins with classroom-based watershed lessons, after which the students visit local waterways, collecting physical, chemical, and biological data that is uploaded to online databases.

Public outreach programs educate and inform all citizens about watershed issues.

From the smallest lake association to the largest non-profit organization, nearly every group working to improve

water quality and habitat in the Basin has offered outreach programs. The long list of efforts conducted across the Basin includes school and camp programs, river steward initiatives, rain barrel and green infrastructure seminars, and outreach on lake-friendly lawn care. The LCBP alone awarded 58 grants for nearly a half-million dollars between 2015 and 2017.

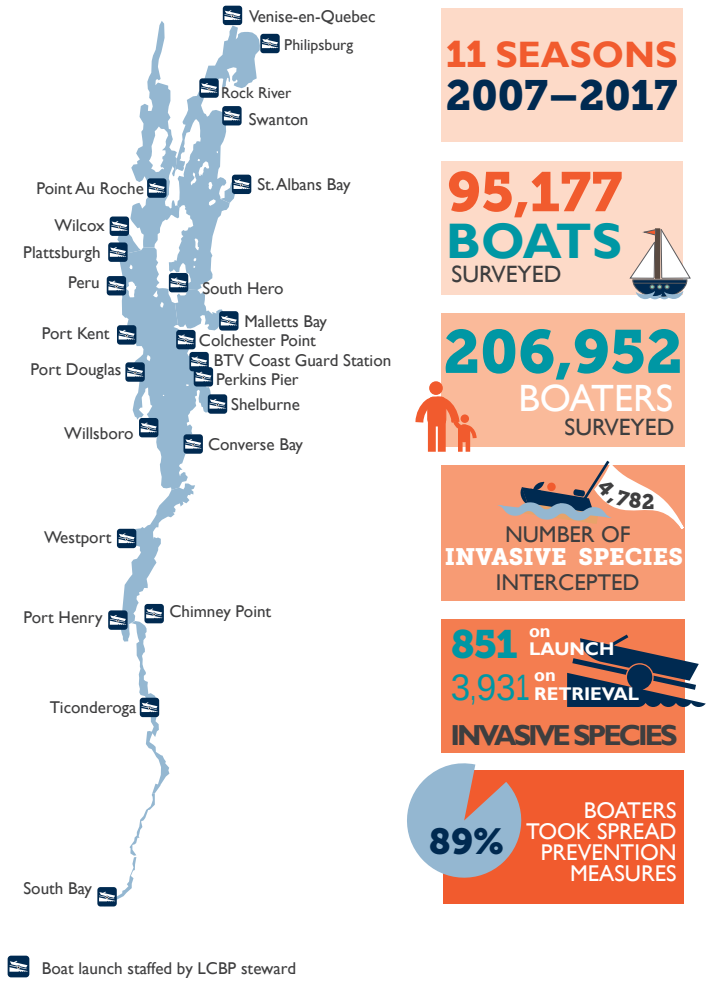
In recent years, many larger organizations have expanded public programming opportunities and field experiences designed to get more people out on the Lake to enjoy its scenic beauty while learning new information about waterways. These organizations include Lake Champlain Sea Grant, ECHO, Leahy Center for Lake Champlain, Community Sailing Center (Burlington), Fort Ticonderoga, Lake George Association, and the Lake Champlain Maritime Museum (LCMM).

With its fleet of nineteen boats, LCMM provides school and community rowing programs throughout the watershed; each season, the programs serve more than 700 students and 500 adults. Nine high schools and two middle schools now have student rowing teams, thanks to LCMM's support. In 2015, LCMM brought long boats to New York for the first time, supporting a successful program in the village of Champlain.

In 2017, the LCBP's Resource Room at ECHO, Leahy Center for Lake Champlain in Burlington welcomed more than 30,000 guests. These visitors learned about watershed issues and about personal actions that can have a positive impact. Each year, Resource Room staff also conduct programs on Lake and Basin issues for schools, community groups, and visiting watershed managers, including those visiting via international exchanges. Resource Room staff develop interpretive materials and highlight events and volunteer opportunities around the Basin.

Recent years have seen a growing effort by partners throughout the watershed to educate the public about threats posed by aquatic invasive species. The Adirondack Watershed Institute at Paul Smith's College, the Lake George Association, the LCBP, and numerous small lake associations and watershed organizations have operated steward and greeter programs. These programs place staff at boat launches to share information with lake users about invasive species and the steps individuals can take to prevent their spread (Figure 16).

Students get hands-on experience in lake ecology aboard the R/V Melosira. *Photo: Lake Champlain Sea Grant.*



DATA SOURCES: Data from 2007-2017 LCBP Boat Launch Steward interactions with visitors at NYSDEC Access Areas and VT Fish and Wildlife Access Areas. 2017 QC data from OBVBM stewards.

Figure 16 | Lake Champlain aquatic invasive species spread prevention program summary, 2007–2017

CITIZEN ACTION

Each year, many people take personal steps to improve water quality in the Basin and become involved in local watershed groups and other organizations. Citizens have become involved in volunteer efforts ranging from a single day of tree planting to long-term citizen science projects. The Lake Champlain Committee annually trains more than 200 volunteer monitors from New York, Québec, and Vermont to survey the Lake Champlain shoreline for the presence of cyanobacteria (also known as blue-green algae) blooms and to collect water samples for laboratory analysis when necessary. This program complements the Lake Champlain Long-Term Water Quality Monitoring Program conducted by New York and Vermont with funding provided by the LCBP and the two states.

Many citizens have reduced runoff by incorporating green infrastructure into their property or neighborhood. More than 20 river and watershed associations have hosted workshops to teach residents how to install rain barrels, rain gardens, and pervious driveways. In addition, these groups provide information on simple steps that people can take to maintain private roads, remove invasive species, build healthy soils, and implement lake-friendly landscaping practices.

Residents are also taking advantage of pharmaceutical collection and disposal days that help keep medications—and the environmentally dangerous chemicals many contain—from being flushed down the drain and into waterways.

Many citizens have gotten their feet wet and hands dirty in efforts to control aquatic invasive species. Each summer, The Nature Conservancy, Adirondack Park Invasive Plant Program, Vermont DEC, and New York DEC organize volunteer days to pull water chestnut, frogbit, and other invasive aquatic plants from infested areas of the Lake. The Vermont Invasive Patroller program run by Vermont DEC has trained volunteers to identify and report invasive species in lakes and ponds throughout the state. In New York, citizen scientists are using iMap Invasives, a mobile app for tracking and reporting species.

By training the next generation to make balanced decisions about the Lake's ecosystem and by providing the public with opportunities to improve water quality, a real difference is being made. In communities throughout the Lake Champlain Basin, water quality and habitat improvement are not only being made a priority, they are the focus of a tremendous amount of activity that is having an important and powerful impact.

Citizens fight the spread of aquatic invasive species by pulling frogbit and other invaders. Photo: LCBP.

Students raise and release fish into local streams as part of the Salmon in the Classroom program. Photo: LCBP.

Volunteer monitors identify and report cyanobacteria blooms in the summer. Photo: LCBP.

Dive In

The LCBP's *Diving In* video series highlights the variety of ways that citizens are learning about and helping to improve water quality and habitat in the Lake Champlain Basin. Watch the videos at www.lcbp.org/diving-in.

ECOSYSTEM INDICATORS
by LAKE SEGMENT

		MISSISQUOI BAY		NORTHEAST ARM		MALLETTS BAY		MAIN LAKE		SOUTH LAKE	
		STATUS	TREND	STATUS	TREND	STATUS	TREND	STATUS	TREND	STATUS	TREND
PHOSPHORUS	Phosphorus in Lake (p. 11)										
	Nonpoint source loading to Lake (p. 12)				*						
	Wastewater facility loading+ (p. 13)										
				* There are no monitored tributaries in the NE Arm.							
HUMAN HEALTH & TOXICS	Beach closures (p. 8)	o								o	
	Cyanobacteria blooms (p. 10)										
	Fish advisories for toxics+ (p. 7)										
BIODIVERSITY & AQUATIC INVASIVE SPECIES	Sea lamprey wounds+ (p. 19)										
	Aquatic invasive species arrivals (p. 20)										
	Water chestnut infestations (p. 23)										

+ These indicators are lake-wide; therefore, scores are the same for all lake segments.
o Québec and South Lake do not have monitored public beaches

The 2018 Ecosystem Indicators Scorecard describes the status and trends of Lake Champlain's five major segments, Missisquoi Bay, Northeast Arm, Malletts Bay, Main Lake, and South Lake using the most current data available. Nine indicators are used to characterize the current condition of Lake Champlain. Many pressures influence the indicators for each segment, and affect the five segments differently depending on their distinct physical and biological characteristics. Responses and management actions of LCBP and our partners have improved some of these indicators in many ways; others will continue to improve as we work toward our mission.

Indicators were chosen with the guidance of dozens of scientists and state, provincial, and federal technical experts as the best means of characterizing progress, or the lack of it, in areas where adequate data exists. Detailed explanations of each indicator and the criteria used to determine the scores are available on the LCBP *State of the Lake* website (sol.lcbp.org).

The State of the Lake Summary on pages 4 and 5 of this document highlights key issues for each of these five major lake segments.

NOTE:
The figures used throughout the document to determine the status and trends for indicators are denoted with the following symbol:

STATUS
- GOOD
- FAIR
- POOR
- NO STATUS DATA AVAILABLE

TREND
- IMPROVING
- NO TREND
- DETERIORATING
- NO TREND DATA AVAILABLE

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Visit sol.lcbp.org to read the full report, including supplemental content, and to obtain references.

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Students from Hunt Middle School, Burlington, VT
...and many others who provided input on indicators.

Lake Champlain management partners gathered for the release of the LCBP's management plan Opportunities for Action *under the gaze of the Champlain Bridge in Crown Point, New York in June 2017. Photo: LCBP*

Read the full *State of the Lake* report, including supplemental content, at:

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