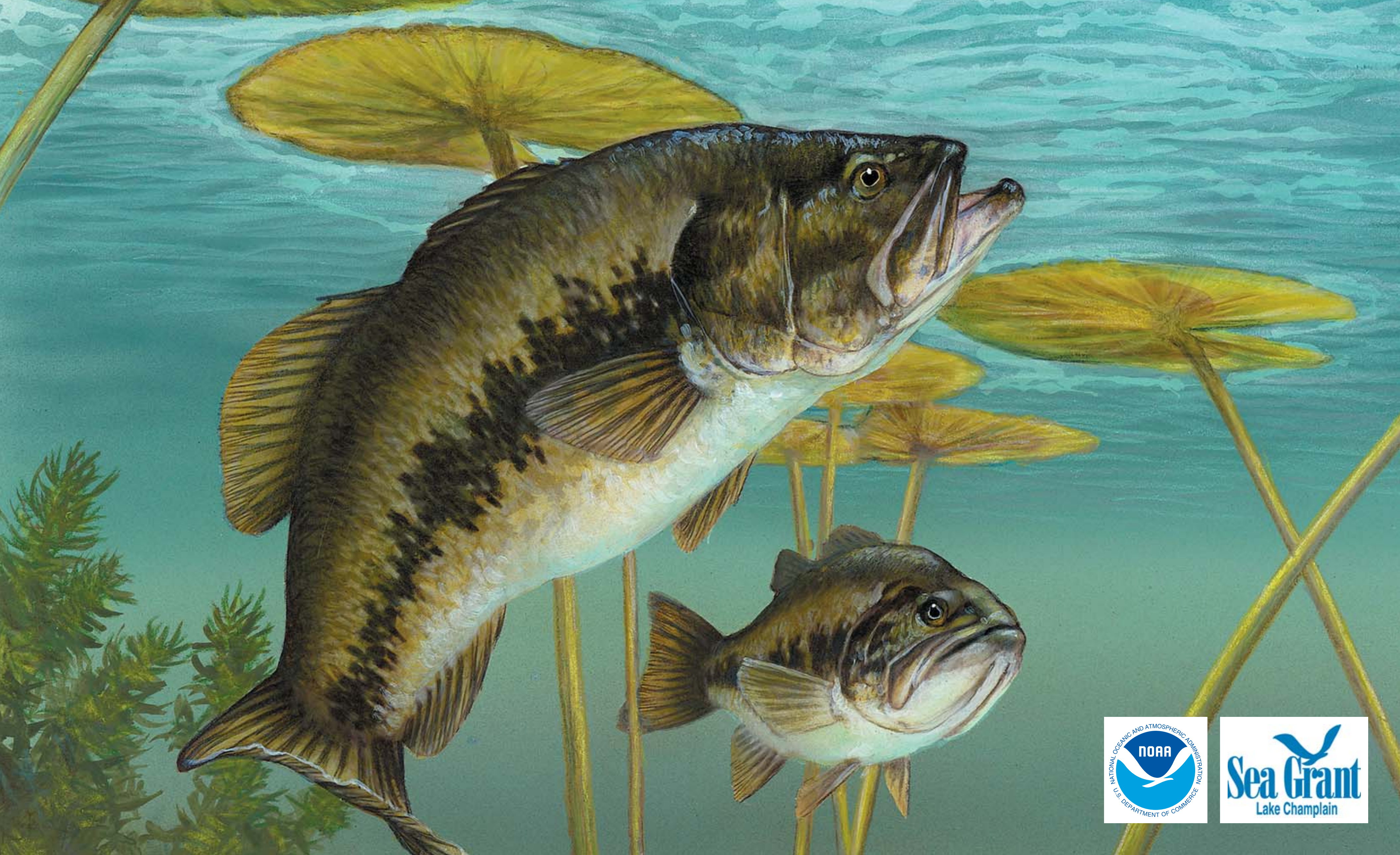
Lake Champlain Fisheries Habitat

A PRIMER FOR LAKE CHAMPLAIN STAKEHOLDERS



NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

Sea Grant Lake Champlain

Lake Champlain Fisheries Habitat

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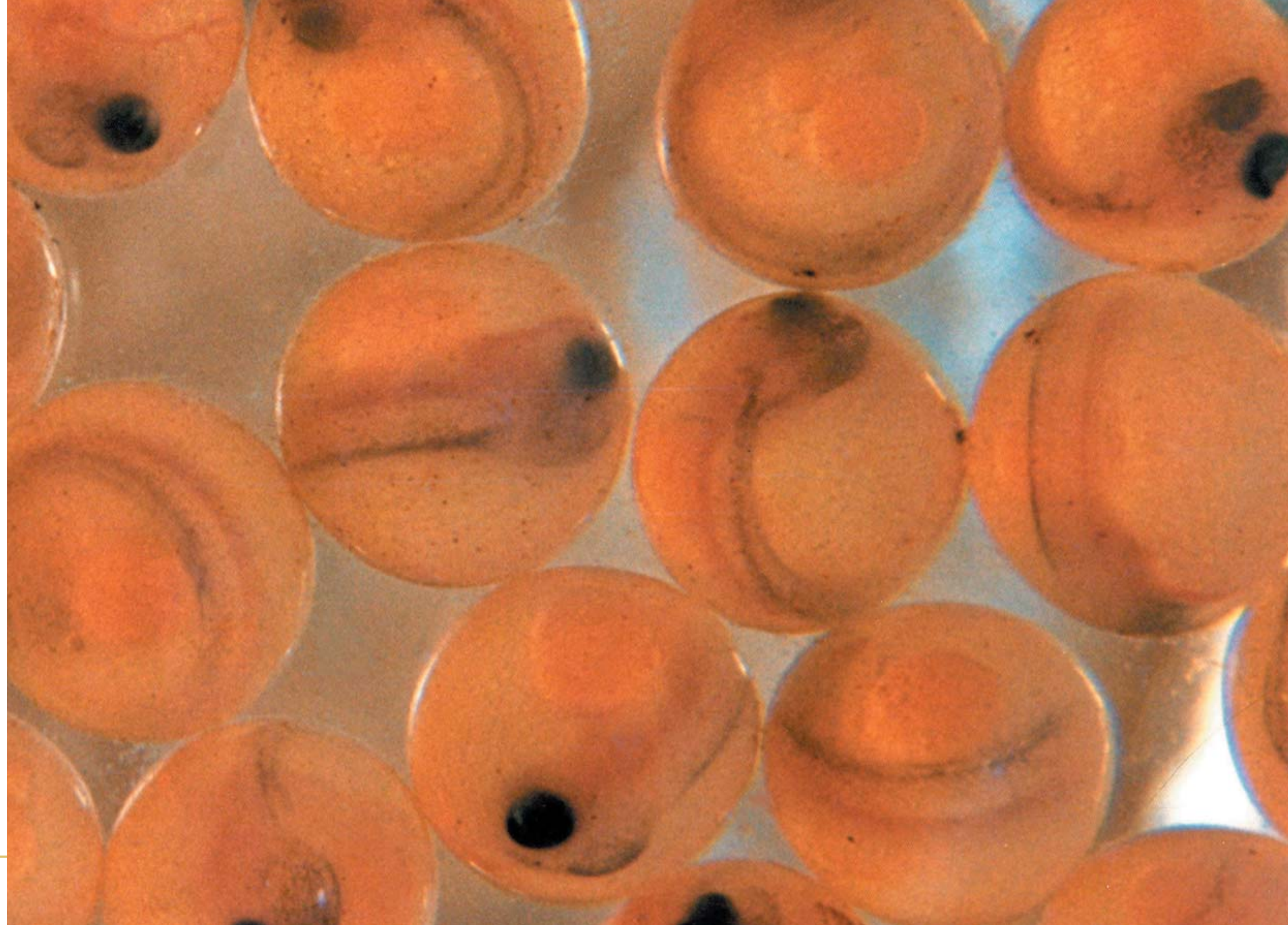

Atlantic Salmon eggs/Peter Steenstra, USFWS

Table of Contents

Yellow bullhead/Eric Engbretson, USFWS

Introduction

The broad lake from Burlington/Gary Randorf

Within the lake's 587 miles of shoreline lie a variety of aquatic environments harboring about 85 native and introduced fish species.

Lake Champlain is one of the largest freshwater lakes in the United States, with 435 square miles of surface water, over 70 islands, and 6.8 trillion gallons of water. The lake is unique, in part because of its narrow width (measuring only 12 miles at its widest point), great depth (some parts are more than 400 feet deep), and the size of the land area, or watershed, through which 90% of the water delivered to the lake flows. The total area of the Basin is 8,234 square miles, which is roughly the size of New Jersey.

Within the lake's 587 miles of shoreline lie a variety of aquatic environments harboring about 85 native and introduced fish species. A handful of species serve as the foundation of an important fishery resource, providing enormous natural and economic resource benefits to a variety of stakeholders in northern New York and Vermont. Tourism, fishing related businesses, fishing tournaments, and others are directly impacted by this fishery. Despite this linkage, stakeholders may not fully understand the complex interactions between fish and Lake Champlain's fish habitat. The information presented here is designed to help stakeholders better grasp these interactions, whether their interest is tournament bass, landlocked Atlantic salmon, or youth pursuing panfish. Having a better understanding of Lake Champlain's fishery may help stakeholders advocate for the protection and restoration of the lake's biological and physical habitat.

Lake Champlain

HABITAT TYPES

Lake Champlain provides a diverse set of environments that enable a wide variety of fish species to grow, avoid predators, and reproduce. The habitats providing these functions underlie a biologically rich fish community, with commensurate social and economic benefits. However, the Lake Champlain ecosystem cannot produce fish in just any place, anytime, in unlimited numbers. Non-living, or abiotic factors (climate, sunlight, temperature, depth, movement of water, nutrient and dissolved oxygen concentrations, shoreline characteristics, and many other factors) work together to affect the amounts and types of plant and animal life that can be supported in the lake.

Obviously, water as the medium in which fish spend their entire lives is the critical fish habitat component. Yet, it is not just the water that matters, but more importantly, the *quality* of it. A discussion of water quality as it relates to fish habitat typically includes aspects of temperature, dissolved oxygen, pollution, and pH. Other habitat components include substrate and natural structure, biota, nearshore waters, offshore waters, wetlands, artificial structures, and tributaries. All of these are reviewed below.

Aspects of water quality

Temperature

The health of aquatic life in a lake depends on water temperature. Each organism has a range of temperatures that is optimal for its health. Growth and reproduction occur most efficiently at preferred temperatures.

Warmwater fish: prefer summer temperatures between 80-87° F (27-30°C). Includes catfish, bullheads, largemouth bass, sunfish (bluegill, pumpkinseed)

Coolwater fish: prefer summer temperatures between 69-77° F (21-25°C). Includes yellow perch, walleye, northern pike

Coldwater fish: prefer summer temperatures below 59° F (15°C). Includes lake trout, Atlantic salmon, sturgeon, rainbow smelt, lake whitefish

Water temperature in Lake Champlain is affected by a number of factors, including:

- solar radiation
- wind
- lake currents

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Northern pike/USFWS, Robert W. Hines

- the shape of the lake basin
- water gains from inflows such as rivers and groundwater, and water losses from evaporation or outflow
- the temperatures of the air above the lake
- turbidity (cloudiness)
- the amount of shading from vegetation along the lakeshore

Temperature influences on fish

- **Metabolic rate**

Fish can sense slight changes of temperature. Their growth is directly affected by temperature, affecting their metabolic rate (the rate at which they process food). Since fish and most aquatic organisms are cold-blooded, their metabolic rate changes with the temperature. Some fish process food most efficiently in colder water, while others prefer warmer water. Each species of fish has an optimum average temperature for growth. Temperatures above or below this average slow their growth.

- **Spawning**

Spawning (mating and laying eggs) success also depends on temperature. Each species has its own preferred temperature range for spawning. The survival of newly hatched larvae or fry is dependent on certain temperature ranges. If temperatures are above this maximum (or below the minimum) for a prolonged time, the larvae will die.

- **Fish migration**

Fish migration is often triggered by temperature changes. Fish in northern climates can withstand a wide range of temperatures. However, they must have time to adjust and cannot withstand sudden changes.

Dissolved oxygen (DO)

Dissolved oxygen (DO) is the presence of oxygen gas molecules in the water. Most aquatic animals have some way of breathing the oxygen dissolved in the water (fish use gills), with different species needing varying amounts. Temperature is related to DO; the impact of changes in DO fluctuation applies to temperature. Colder water usually has more oxygen than warmer water, so those fish that need a lot of oxygen, such as trout and salmon, live in colder water. Some fish require less oxygen, such as catfish and carp, and can survive in warmer waters. Waters of consistently high DO are generally considered healthy ecosystems, capable of supporting many different kinds of aquatic organisms.

Seasonal changes in temperature of lake water provide the required habitats for each of the fish species. In the summer, most of Lake Champlain undergoes **thermal stratification.** A warm surface area of a lake is called the **epilimnion,** and is usually the warmest part of the lake. It also has the least amount of DO because of the warmer temperatures. Beneath the epilimnion is the **metalimnion,** a thin (usually) layer of water that separates the surface waters from the deep waters. Another name for this layer is the **thermocline.** The thermocline is usually defined as that zone where temperature drops at least 10° C with each 1 meter increase in depth). The colder, heavier water is located at the bottom of the lake and is called the **hypolimnion.** This deeper water provides the most DO for those fish that require it.

In the fall, as surface waters cool and become denser (heavier) than the underlying water, these colder waters sink while warmer water at depth is forced to the surface. This is called a ***turnover*** or destratification.

Brown bullhead/Duane Raver, USFWS

Seasonal changes in temperature of lake water provide the required habitats for each of the fish species.

Green algae as a result of phosphorus runoff/Chantal d'Auteuil, Missisquoi Bay Basin Corporation.

> Turbidity may be caused by the presence of soil particles, algae, plankton, microorganisms, and other substances that can enter the water through natural or human-induced activities.

The same process happens in the spring, when the sun melts the ice and warms the water to its densest point (4°C or 39.2°F), it sinks to the bottom of the lake again. During these times, nutrients and oxygen in the deeper parts of the lake are mixed throughout all of the lake. These turnovers may only last for a period of hours to just a few days, depending on the interactions of sun, wind, rainfall, etc.

Common pollutants

Fish require a balance of nutrients in order to remain healthy. When certain levels of nutrients exceed the normal levels they can become toxic to many fish species. Likewise, if these same nutrients become too scarce it can have detrimental effects on the development of certain fish. Nitrogen and phosphorus are two examples of nutrients that can have adverse effects on aquatic life if not maintained at normal levels. Toxic substances are also well known for their impacts on a variety of animals (including humans). These pollutants are discussed in greater detail under the Habitat Degradation heading.

Turbidity

Turbidity describes how particles suspended in the water column affect its clarity. Turbidity may be caused by the presence of soil particles, algae, plankton, microorganisms, and other substances that can enter the water through natural or human-induced activities.

- Natural activities that can increase turbidity in a waterbody may include runoff after a rain event, erosion from wave activity, and as a result of biological activity, as when bottom feeding organisms stir up the lake bottom. Algae and plankton growth may also cause increased turbidity.

- Human activities that can increase turbidity include direct discharge of particles into the water through pipes, any disruption of the lakebed, such as dredging, and any activity on the surrounding land that disturbs the soil so that it erodes or gets carried by surface runoff into the lake. Common land uses that can cause erosion, sedimentation, and turbidity include logging, cultivating, grazing, development, road construction, road drainage, sand application to roads in the winter, excavation for buildings, and extraction of minerals.

PH or acid/base balance

The pH is measured on a scale of 0 to 14. Numbers from 0 to 5 are considered to be acidic, from 6 to 7 is neutral, and from 8 to 14 is known as basic or alkaline. The lower the number, the more acidic the waters. Changes in pH can be caused by atmospheric deposition (acid rain, snow, and dry particles) of sulfur and nitrogen compounds produced by the burning of fossil fuels by cars, factories, and coal smelters. Other sources include wastewater discharges from business and industry, acid mine drainage, and contribution from surrounding soil and rock. A major flush of acid to lakes can occur in the spring if the snowmelt is acidic.

Lake Champlain's pH is strongly determined by bedrock geology in the basin and the lake proper. Unlike higher elevation Adirondack lakes, there is a strong buffering capacity afforded by calcareous (i.e. limestone, dolomite, marble) bedrock underlying much of Lake Champlain. This buffering capacity serves to largely offset any changes to this lake's acid/base balance.

Substrate and natural structure

The bottom of Lake Champlain holds a variety of different substrate types (bottom material). Different areas can consist of mud, clay, silt, sand, gravel, cobble, boulders, bedrock outcrops, logs, tree limbs or organic material such as leaves. Rooted plants (macrophytes) are also considered substrate structure types.

Many species of fish tend to orient themselves to particular substrate types, or to objects formed by the substrate, such as rocky reefs and gravel bars. Some prefer to maintain close quarters among terrestrial objects such as logs, limbs, and sticks, or near living plant material such as macrophytes and algae. The fish use these physical structures for many different purposes. Structure aids in predator avoidance; provides shelter from storm currents; and assists fish in their temperature regulation by the provision of shade. Physical structure also serves to protect eggs after deposition; shield a fish's presence when ambushing prey; and allows fish to escape high flow conditions near tributaries. The specific type of structure available will also determine the species of fish that will utilize the area for spawning and nursery habitat (see below).

Recent observations by scuba divers and remote underwater vehicles suggest much of the lake's hard structure is covered with layers of silt, reaching as high as 4-8 inches in some areas. Some organisms, called benthic (bottom-dwelling) organisms, prefer

Lake Champlain shoreline/Gary Randorf

Zebra mussel attached to a native mussel/USFWS

The invasive zebra mussel will attach themselves to native species of mussels, making their shells the zebra mussel's habitat. This leads to eventual starvation, disease, or osmoregulatory problems.

to live in this bottom zone. Here, in the sediments or among the different bottom materials, live bacteria that help decompose dead organic material and *detritivores*, small animals that feed on decomposing matter. Some fishes (such as carp and sturgeon) prefer to live in the benthic zone, feeding on the small organisms that live there. Other fish often use this bottom substrate for refuge from predators, as spawning grounds, to feed on macroinvertebrates or to take advantage of the cooling effects of groundwater filtering up into the lake.

Combined plant and animal communities (biota)

Fish habitat is not just limited to non-living parts of the environment. Rooted macrophytes such as eel grass, pickerel weed, and other plants also provide structure to fish. Microscopic parasites, bacteria, and fungi will often colonize certain fish species as their host habitat. These may or may not harm the fish, depending on the type of parasitic organism.

The invasive zebra mussel will attach themselves to native species of mussels, making their shells the zebra mussel's habitat. This leads to eventual starvation, disease, or osmoregulatory problems. On the other hand, zebra mussel colonies create interstitial spaces (space between each mussel) that serve as habitat for macroinvertebrates. In doing so, the zebra mussels and macroinvertebrates compete in filtering small particles of organic matter out of the water for food.

Native mussel larvae often attach to fish gills to complete their life cycle. Even heavily infested hosts show little ill-effect from this behavior. The larvae depend on their motile fish hosts to disperse them throughout river systems and lakes, whereas otherwise they would eventually be carried out to sea.

Nearshore waters

Lake Champlain has a variety of habitats available for fish. Bays, rocky reefs, and the sheltered areas around islands provide the shallows that many fishes find necessary at some time in their life cycles. These nearshore waters are also warmer and more nutrient-enriched by organic material flowing in from streams and tributaries. This area of the lake is known as the ***littoral*** zone. These are highly productive areas that produce an abundance of food for minnows, fingerling stage fish, and organisms lower on the food chain. Here, the structural complexity is higher, with rooted macrophytes and more woody debris and rocky areas to provide shelter from predation of eggs, larvae, and juveniles.

In this zone, waters are shallow enough for sunlight to penetrate the water and reach the lake bottom where aquatic plants thrive. These rooted plants provide cover for fishes and other aquatic life. Some species of fish find these habitats as their permanent residence. Other offshore species of fish migrate inland and use these areas to feed or as spawning grounds. Fish species diversity and productivity is usually higher in nearshore waters than in offshore waters. Fish commonly associated with the nearshore/littoral zone include warmwater fish such as catfish, bullhead, bass, sunfish, and others.

Lake Champlain's rocky shoreline/Burlington Parks and Recreation

Lake Champlain has a variety of habitats available for fish. Bays, rocky reefs, and the sheltered areas around islands provide the shallows that many fishes find necessary at some time in their life cycles.

The main lake/Gary Randorf

The open water of the lake is called the pelagic zone. Here, the waters are typically colder (at depth), less productive, and subsequently home to fewer species of fish.

Offshore waters - main lake

The open water of the lake is called the ***pelagic*** zone. There is no identifiable boundary between the littoral zone and the pelagic zone, but some authors suggest the 50 foot depth contour serve as an approximate divide between these zones. Here, the waters are typically colder (at depth), less productive, and subsequently home to fewer species of fish.

Productivity in the pelagic zone however, varies from low (oligotrophic) to high (eutrophic) depending upon the lake segment. Some adult fishes, such as salmon and smelt, prefer to spend a large part of their time in the colder portions of this zone. These open waters often undergo thermal stratification during the summer months. This stratification partitions the pelagic zone, enabling warmwater fish, cool-water fish, and cold-water fish to find suitable habitat.

The ***benthos,*** or bottom region beneath the pelagic zone may serve as home to lake trout, burbot, opossum shrimp *(Mysis relicta)*, and an array of crustaceans, insect larvae, and burrowing worms that live on the rich accumulation of organic matter. Smelt utilize deepwater benthic environments for spawning, and zebra mussels may colonize hard substrates as deep as 160 feet. Lake Champlain contains about 125,000 acres of deepwater benthic environments.

In summer, the strong density gradients usually separate eplimnetic waters from the hypolimnion and benthic environments. Scientists who study these processes in Lake Champlain have recently documented that wind forcing at the surface commonly generates internal waves (seiches) which may temporarily breakdown these gradients. The seiches also generate horizontal water movement over vast distances. The biological impact of these events remains unknown. However, it is possible that such seiches could aid in the distribution of eggs and larvae from one region of the lake to another.

Wetlands

Wetlands are transitional areas between dry land and water bodies. They may be temporary or permanent, static or flowing, and they come in a variety of sizes, shapes and depths. Water is a necessary ingredient but does not have to be present at all times. Some are wet all year long and some are dry for part of the year. The Lake Champlain Basin contains more than 300,000 acres of wetlands. Wetlands, with their warm, shallow, nutrient-rich waters, contain some of the richest and most productive natural communities in the Basin.

Wetlands provide a variety of important functions within the Basin; they improve water quality by filtering sediments, excess nutrients, and pollutants. They provide habitat and nourishment for fish and wildlife, including rare, threatened, and endangered species. They protect groundwater and drinking water supplies by processing chemical and organic wastes. They stabilize shorelines, prevent erosion, and control flooding. They also provide recreational opportunities and contribute to the aesthetic quality of the landscape.

(source: The Lake Champlain Basin Atlas 2004, Lake Champlain Basin Program).

Wetland environments may include shallow areas of open shoreline, unrestricted bays, sloping beaches, river outlets connected to the lake, and barrier beaches. The most common example of wetland is that of the freshwater marsh containing grasses, sedges, and cattails. These marshes may also include such non-native or invasive species as purple loosestrife and common reed (phragmites).

Lake Champlain Basin wetlands function to transport water during floods. They slow the flow of water as it passes through vegetation, or actually store it and prevent excess runoff. These areas also act as barriers and protect shorelines from erosion at times of high wave activity during storms and strong winds. Wetlands filter excess nutrients from landscape runoff and improve water quality by preventing eutrophication in these areas of the lake.

These highly productive areas produce an abundance of aquatic organisms lower on the food chain, such as macroinvertebrates. Wetlands have a positive effect on the food chain by providing diverse habitat for both terrestrial and aquatic organisms (i.e. birds, mammals, reptiles, amphibians, fish, and invertebrates). All of these species depend on wetlands for at least one life stage. Wetlands are important to fish, particularly northern pike, as they provide valuable spawning areas and nurseries for juvenile fish.

Artificial structures

There are a variety of artificial structures in Lake Champlain. These environments are often destructive to natural littoral habitat and the commensurate loss of spawning and juvenile fish habitat for warm-

Wetlands in Alburg Dunes State Park/
VT Department of Forests, Parks and Recreation

Gary Randorf

Artificial substrates such breakwaters, mine tailings, intake structures, etc., often mimic rocky reefs and outcroppings in both appearance and function for eggs and larval stage fish.

water species. However, this destruction may be offset by the provision of other habitat functions. Artificial substrates such breakwaters, mine tailings, intake structures, etc., often mimic rocky reefs and outcroppings in both appearance and function for eggs and larval stage fish. These structures offer concealment from predators and protection from strong currents. In some cases these structures serve as lake trout spawning habitat. They can also provide shelter and serve as valuable feeding areas for large fish preying on small fish. As "disturbed" sites they are often the 1st choice of invading species (i.e. zebra mussels).

Mine tailings

Archeological investigations along Split Rock Mountain on the New York shoreline has confirmed the presence of considerable rock debris blasted or excavated from the mountainside during 19th century mining operations. The importance of this material as fish habitat remains unstudied, however, it is hypothesized that this material may serve as suitable lake trout spawning habitat.

Break walls

Break walls are created of stone or cement and are placed in the lake outside of marinas or harbors. Some wave-swept stone break walls are documented as important lake trout spawning and egg-stage habitat due to the abundant "nook and crannies" found among the quarried cobble and armor stone.

Riprap shoreline

Riprap shoreline is a stabilizing formation of rock created either naturally (below a rockfall area of a cliff) or by man to help prevent erosion. These areas create hiding places for smaller fish along the shoreline and also provide shade and cooler water temperatures.

Concrete piers

Concrete piers from bridges or docks help to create a break from wave action and provide calmer waters for certain fish species.

Intake and outflow pipes

Intake and outflow pipes often make changes to the surrounding water, such as raising and lowering temperatures or adding nutrients.

Shipwrecks

Shipwrecks like other artificial substrates typically serve as attachment sites for fouling organisms (i.e. zebra mussels). In some cases they also serve as habitat for freshwater drum, and likely many other species.

Tributaries

Tributaries are rivers or streams that feed directly into a lake. Major Lake Champlain Vermont tributaries include: the Otter Creek, the Winooski River, the Lamoille River, and the Missisquoi River. New York tributaries include the Great and Little Chazy Rivers, the Saranac River, the Ausable River, and the Boquet River. The Poultney River drains into significant portions of both states.

Tributaries provide important habitat to many fish species. They are used as spawning and nursery areas where the incoming river water provides increased oxygen and nutrients to the egg and fry stages of many fish species. As an example, walleyes and salmon often ascend key tributaries on spawning runs. Tributaries serve as feeding areas as they deliver organic debris, macroinvertebrates, and small fish toward the lake. Some fish prefer to overwinter in the backwaters, where the river slows as it meets an obstruction such as a riverbank or where it enters the lake proper.

Atlantic salmon/Robert W. Hines, USFWS

Walleyes and salmon often ascend key tributaries on spawning runs. Tributaries serve as feeding areas as they deliver organic debris, macroinvertebrates, and small fish toward the lake.

Lake Champlain

FISHERIES HABITAT USE

Healthy and abundant habitats are important in supporting diverse and productive fish populations. Each type of habitat provides a fish with the necessary elements for survival.

To grow and reproduce, fish need habitat for resting, feeding, and spawning. The habitats providing these functions are essential to fisheries conservation efforts. Indeed, marine fisheries conservation efforts have recently placed emphasis on the identification and protection of essential fish habitat (EFH). While such legal efforts are not envisioned for Lake Champlain, basin residents and visitors should recognize that healthy and abundant habitats are important in supporting diverse and productive fish populations. Each type of habitat provides a fish with the necessary elements for survival.

Feeding

Many species of fish have adapted to specific habitats for feeding. *Benthic* (bottom-dwelling) fish, such as catfish, mudminnows, and sturgeon, might be found over sandy, silty or muddy areas where they may find macroinvertebrates or mussels that inhabit softer sediments. *Planktivorous* species (those that eat plankton), such as smelt, may inhabit open water where zooplankton and phytoplankton are found in the pelagic areas. Ambush predators, such as northern pike, may be found in areas with high structural complexity (i.e. weed beds), where they can conceal themselves from prey. *Pelagic* predators, such as trout and salmon, inhabit the open water areas and often feed on schooling prey species. Any substrate or environment holding preferred prey species (including insects, small fish, etc) is seen as feeding habitat.

Spawning and nursery areas

Spawning occurs when fish breed and deposit eggs on the lake or river bottom. Different fish species spawn in different habitats, each with a special set of characteristics. Often, these same environments serve as nursery areas, where fry or larval stage fish can find both food and shelter from abundant predators. Woody material, such as logs, limbs, and sticks, allow fish to either deposit eggs directly onto the object or to broadcast their eggs above it, allowing the eggs to settle into the interstitial spaces. Some organic material, such as aquatic macrophytes (underwater plants), allow fish to deposit eggs on the undersides of the leaves or within the plant or algal masses.

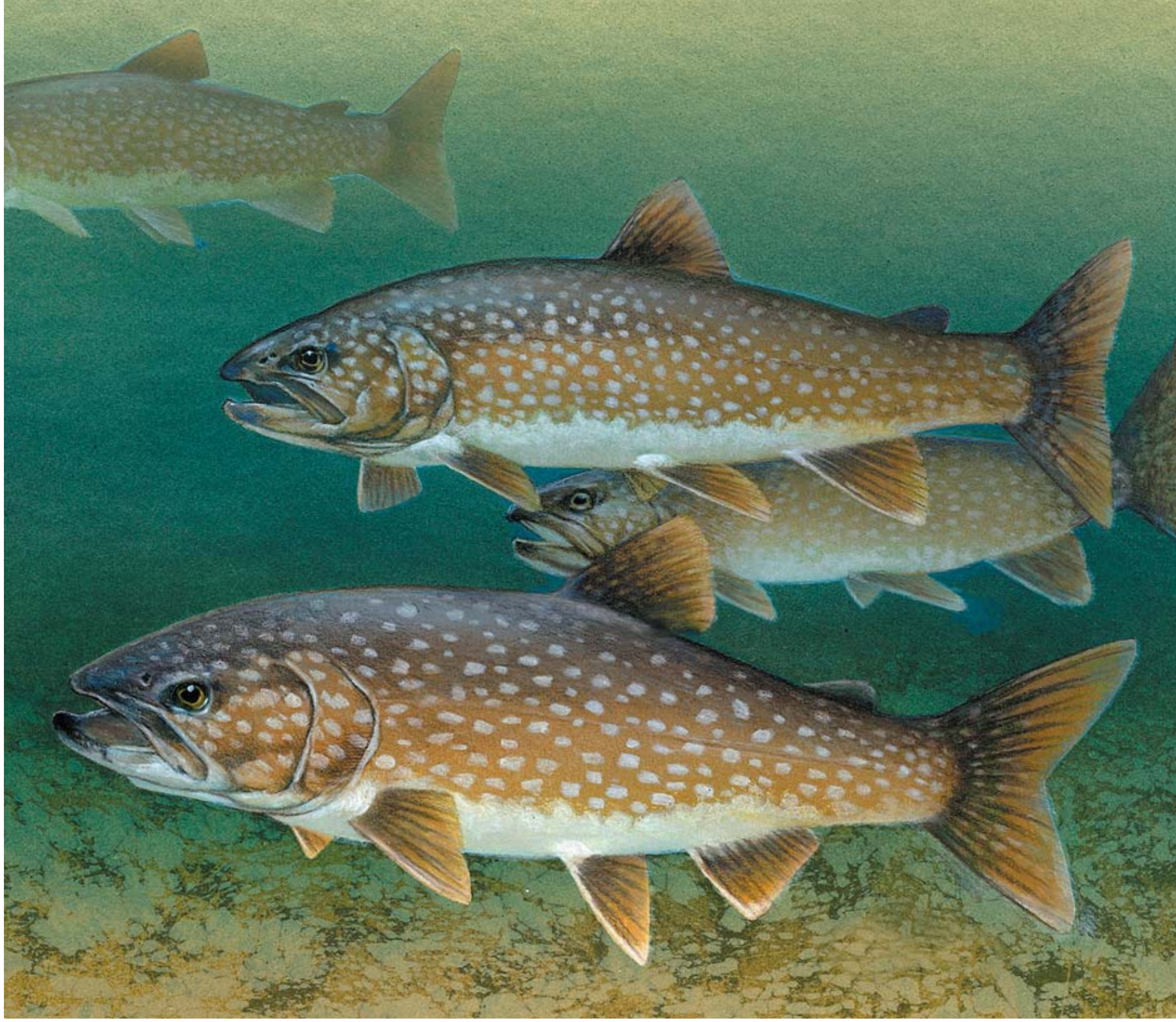
Some fish prefer to deposit their eggs over sand, where the eggs may travel with the current along the sandy bottom. Some prefer gravel, where the eggs are deposited in the interstitial spaces. Eggs tend to be similar to gravel in color, size, and shape, which serves to camouflage the eggs. Other fish choose to deposit their eggs over larger rocks, where the eggs will either adhere to the sides or fall underneath the rocks into the interstitial spaces. Many members of the sunfish family, for example, are well known for their circular nests sculpted in littoral areas. Lake trout conversely broadcast their eggs in wave-swept cobble areas.

Migration

Many species of fish will migrate from one type of habitat to another over the course of their life cycle. They migrate to special areas in order to spawn and move to other areas to feed or reside. Often fish will overwinter in an area far removed from their summer residence in order to find consistent or tolerable temperatures. In order to make it from one place to another, fish will use a variety of habitats along the way, including open water, channels, or nearshore areas. Tributary systems also play a major role in fish migrations, with such well-known phenomena as walleye spawning runs in the Poultney River and salmon runs on the Boquet.

Overwintering/other seasonal uses

Most fish species are transient, meaning that they often utilize different habitats during different seasons of the year. During the spring, a variety of habitats are crossed during migration, en route to spawning grounds, and to reach feeding areas. Once summer arrives, juvenile fish may move nursery areas, while adults move out to deeper water as water temperatures increase inshore. Some species of fish spawn during the summer and move to new habitats to do so. Come fall, there are still other species of fish that are fall spawners (lake trout) and feeding patterns once again change, requiring fish to search for another change in habitat. The onset of winter brings the need for fish to find a site to overwinter. This may be in the deeper, open water where temperatures are slightly higher than the shallow areas. It may also be in the deeper backwater areas in tributaries where the fish can escape from winter storm events.



Lake trout/Timothy Knepp, USFWS

Most fish species are transient, meaning that they often utilize different habitats during different seasons of the year.

Lake Champlain

HABITAT DEGRADATION

There was no single event to blame, but a combination of activities that had gone unnoticed and unmanaged during the growth and development of this region.

Settlement of the Lake Champlain Valley began in the early 1800s with the cutting of timber and the mining of iron ore. The economic success of shoreland settlements quickly became dependent on the development of these natural resource industries. The lumber camps and mining towns that supported these industries fueled additional economic activities such as farms to supply food, and railroad and canal boats to move timber and iron to market. However, along with the development of these industries came multiple stressors to the lake environment.

Impacts to the Lake Champlain Basin

Impacts to the Champlain Basin became evident after a period of such intense use. There was no single event to blame, but a combination of activities that had gone unnoticed and unmanaged during the growth and development of this region.

Exploitation of area resources

Logging

Logging in the area led to the clear-cutting of forests. As the forests were removed, protective shade was removed from rivers and lake shores and less organic material was available as food by aquatic life. Sawmills left the streams and embayments clogged with sawdust, eliminating crucial habitat of bottom-dwelling species, while clogging the gills of certain fish.

Extensive farming

Extensive farming involved the conversion of forests to fields and pastures. Exposed soils washed away with rain and wind. When these soils reached the streams and rivers, valuable habitat was buried under sediment and water temperatures increased as the sediment absorbed heat from sunlight. This altered the preferred habitat of some species and caused changes in the types of aquatic life found there.

Fishing

In the Great Lakes, fish stocks were harvested indiscriminately reducing a seemingly endless abundance of fish. Important species that declined greatly in those waters include the blue pike, lake trout, and sturgeon. In Lake Champlain, similar exploitation likely occurred, but the decline of stocks as a function of overfishing is not clearly documented. For much of the late 19th and 20th centuries, commercial fishing was an important part of the Lake Champlain fishery. Species harvested included black bass, bullhead, catfish, eels, yellow perch, northern pike, walleye, pickerel, rock bass, smelt, salmon, whitefish, and sturgeon. Lake trout and salmon likely provide the best examples of over exploitation of aquatic resources. Lake trout populations were apparently reduced by the late 1880s, though causes for this decline remain speculative. Reliable records indicate the disappearance of Atlantic salmon in Lake Champlain by the mid-1800s, with the last documented run on the Ausable River in 1838. Clearly, salmon suffered a dual fate of overfishing combined with the loss of access to spawning habitat due to the proliferation of dams.

Dams

Dams are clearly implicated in the demise of some Lake Champlain fisheries. A lawsuit filed in Plattsburgh, N.Y. in 1818 cited the demise of salmon runs on the Saranac River following the installation of a mill dam in the preceding year by Zephaniah Platt. The 1817 dam replaced earlier structures complete in 1786 and 1797. Other tributaries subject to damming and loss of salmon runs include the Great Chazy, Little Chazy, Salmon, Little Ausable, Ausable, Boquet, Winooski, Lamoille, Missisquoi, and Otter Creek.

Many other species are also impacted by the presence of dams and other stream barriers. Vermont Fish and Wildlife staff have noted that “81 of Vermont’s 91 fish species are found [in Lake Champlain]. [Many] of these rely on both the lake and its tributary rivers for different parts of their life cycles, such as spawning, juvenile rearing, and feeding. Notable among them are walleye, salmon, lake sturgeon, and a

Walleye, yellow perch and pike/Robert W. Hines, USFWS

Champlain Canal/Michael Hauser

Dams and canals also allowed for the introduction of non-native species into Lake Champlain. Many of these species are considered a nuisance as they threaten the native fish populations and have substantial ecological impact.

host of lesser known species including suckers, bass, minnows, pike, perch, and others. The connection between Lake Champlain and its tributaries is vital to this group of species. While they use the slow lake-like lower river reaches, they also rely on the rocky habitat with swifter current that is found where the river gradient is steeper. Unfortunately, most of the larger Vermont tributaries to Lake Champlain are blocked by dams and very little of this rocky habitat remains."

Industry and agriculture

The Industrial Revolution

The Industrial Revolution brought with it the invention of man-made chemicals such as polychlorinated biphenyls (PCB's) used in industrial machinery, plastics, and paints, and Polycyclic/Polynuclear Aromatic Hydrocarbons (PAH's) found in the production of paper in paper mills. These chemicals, along with others, accumulate in the bottom sediments when they reach the lake in overland runoff and discharge from industrial plants. They are then consumed by bottom-dwelling aquatic organisms and are stored in the body fat. When these organisms are consumed by larger organisms, these chemicals are passed up the food chain. Suspected fisheries impacts include reduced egg viability, reduced growth, and increased susceptibility to disease.

Agricultural advances

Agricultural advances such as non-organic fertilizers applied to agricultural fields have contributed to excess nutrients being washed into the lake. These nutrients, such as phosphorus, cause problems in the lake such as algal blooms, eventually leading to lowered oxygen levels during decomposition of plant material. Many desirable fish species become less competitive and are replaced by fish such as carp or tench.

Urbanization

As populations increased, cities developed and created the demand for more accessible transportation. Dams and canals were built to enable boats to travel long distances up the lake. These structures altered the flow of water, caused sedimentation when slower water material settled to the lake bottom, and increased temperatures in areas where water was unable to circulate at its normal rate. Dams and canals also allowed for the introduction of non-native species into Lake Champlain. Many of these species are considered a nuisance as they threaten the native fish populations and have substantial ecological impact.

Issues with waste management have also emerged with the increasing populations. Wastewater treatment plants were often filled beyond capacity, causing overflow into the lake and damaging the aquatic habitat in those areas. Many people in rural areas were building septic systems that over time have developed leaks and caused raw sewage to seep into surrounding bodies of water. As a result, the diversity of fish species is often reduced in areas that have been degraded from the input of human waste.

Human management

Currently the lake ecosystem is heavily dependent on the management of many environmental issues. Efforts have been made to reduce the amount of phosphorus that enters the lake through wastewater treatment upgrades, nutrient and waste management of farms, streambank erosion control, and programs aimed at reducing phosphorus runoff from lawns and roads in developed areas. Although phosphorus inputs have been reduced in the lake in recent years, phosphorus levels in some lake segments remain problematic.

Brown trout/Eric Engbretson, USFWS

Pollution prevention projects have been implemented to reduce the amount of toxic chemicals that enter the lake. These include pesticide reduction workshops for farmers and homeowners, as well as, programs to inform the dental community about proper mercury disposal. Restoration projects include a 1999-2001 effort to remove contaminated sediments from Cumberland Bay. Other areas, such as Burlington Harbor, are being measured to determine the level of contamination and what action should be taken.

Some populations of fishes are maintained (or at least supplemented) by stocking. These stocking procedures are made only after careful consideration of the possible adverse effects such introductions may have. Lake trout, salmon, brown trout, and rainbows represent the popular gamefish that are stocked annually in Lake Champlain.

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When the aquatic plant life dies, dissolved oxygen is used up in the decomposition of the dead organic matter leaving less for the fish and other aquatic organisms. This causes the fish community structure and population dynamics to change.

Other potential management practices include habitat improvement (typically streambank restoration) and active control of nuisance species. Control of undesirable nuisance species is currently being researched. One possible solution is the construction of canal barriers that would prevent exotic species, such as Eurasian ruffe and the spiny waterflea, from migrating into non-native habitat.

Impacts to nearshore and offshore waters

Human settlement

Human settlement has had noticeable impacts on lake conditions. Destruction of riparian areas (terrestrial plant life that borders nearshore water), that occurs during tree removal or excavation for construction, has changed the quality of habitat that borders these areas. The water along the shore is no longer shaded, which causes its temperature to increase. The amount of aquatic plant life increases due to more sunlight, causing increased photosynthesis and primary production. When the aquatic plant life dies, dissolved oxygen is used up in the decomposition of the dead organic matter leaving less for the fish and other aquatic organisms. This causes the fish community structure and population dynamics to change. Species such as trout that are intolerant of higher temperatures and low dissolved oxygen are lost to that area, while more tolerant species may increase in population.

Non-native species

Introductions of non-native fishes and other biota have resulted in negative interactions of exotic species with native species in nearshore and offshore habitat. Lake trout spawning habitat is now compromised by the carpet of zebra mussels found on otherwise suitable spawning shoals. Habitat impairment and losses as a result of water chestnut and Eurasian milfoil growth (particularly in the South Lake segment) are legendary. The recent arrival of alewife in the lake will likely not bode well for our native smelt due to likely diet overlap. Other invasives impacts are less clear, but no less real.

Impacts to substrate and natural structure

Shoreline development

Impervious surfaces

The construction of impervious surfaces can have an impact on nearshore waters. Cement and asphalt are relatively impermeable to water and heat quickly in the sun. During rainfall, there is increased surface runoff and the warm surface increases the temperature of the runoff that reaches a waterbody. This in turn increases the temperature of shallower waters near shore and has an effect on the aquatic organisms that live there.

Eric Engbretson, USFWS

Altered flow regimes

Altered flow regimes are typically generated at construction sites. With the altered flow regimes there is a potential change in water temperature and in turn a change in habitat. What may have initially been a stream running through a shaded forests, may be altered to flow through an unshaded lawn or other open area. This lowers the stream temperature and also adds more organic material to the water. Also, small modifications to the Richelieu River riparian areas have decreased the flow capacity of the river during the 20th century. These modifications, have contributed to slightly higher lake levels than those recorded in long term averages.

Retaining walls

Many times natural shoreline is replaced with rip-rap, a sustaining wall of stones used to prevent erosion. The stones replace natural vegetation, and instead of keeping the shoreline cool and shaded, they absorb heat and warm the water. Interstitial spaces in the rocks provide habitat for certain aquatic organisms. Changes in these spaces result in change in the species of organisms present.

Harbors

Harbors have emerged along the shoreline of Lake Champlain over time. Industrial activities associated with these sites during the 19th and 20th centuries likely degraded such areas as Burlington Harbor, Port Henry, and Cumberland Bay. Fisheries impacts likely occurred, but were never quantified.

Canals

Canals have also been built in or just outside the Lake Champlain Basin to allow passage of boats from one area to another. Canals can create passageways for non-native aquatic species to enter the Lake Champlain system. Canals may also pose as barriers to spawning fish and disrupt reproduction patterns of species that migrate to spawn.

Agricultural fields

Agricultural fields are created by plowing over vegetation and overturning the soil. During high rains, sediment runs off into waterbodies as there is no longer any vegetation in place to retain the soil. Once this sediment reaches the lake, light penetration through the water is decreased and affects the process of photosynthesis by plant life. This in turn

Once sediment reaches the lake, light penetration through the water is decreased and affects the process of photosynthesis by plant life. This in turn reduces the amount of oxygen available to aquatic life, resulting in the death of some plant and animal species.

Lake trout/USFWS

Few other fish have suffered as much from human activity as trout. Even the most adaptable trout cannot survive much human interference with its environment.

reduces the amount of oxygen available to aquatic life, resulting in the death of some plant and animal species. Sediment also embeds in between the interstitial spaces of gravel and rocks, reducing habitat for aquatic organisms and limiting productive spawning grounds for fish.

Impacts to indigenous fish

Lake trout

Few other fish have suffered as much from human activity as trout. Even the most adaptable trout cannot survive much human interference with its environment. All trout require cool, clean, well-oxygenated water and it is very easy for human activity to adversely affect this condition. Trout also require clean gravel or cobble sites to spawn. Activities such as clearing forests for farming, housing, or development can convert cool, fast-flowing gravely streams into still, warm, silty waterways incapable of supporting trout. Various industrial, agricultural, or domestic sources can pollute the water, reducing the high levels of oxygen that trout need to survive. In some areas, toxic chemicals, have been released into the Lake Champlain waters as noted above. The presence of trout is, and has been for many years, used as a measure of water and habitat quality when making decisions regarding permitted land or water use. Trout are often the first species to disappear from polluted waters.

The well-documented decline of lake trout in the Great Lakes is attributed to both overfishing, declining water quality, and severe parasitism from non-native sea lamprey. The lake trout story in Lake Champlain is much more of a mystery, with reports that the population was at very low levels in the 1800s and early 1900s. Reasons for this decline and persistent failure to rebound are still unclear. Recent research results indicate that lake trout are successfully spawning at several sites with large numbers of eggs and fry produced annually. While parasitism by lamprey (now thought to be native to Lake Champlain) continues to plague restoration efforts, it does not explain the failure of lake trout fry to survive and grow in significant numbers. It is likely that some yet unknown combination of environmental and genetic (i.e. loss of native genotype) factors are to blame.

Atlantic salmon

Atlantic salmon were native to Lake Champlain, but did not survive the environmental changes during the 1800s. Mill dams and other man-made obstructions prevented them from reaching their spawning grounds. Deforestation led to increased temperatures and silting of viable habitat. Pollution from nutrient loads and toxic contaminants affected the health of the species. Overfishing by early fisherman who used nets to catch Atlantic salmon led to drastic drops in their population until the last reported sighting of a native salmon in Lake Champlain in 1852.

Currently, very little natural reproduction of Atlantic salmon occurs in Lake Champlain. Annual stocking by state and federal agencies is required to keep a fishable population in place in the Lake. The New York State Department of Environmental Conservation has been stocking Atlantic salmon since 1948.

Lake sturgeon

Lake sturgeon once supported an important commercial fishery in Lake Champlain with a pattern of exploitation similar to that seen in the Great Lakes. Sporadic commercial sturgeon fishery landings were available from 1897 to 1962. This fishery peaked around 1944-1946 with landings of 93 fish totaling nearly 6,000 pounds. The average number of fish increased to 112 during the period 1948-1949, but the average weight dropped to about 1000 pounds. Average annual catch was at 13 fish during 1961-1962.

Atlantic salmon release/USFWS

Sauger/Duane Raver/USFWS

Sauger were never as numerous as the closely related walleye. Recently however, this species seems to have nearly disappeared from the lake. Causes remain unknown.

Today, sturgeon are at very low levels, but evidence of spawning (i.e. eggs) has recently been found in four Vermont tributaries including: Missisquoi River, Lamoille River, Winooski River, and Otter Creek. Clearly, overfishing played a major role in the decline of Lake Champlain lake sturgeon. The extent to which habitat degradation (including dams) contributed to the decline is unknown.

Lake whitefish

Little information is available to document lake whitefish population status or trends. However, the failure of a commercial fishery for this species in Missisquoi Bay in the 1970s is indicative of overfishing and/or habitat problems. Whitefish are now thought to be present at low levels, but exact causes and future trends are unknown.

Round whitefish

This species has apparently been extirpated from Lake Champlain, likely due to: 1) competition/predations from invasive species; 2) overfishing; and 3) water quality/habitat impairments. Round whitefish restoration efforts are taking place in other Adirondack waters. It is doubtful that current habitat/water quality conditions in Lake Champlain would justify such a restoration effort.

Sauger

Sauger were never as numerous as the closely related walleye. Recently however, this species seems to have nearly disappeared from the lake. Causes remain unknown.

Impacts to wetlands within Lake Champlain

Since the Industrial Revolution, many of the Basin's wetlands have been drained and filled for agricultural, residential, or commercial development. Development of adjacent uplands has also contributed to sedimentation and degradation of wetlands. The altered wetlands lead to habitat fragmentation, where an area within an ecosystem becomes unsuitable for many organisms that once thrived there. Along with development comes the introduction and invasion of non-native aquatic species such as purple loosestrife, waterchestnut, and Eurasion watermilfoil. These species tend to further degrade habitat by displacing native plants.

Loss

Approximately 35-50% of the Basin's wetlands have been lost due to developmental pressures and landscape modifications since European settlement. As scientists gain an understanding of the ecological role of wetlands, federal and state laws and regulations incorporate this information to prevent further losses.

Protection and restoration

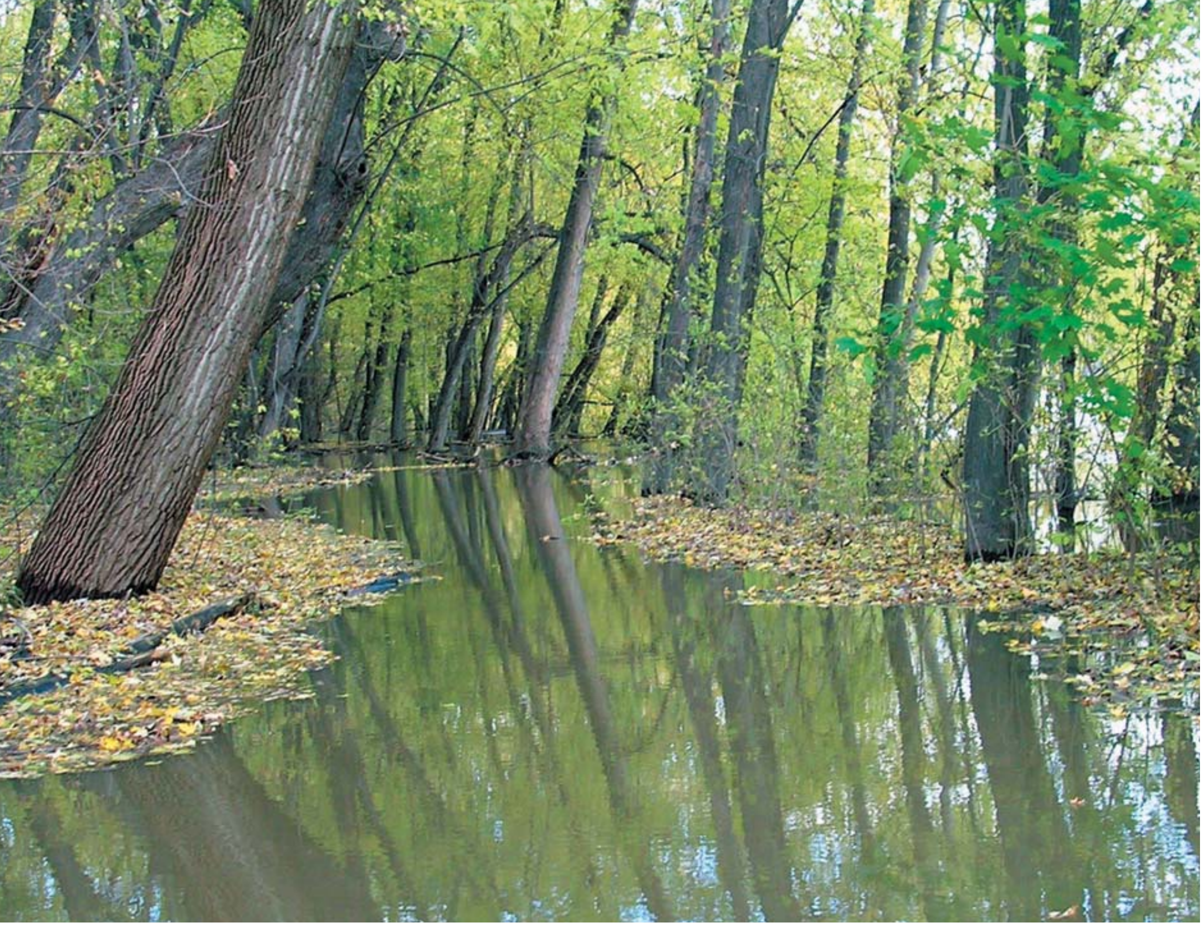
There are many organizations that have initiated protection of vulnerable wetlands, or contributed to their restoration. The Lake Champlain Basin Program sponsors projects offering incentives to landowners to return previously drained wetlands to their original condition. Further support comes from the North American Wetlands Conservation Act, U.S. Fish and Wildlife Service, Vermont Department of Fish and Wildlife, New York Department of Environmental Conservation, Ducks Unlimited, the Nature Conservancy, as well as private landowners and nonprofit organizations.

Impacts to tributaries (rivers and streams)

Over time, development changes the character of streams and rivers, whereby the biota that inhabits these waterways are adversely affected. Sedimentation caused by development and pollution run-off has become a growing problem. Once areas adjacent to riverbanks are developed, erosion control and bank stabilization further alters the riparian (streambank) zones. In addition, flood control alters the flow of streams and rivers, transforming the riparian landscape by accommodating bridges and roads. Water levels of streams and rivers have also changed due to hydroelectric dams for power generation and resulting irrigation for agriculture.

Poultney River/Poultney Mettowee Watershed Partnership

Planting vegetation such as shrubs helps to protect and stabilize riverbanks.



Intervale Foundation

Healthy riparian forests can help prevent serious erosion problems.

Impact Types

Floodplain loss

When the physical characteristics of streams and rivers are changed, it impacts a number of other properties. Loss of the historic floodplain due to leveling the landscape for development and agriculture leads to increased spring flooding to surrounding areas. These activities also increase river channel instability, making them more prone to erosion.

Degradation of water quality

Degradation of water quality from sedimentation and pollutants leads to *eutrophication* (high nutrient load) and increased water temperatures. Many of the aquatic organisms, including trout, find these conditions intolerable to live in. Increased sedimentation on the stream bottom fills in spaces between gravel and pebbles that bottom-dwelling organisms require for habitat.

Decreased water levels and flow characteristics

Decreased water levels and flow characteristics make streams and rivers unsuitable for some fish and wildlife habitat as each species of aquatic organism prefers a certain water level and rate of flow in order to function efficiently. When these conditions are changed, the native species populations begin to decline and other more tolerant species move in.

Channelization

Many of these alterations have caused *channelization* (straightening) of streams and rivers. This in turn allows the water to flow at greater speeds and decreases the number of pools that form around curves in the river. These areas are important habitat for certain species of fish and other aquatic organisms.

Problems/consequences

Pollutants

Tributaries carry increased pollutants and sediment loads into lakes, and continue to affect habitat and aquatic organisms living there. Fish and wildlife have been killed or impaired by the affects these contaminants have had on the water quality and food sources.

Impaired spawning habitat

The suitability of tributaries as fish spawning habitats has been seriously impaired by the impacts of development along the riparian zones of streams and rivers. Sedimentation has covered many gravelly areas that spawning fish seek in order to protect their eggs from predators.

Urban impact

Pollution from agriculture, industry, and development have been most severe in urban areas. In turn, the beneficial uses of tributaries have been impaired by the continued damage due to development and irresponsible land use.

Winooski River/Intervale Foundation

Tributaries carry increased pollutants and sediment loads into lakes, and continue to affect habitat and aquatic organisms living there.

Bluegill/USFWS Eric Engbretson

Impacts of pollution on Lake Champlain habitat

Air and water pollution occur when there is any chemical, biological, or physical change to air and water quality that has harmful effects on living organisms or makes water unsuitable for desired uses.

Types of pollution

Point source pollution

This type of pollution occurs when its origins can be traced back to a specific entry point such as a drainpipe. Sources of point pollution may include:

- **Medical, municipal, and industrial facilities,** where by-products or wastes of the production processes are emitted back into the environment. Oil and gas operations often use water in their operations as a coolant, after which it may be discharged back into a body of water with contaminants added.

- **Sewage systems or waste water treatment plants,** where partially or untreated sewage may bypass the treatment process or overflow before being treated, such as after a large rain event.

- **Unpermitted or illegal discharge** of point source pollution is a problem when individuals dump paints, varnishes, and household cleaners down the drain or directly over land without any kind of proper treatment. Chemicals found in these common products are then leached into groundwater that eventually flows into a body of water, or they combine with runoff after a rainfall and are carried directly into a waterbody.

Non-point source pollution

The origins of non-point source pollution come from many different diffuse sources that are difficult to regulate and control. Such sources may include:

- **Atmospheric deposition** during rain or snowfall and subsequent runoff from impervious surfaces, such as asphalt, is one way that pollution can enter a waterbody. Sources of airborne pollutants include: street dust, such as tire rubber; particulate matter from automobiles; and natural sources such as pollen and ash from wildfires. The burning of fossil fuels is a major source of nitrogen and contributes considerably to atmospheric deposition. Nitrogen contributes to acid rain, which is the most well known atmospheric pollutant. In addition, other chemicals such as PCB's, phosphorous, and mercury are all transported by air as well. These substances reach waterways such as streams, rivers, and lakes, where they degrade water quality and alter habitat. Airborne pollutants such as these are a more significant source of pollutants in urban watersheds due to the amount of highly impervious cover (rooftops, roads, sidewalks, and other pavement) that allow rainfall to run off easily into surrounding waterbodies.

- **Agricultural practices** are another significant source of non-point source pollution in our watershed. Substances used to enhance farming, such as crop fertilizers, insecticides, or pesticides run off with each precipitation event. These types of chemicals are often harmful to aquatic life once it reaches a waterbody. Sediment from eroded fields can also be washed into a waterbody and causes alterations to the habitat when it fills in the spaces between the substrate. Currently, phosphorus loading into Lake Champlain remains a serious problem. Some agricultural practices can contribute excess phosphorus or nitrogen to the lake as discussed above.

- **Urbanization** typically generates a great deal of non-point source pollution due to the degree of alterations to the landscape and addition of non-organic substances to the environment.

- **Cities** allow the growth of a population to expand to the extent that there is a greater impact on the

Joel Flewelling

Whatever we put into stormdrains ends up in the rivers and Lake Champlain.

Upper Winooski/Intervale Foundation

surrounding environment. As sizable populations produce large amounts of trash, disposal becomes an issue. Landfills have a tendency to leach toxins into groundwater, which can eventually reach other surface waters and degrade water quality. The expansion of structures and impervious surfaces decreases the amount of vegetation in areas near cities, and affects the amount and temperature of runoff into waterbodies. Increased amounts of runoff also have the ability to carry pollutants and sediment to nearby waters.

- **Construction sites** contribute to increased sediment inputs to surrounding waters when the appropriate runoff diversions (such as hay bales or berms) are not put in place.

- **Homeowners** may unintentionally add to water pollution by applying excessive amounts of lawn fertilizers to their lawns—anything not absorbed by the vegetation runs off with rainwater toward any surrounding waterbodies. Improper disposal of paints, varnishes, and household cleaners can also degrade water quality, such as dumping them directly onto the ground.

- **Highways** distribute grease, oil, and chemicals from automobiles to the surrounding landscape, where they are added to runoff. Exhaust from automobiles delivers pollutants such as nitrogen oxides, carbon monoxide, and hydrocarbons in the air, which can reach a waterbody when it combines with precipitation. Salt used to melt icy roadways also contributes to polluted waters and alters suitable aquatic habitat.

- **Unstable shorelines** occur with shoreline development and the removal of vegetation. These activities increase erosion and boost sediment inputs into nearby waters.

Classes of pollution (point and nonpoint sources)

Inorganic plant nutrients

- **Nitrogen** is and essential nutrient that is important for aquatic plants, specifically in the form of nitrate. Plants use nitrate to form proteins as building blocks. Nitrate exists naturally in the environment, most of which (80%) is a gas found in the air. It is also found in the soil, animal wastes, and decomposing plants. Most plants cannot use nitrogen gas from the air directly; however, blue-green algae in the water and some kinds of terrestrial plants (legumes) contain bacteria that covert nitrogen gas into a form that is usable by plants. When combined with phosphorus, nitrates in excess amounts can accelerate eutrophication, causing great increases in aquatic plant growth and changes in the types of plants and animals that live in the water. This in turn affects dissolved oxygen and temperature among other things. Cold water fish (trout and salmon) are more sensitive to nitrate levels than warm-water fish, and will leave a habitat that becomes enriched with too many nitrates. Excess nitrates can enter a lake by way of sewage from wastewater treatment plants or failing septic systems, fertilizers from agriculture or landscaping, wastes from farmlands and domesticated animals, and from industrial discharges.

Black Bullhead/Duane Raver, USFWS

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Conversions:

- ***Fixation*** is the conversion of gaseous nitrogen (N_2) to a usable form by living organisms.

- ***Mineralization or ammonification*** is the conversion of protein and nucleic acids in dead plant or animal material into amino acids, which are oxidized to carbon dioxide (CO_2), water (H_2O), and ammonia (NH_3).

- ***Nitrification*** is the process in which ammonia (NH_3) is oxidized to nitrate (NO_3^-) and nitrite (NO_2^-), which produces energy.

- ***Denitrification*** is the process in which nitrates (NO_3^-) are reduced to gaseous nitrogen (N_2) by certain organisms to obtain oxygen. The cycle starts again from here.

Effects of ammonia (NH_3), ammonium (NH_4^+), nitrate (NO_3^-) & nitrite (NO_2^-)

- NH_3 and NH_4^+ are essential to plants, but toxic to fish.

- NH_3 is used in fertilizers; surface runoff can pollute water.

- NO_2^- readily leaches through soils—excess amounts cannot be taken up by plants alone. It can pollute water and is toxic, but less so than NH_3 and NH_4^+.

- NO_3^- is not toxic, but high concentrations may cause problems with algal blooms.

Phosphorus is naturally occurring, but is also found in many man-made substances such as lawn and garden fertilizers, detergents, disturbed land and also manure from farmlands. Many times these substances are used in excess, and are washed into lakes with runoff after a period of rainfall. When too much phosphorus gets into a body of water it can cause algal blooms and excessive growth of other aquatic plants. When these plants die, decomposing matter causes the water to become cloudy and the temperature of the water rises. Bacteria that help to decompose the plant matter use up the oxygen in the water in the process—the more plant life, the more oxygen is used. This typically decreases the amount of dissolved oxygen available to fish, especially in the hypolimnion.

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Types of phosphorus:

- Ortho forms are produced by natural processes and are found in sewage.

- Poly forms are used for treating boiler waters and in detergents. In water, they change into the ortho form. These are also known as inorganic phosphates (PO_4^{3-}).

- Inorganic phosphates are utilized by phytoplankton.

- Organic phosphates are important in nature. Their occurrence may result from the breakdown of organic pesticides, which contain phosphates. They may exist in solution, as particles, loose fragments, or in the bodies of aquatic organisms. They are utilized by bacteria, which are eaten by microbial grazers. Microbial grazers then excrete the phosphates they ingest.

• Inorganic phosphates and organic phosphates are excreted by zooplankton, which feed on phytoplankton.

• Soluble colloidal phosphorous is derived from organic phosphorous.

• Both organic and colloidal phosphorous release phosphate to the inorganic fraction.

• Phosphates are present in sewage effluent. This pathway accounts for nearly all the phosphorous that reaches rivers and lakes.

Effects of excess phosphorus

• Excessive phosphorus from runoff and erosion can fertilize surface waters. In this process, (eutrophication) microscopic floating plants, known as algae, multiply rapidly when fertilized by phosphorus.

• These algae cloud the water making it difficult for larger submerged aquatic vegetation to get enough light. The vegetation may die back, reducing available habitat of aquatic animals.

• When the algae themselves eventually die they decompose. During decomposition dissolved oxygen is removed from the water. Lowered oxygen levels make it difficult for other aquatic organisms, such as fish, to survive.

Black bullhead/Duane Raver, USFWS

• Phosphorus, attached to sediments derived from soil erosion, may accumulate in the sediments of lakes and streams. This phosphorus may be recycled slowly or released more rapidly when these sediments are disturbed, for example during a storm or flood. Pollution from phosphorus is therefore a long-term problem.

• Phosphates are not toxic to people or animals unless they are present in very high levels. Digestive problems could also occur from extremely high levels of phosphate.

Inorganic chemicals

• **Heavy metals** such as cadmium, chromium, copper, lead, mercury, and nickel may occur naturally in

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Brown trout/Robert W. Hines, USFWS

Slightly elevated metal levels in natural waters may cause the following sub-lethal effects in aquatic organisms.

the environment through physical weathering, but are often times emitted into waterbodies from *anthropogenic* (human-caused) sources such as industrial waste, mining operations, stormwater runoff, combustion of fossil fuels, and wastewater effluent. Aquatic organisms may be adversely affected by heavy metals in the environment. The toxicity is largely a function of the water chemistry and sediment composition in the surface water system. Slightly elevated metal levels in natural waters may cause the following sub-lethal effects in aquatic organisms, such as:

- change in tissues
- changes in physiology, such as suppression of growth and development, poor swimming performance, or changes in circulation
- change in biochemistry, such as enzyme activity and blood chemistry
- change in behavior
- changes in reproduction

Mercury is the only heavy metal that bioaccumulates in the environment. As a result, there is a risk of ingestion by humans when we consume fish and other organisms that have consumed mercury-laden substances themselves. The side affects of chronic mercury poisoning may cause liver damage, neural damage, and teratogenesis—the process through which fetal development is altered and birth defects occur.

- **Acids** such as nitric acid and sulfuric acid are the main pollutants in acid rain. Particles of sulfur and nitrogen emitted by cars and coal-fired power plants can be carried great distances and deposited anywhere from a few hundred to a few thousand kilometers from their source area.

Gary Randorf

Acid rain has been proven to have serious detrimental effects to the aquatic life in many of the lakes in the Adirondacks. Some of these lakes are so acidic that they no longer support any fish species. Adirondack lakes are especially sensitive to acid rain because of the hard bedrock of the Canadian Shield (an ancient sheet of Precambrian granite) and the poor soil cover which has limited buffering (acid-neutralizing) ability.

Acid rain causes a cascade of effects that harm or kill individual fish, reduce fish population numbers, completely eliminate fish species from a waterbody, and decrease biodiversity. As acid rain flows through soils in a watershed, aluminum is released from soils into the lakes and streams located in that watershed.

As pH in a lake or stream decreases, aluminum levels increase. Both low pH and increased aluminum levels are directly toxic to fish. In addition, low pH and increased aluminum levels cause chronic stress that may not kill individual fish, but leads to lower body weight and smaller size and makes fish less able to compete for food and habitat.

Some types of plants and animals are able to tolerate acidic waters. Others, however, are acid-sensitive and will be lost as the pH declines. Generally, the young of most species are more sensitive to environmental conditions than adults. At pH 5, most fish eggs cannot hatch. At lower pH levels, some adult fish die. Some acid lakes have no fish.

Acid rain causes a cascade of effects that harm or kill individual fish, reduce fish population numbers, completely eliminate fish species from a waterbody, and decrease biodiversity.

Bowfin/Duane Raver, USFWS

To date, elevated chloride levels (method used to measure salt in lakes) are not seen as problematic for Lake Champlain aquatic organisms.

Together, biological organisms and the environment in which they live are called an ecosystem. The plants and animals living within an ecosystem are highly interdependent. For example, frogs and trout may tolerate relatively high levels of acidity, but if they eat insects that are less tolerant, like the mayfly, they may be affected because part of their food supply may disappear. Because of the connections between the many fish, plants, and other organisms living in an aquatic ecosystem, changes in pH or aluminum levels affect biodiversity as well. Thus, as lakes and streams become more acidic, the numbers and types of fish and other aquatic plants and animals that live in these waters decrease.

- **Salts** that reach a watershed from activities such as deicing roads have numerous negative effects on the aquatic environment. Road salts are harmful to fish and other aquatic life to varying degrees; the toxicity of salts to aquatic life varies with the amount of exposure. Short-term high values, if infrequent and not too high, may pose less risk than a lower level that is sustained for many months.

Salts can adversely affect lakes and streams if there is only a small strip of land between the roadside and a body of water. In these areas, the shoreline vegetation may receive relatively high amounts of road salt. The actual damage is mostly caused by the chloride portion of the salt, and is toughest on young trees and evergreens. It essentially creates an extra period of drought conditions for the plants. However, the extremely high concentrations on leaf and twig tips from direct salt spray from vehicles can directly damage plant tissues. The shoreline vegetation is extremely important to aquatic ecosystems because it helps prevent erosion and provides habitat to aquatic organisms as well as birds and other animals.

To date, elevated chloride levels (method used to measure salt in lakes) are not seen as problematic for Lake Champlain aquatic organisms.

Organic chemicals

- **Oil, gas, and solvents,** or any petroleum products, cling to the surfaces of aquatic life, leading to suffocation or poisoning. These substances decompose over time but at a very slow rate, leaving them to degrade the aquatic environment.

- **Toxic substances** are chemicals that can harm plants and animals, including humans. In general, these substances are found in low concentrations in Lake Champlain. However, toxic quantities of such contaminants still remain in bottom sediments where these non-water-soluble chemicals settled. Disturbance of sediments by dredging, boating activity, storms, marine salvage operations, and burrowing organisms may bring these contaminants back into the food chain Many of these substances are not very visible or obvious. They are introduced into lakes with increasing human populations and activities, and degrade the habitat for fish and other aquatic life. Substances used in pesticides and manufacturing, and their by-products, often break down slowly and remain in the environment. Many of these contaminants are stored animal tissues and become available to predators at each trophic level. As zooplankton graze phytoplankton, they concentrate these materials. Small fish preying upon zooplankton repeat the process, as do large fish consuming small fish—a process called *bioaccumulation* or *biomagnification*. Long lived species of fish, and/or those at the top of the food chain acquire the largest amounts of contaminants. Only a few of these materials have been studied in fish. The focus remains one of human health impacts as a function of fish consumption. Major fish contaminants include:

- **Polychlorinated biphenyls (PCB's).** Manufactured chemicals formerly used in transformers and capacitors for insulating purposes. They were also widely used in plastics, paints, carbonless copy paper, adhesives, fire retardants, lubricants, commercial refrigeration units, inks, and carpets. Although the use of PCB's was banned in 1977, they still enter the environment through improper disposal of products containing them. PCB's are suspected of causing cancer in humans and other animals. They may also operate as endocrine disrupters, mimicking hormones in many vertebrates. Endocrine disrupters can alter fish population sex ratios and result in reduced fertility. Related effects have been seen in several vertebrate groups, including fish, alligators, and turtles.

PCB contaminated sludge in Cumberland Bay served as a major PCB source to the lake. PCB's in Cumberland Bay core samples have dropped significantly since the completion of a $35 million clean up in 2001. PCB levels in fish from this region of the lake also are expected to drop in the coming years.

PCB's are "fat soluble" and therefore tend to accumulate fatty tissue in fish with greater concentrations in those fish with higher fat content. Hence, angler advisories typically suggest avoidance of larger, older fish and those species higher in fat content.

- **Mercury** is the most common toxic contaminant of concern in the Lake Champlain Basin. It is a heavy metal used in scientific instruments, latex

Many of these substances (toxics) are not very visible or obvious. They are introduced into lakes with increasing human populations and activities, and degrade the habitat for fish and other aquatic life. Substances used in pesticides and manufacturing, and their by-products, often break down slowly and remain in the environment. Many of these contaminants are stored animal tissues and become available to predators at each trophic level.

High priority substances include: PCB's, mercury, arsenic, cadmium, chromium, dioxins/furans, lead, nickel, PAH's, silver, and zinc. Potential concern toxics include: Ammonia, persistant chlorinated pesticides, phthalates, chlorinated phenols, chlorine, copper, VOC's (benzene, acetone), pesticides (atrazine, alachlor), strong acids and bases, and potential pollutants such as fluoride.

paints, fluorescent lights, batteries, and dental fillings and is found in some ores and fuels. Elemental mercury can be converted by physical and biological processes to the more toxic methyl mercury, and it is this form typically found in aquatic environments. Most of the mercury is transported through the atmosphere having originated in coal-fired power plants and municipal waste incinerators located outside the basin. Mercury can damage the central nervous system in humans, and has been linked to birth defects, cancer, and other illnesses. Unlike PCB's, mercury is stored throughout the muscle tissue, and therefore cannot be trimmed away or avoided (by species selection) as easily as PCB's.

- **Other and newer substances of concern** include Polycyclic/Polynuclear Aromatic Hydrocarbons (PAH's), and "newer generation" toxins such as pharmaceuticals, pesticides, fire retardants (PBDE's). PAH's have been shown to reduce the viability of eggs and fry of some benthic marine fishes. PBDE's (like PCB's) may operate as endocrine disrupters.

The Lake Champlain Basin Program reviewed the substances found to date in Lake Champlain and ranked them as "high priority" and of "potential concern." Ranking was based on the extent and levels at which they are found, the risk that they may pose to human health, and the risk they may pose to the ecosystem. This set of priorities will be used to: 1) direct further research on presence and effects; 2) serve as a focus for source identification efforts; and 3) direct management efforts, including source reduction, treatment and remediation.

High priority substances include: PCB's, mercury, arsenic, cadmium, chromium, dioxins/furans, lead, nickel, PAH's, silver, and zinc. Potential concern toxics include: Ammonia, persistant chlorinated pesticides, phthalates, chlorinated phenols, chlorine, copper, VOC's (benzene, acetone), pesticides (atrazine, alachlor), strong acids and bases, and potential pollutants such as fluoride.

Some areas of the Lake have higher concentrations of toxic substances than other areas of the Lake. In addition, some areas have more than one toxic substance present. The three sites and the substances of concern are listed in the following table.

Sites of concern	Cumberland Bay	Inner Burlington Harbor	Outer Malletts Bay
Substances of concern	copper zinc, PCB's, PAH's	lead, mercury, silver, zinc, and PAH's	arsenic and nickel

(source: http://www.lcbp.org/toxicsum.htm)

Mercury and PCB's are present in low levels throughout the Lake, and have accumulated in the tissues of several fish species, prompting New York, Vermont, and Quebec to post fish consumption advisories for these fish. These advisories can be found by contacting the respective state or provincial health agency.

In general, nearshore areas that provide critical habitat for fish spawning and for juvenile fishes are particularly vulnerable to pollution and to the input of contaminants from rivers, runoff, and shoreline development. These areas near shore are also the most productive regions of the lakes, influencing their overall health and productivity. Contaminants in organisms in these nearshore areas influence the entire food web of the lake. In addition, most fishing occurs in nearshore areas of the lake such as bays, connecting channels, and lower reaches of rivers, thus bringing humans into more direct contact with potentially contaminated fishes. Despite these generalities, it is difficult to ascribe specific fisheries impacts to given pollutants.

• **Oxygen demanding wastes** are organic wastes decomposed by biological or chemical processes that consume oxygen from the water. Waters enriched with wastes or nutrients from human, domestic, or wildlife are likely candidates for oxygen depletion.

Rapid microbial growth spurred on by excess nutrient availability requires large amounts of oxygen. The net result of this oxygen consumption is that the oxygen supply once available for all other aquatic organisms is now a limited resource. Organisms that require lots of oxygen for their high metabolic rates, especially fast moving fish, are the hardest hit. Freely mobile organisms will move out of these zones, but sessile life including filter feeders and even higher plants, with little means for transport will likely lose out, forming 'lifeless' zones.

• **Sediments** that flow into waterbodies overland or through tributaries increase turbidity (cloudiness of water). Disturbance of aquatic sediments by dredging, boating, and storms resuspends pollutants and contaminants in the water column. Increased turbidity can affect aquatic life by absorbing more heat and causing the water temperature to rise, which in turn reduces the concentration of dissolved oxygen available to fish. Turbidity also reduces the amount of light that can penetrate through the water to aquatic plants, affecting photosynthesis and plant growth. Suspended material can clog fish gills, reducing resistance to disease, lowering growth rates, and affecting egg and larval development. As suspended particles settle in slower areas, they can smother fish eggs. Particles can also settle into the spaces between the rocks on the bottom and decrease the amount and type of habitat available for aquatic invertebrates—a favorite food of many fish.

• **Thermal pollution** occurs when heated water is discharged from power plants, paved surfaces, and industrial buildings into nearby lakes and streams. This affects the normal habitat characteristics of the water, and can have a negative impact on certain species of aquatic organisms that prefer cooler water. Direct sources of thermal pollution currently pose little risk for Lake Champlain. The cumulative im-

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Eric Engbretson, USFWS

pact of thousands of acres of paved surfaces in the Basin may serve to raise water temperatures, though quantifying such pollution would be difficult to accomplish.

• **Pathogens** can enter a waterbody as a result of untreated sewage effluent, which contains fecal coliform bacteria from animal and human wastes. These pathogens cause waterborne diseases in bacterial, viral, and parasitic form. Treatment of sewage effluent with chlorine has drastically reduced waterborne diseases, but it also has properties that can be harmful to aquatic life if present in large amounts. This is typically more of a human health issue than a fisheries habitat concern. However, increased fecal coliform counts are indicative of broader habitat impacts.

Other classes of pollution

Genetic pollution

Though not commonly used, this term describes the unwanted effect of deliberate or unwanted stocking of different genotypes (i.e. races) of fish, where an endemic genotype already exists. This may lead to a loss of fitness in offspring. The current lake sturgeon in Lake Champlain situation provides a good example. Some biologists have expressed interest in stocking lake sturgeon (St. Lawrence genotype) to help rebuild the Lake Champlain population which is at very low levels—clearly a well-intentioned effort. Recent discoveries of sturgeon spawning (see above) in Lake Champlain suggest some risk associated with such a proposal. The introduced genotype might lack the genetic information to prosper in Lake Champlain. For example, native sturgeon might be better at finding the correct microhabitat to ensure spawning success. Fish from outside the system could "swamp" the natives and dilute the genetics that have supported Lake Champlain sturgeon for thousands of years.

Effects of pollution on an ecosystem

Pollution can have lasting detrimental effects on an ecosystem. It not only affects the waterbodies themselves, but the organisms living in and around the waterbody as well, including humans.

Eutrophication

Eutrophication occurs with the input of sediment, silts, and nutrients to lakes, causing enrichment or fertilization and allowing excessive life to grow. This "aging" of a lake is a natural process, over a time scale spanning thousands of years. Agricultural runoff, urban runoff, leaking septic systems, sewage discharges, eroded streambanks, and similar sources can greatly increase the flow of nutrients and organic substances into aquatic systems—process known as cultural eutrophication. These substances can over stimulate the growth of algae, creating conditions that interfere with the health and diversity of indigenous fish, plant, and animal populations, and the recreational use of lakes and estuaries.

Lake Champlain was originally *oligotrophic*, meaning it contained few plant nutrients and was continuously cool and clear due to the size and depth. Oligotrophic lakes support fish communities adapted to low nutrient levels (i.e. trout, whitefish, etc). With the increase of urbanization and agriculture, Lake Champlain has received increased inputs of human-induced nutrients. While the main lake remains border line mesotrophic (midway between oligotrophic and eutrophic), some of the lake segments are now classified as eutrophic. The increased nutrient levels and higher productivity in these areas tends to favor a different fish community (i.e. bass, carp, and various invasives)—one adapted to lower oxygen levels and lower water quality.

Aquatic diseases

- **Large mouth bass virus** (LMBV) first gained attention in 1995, when it was implicated in a fish kill on Santee-Cooper Reservoir in South Carolina. Since then, the virus has been found in lakes and impoundments from Texas east to the Chesapeake Bay area and beyond. During 2002, the virus was reportedly detected in Lake Michigan and in Lake Champlain. Often, LMBV has been found in bass that show no signs of disease, which suggests that some fish might be infected but not ever become ill. (source: http://www.mdwfp.com/Level2/Fisheries/pdf/lmbvFactSheet_2003.pdf)

- **Pike lymphosarcoma.** Beginning in the late 1990s Lake Champlain biologists and anglers began to notice lesions on northern pike, especially those caught during the ice fishing season. Epidemiologists now know this disease as Esocid lymphosarcoma. Scientists believe the disease is caused by a virus, though additional research is required to confirm this theory. It's sudden arrival in Lake Champlain, where is was previously unreported, suggests that it may have arrived in the lake as invasive species—perhaps via the

Lake Champlain was originally oligotrophic, meaning it contained few plant nutrients and was continuously cool and clear due to the size and depth. Oligotrophic lakes support fish communities adapted to low nutrient levels

Blue gill/Eric Engbretson, USFWS

Heated water causes the solubility of oxygen to decrease, meaning that warm water holds less oxygen than cool water.

Champlain Canal. Sampling by Vermont Fish and Wildlife staff, suggests that perhaps 20% of northern pike may be infected with this disease.

Heated water

Thermal pollution can originate from power plants, runoff from paved surfaces, destruction of riparian forests along streams and rivers, and other sources. Heated water causes the solubility of oxygen to decrease, meaning that warm water holds less oxygen than cool water. Some fish species are not very efficient at extracting oxygen from water containing low concentrations and must either move to a new habitat or perish. Behavioral and physiological impacts in fish and other aquatic organisms are well known. For example:

- As temperatures increase, the rate of respiration in fish increases, causing them to consume oxygen even faster.
- The physiological characteristics of a fish may prevent it from meeting the increased demands, causing death. Some of these responses include enzymes that may be rendered inactive; coagulation of cell proteins; reduction in permeability of cell membranes; and production of toxic products.
- The incubation of eggs and fry at high temperatures may be altered.
- High temperatures often eliminate desirable species of algae and produce undesirable species of plant life to grow.
- Warm water causes bacterial levels to increase, which may create problems if they are pathogenic species.

Genetic mutations

Chemicals that bioaccumulate in the food chain are of great concern because long-term exposure to them can increase the risk of genetic mutations. These chemicals can cause harmful changes in the DNA sequence of an organism. Toxic impacts include abnormalities in the liver and endocrine systems. A common genetic change occurs at times when contaminants cause a fish to grow a small air bladder. When these mutations happen, the fish eventually succumb to natural selection as it is less fit than its counterparts.

Reproductive failure/feminization

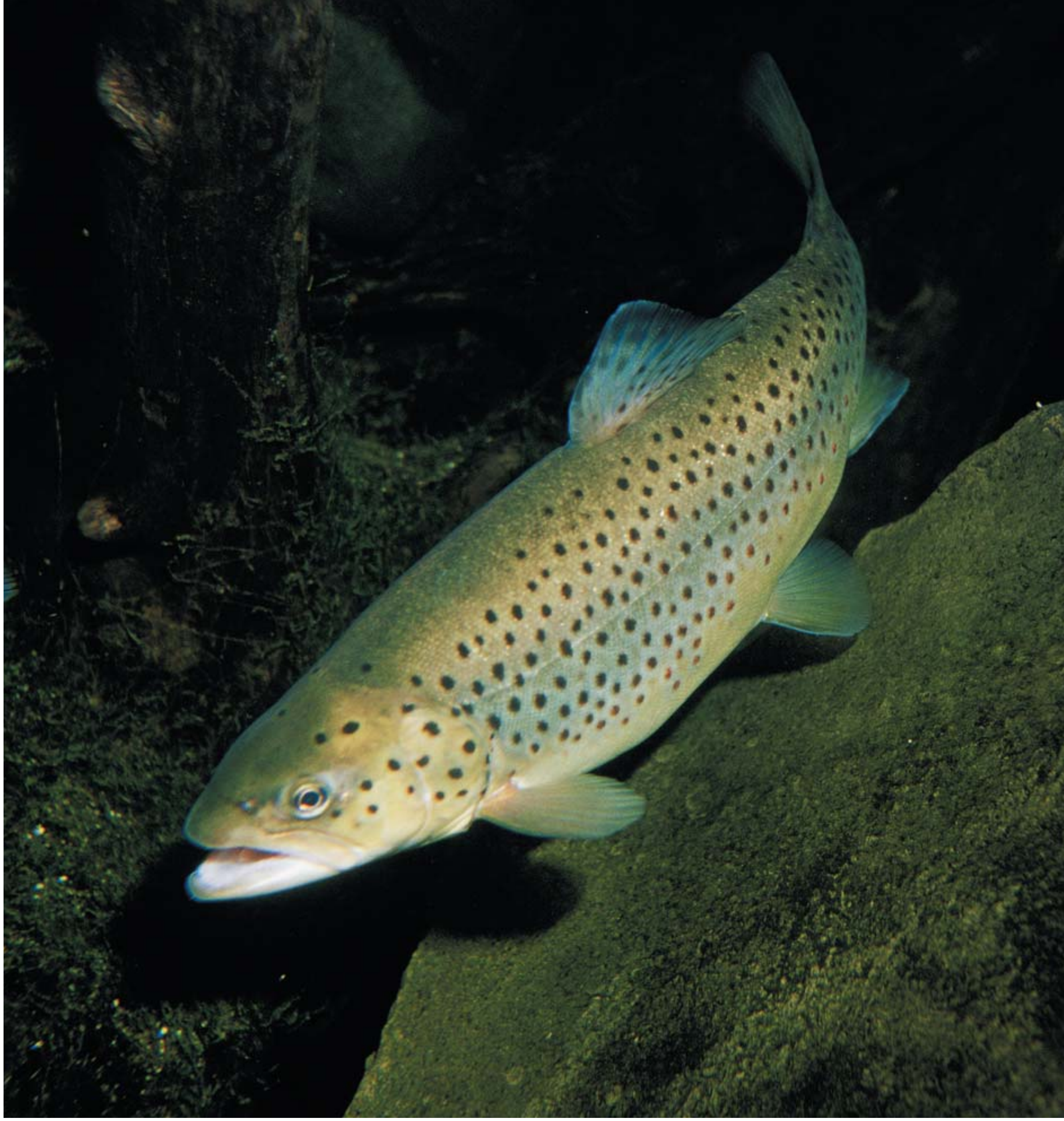
Some forms of organic chemicals have been shown to affect fish to the extent that it can alter sexual characteristics and hormonal function. DDT (a pesticide) and TCDD (a dioxin) mimic estrogen and may cause feminization of sex organs in males and development of male sexual characteristics in females.

Behavioral changes

Pollution can modify the behavior of aquatic life, such as altered feeding habits, changes in migration patterns, and changes in habitat use. These affects are potentially caused by damage to sensory organs (lateral line).

Reduction in genetic diversity

When a lake is artificially stocked with fish, the cultured fish are produced from the same parental stock, giving them the same genes. These fish reproduce with wild stock leading to a reduction in genetic variation. This may lead to a loss of *fitness* (strength) in offspring.



Brown trout/Eric Engbretson, USFWS

Gary Randorf

Despite increased precipitation, lake levels are expected to fall by 1.5 to 8 feet by 2100 because of the higher temperatures.

Impacts of climate change on Lake Champlain habitat

• Energy from the sun drives the earth's weather and climate, and heats the earth's surface; in turn, the earth radiates energy back into space. Atmospheric greenhouse gases (water vapor, carbon dioxide, and other gases) trap some of the outgoing energy, retaining heat somewhat like the glass panels of a greenhouse. Without this natural "greenhouse effect," temperatures would be much lower than they are now, and life as known today would not be possible. Instead, thanks to greenhouse gases, the earth's average temperature is a more hospitable 60°F. However, problems may arise when the atmospheric concentration of greenhouse gases increases.

• Global climate change tends to compound the negative effects of current environmental problems. Global warming means more air pollution and problems with water supplies as precipitation patterns change, as well as huge threats to ecosystems around the world. There will be hotter, longer heat waves and more intense storm systems. Forests, farms, and cities will face troublesome new pests and more mosquito-borne diseases.

• Scientists predict several changes for the Great Lakes. Average temperatures may warm by 2-4° C, and precipitation could increase by 25% by the end of the 21st century. Despite increased precipitation, lake levels are expected to fall by 1.5 to 8 feet by 2100 because of the higher temperatures. Additional effects of global climate change include decreases in annual snowfall, increased cloudiness, more summer precipitation, change in wind patterns and intensity, increases in evaporation rates, and altered stream flows. Similar changes may be in store for Lake Champlain.

Impacts to aquatic ecosystems

Seasonal mixing

The affects of seasonal mixing to Lake Champlain's ecosystem have the potential to be very serious. Lengthened warming seasons will reduce the seasonal mixing that replenishes critical oxygen to biologically productive lake zones, such as at depth. This could cause lake productivity to shrink.

Stream flow reduction

Stream flow reduction coupled with warmer summer temperatures may account for the disappearance of various fish species that spawn in the tributaries of Lake Champlain. Increased temperatures would likely cause water in rivers and streams to warm, causing them to hold less oxygen. Fish species that are intolerant of decreased dissolved oxygen levels will likely move to new habitats or risk dying. If this happens, fish distribution and zonation will change. Warming of the waters will also cause seasonal cycles to be altered, in turn affecting fish spawning cycles. Changing water levels in streams may negatively influence species that depend on an annual spring flood-pulse for access to spawning, nursery, and feeding grounds. Consequently, strength and abundance of year and class of fishes may be impacted. For instance, largemouth bass and white crappie require stable but high water levels in the spring for spawning. Without this habitat, numbers and health may decline in some areas.

Largemouth bass/Duane Raver, USFWS

Shrinking wetlands

Increased temperatures and decreased overall rainfall may cause wetlands used for spawning, nursery, and feeding to dry up.

Shorter growing season

The length of the growing season for fishes will expand, and may alter mortality of young-of-the-year fishes. This could lead to changes in the fish community.

Declining strength of fish

Changing water conditions from higher temperatures coupled with lower water levels may cause decreased health in fish, and in turn fish may be less tolerant to the effects of predation, competition, disease, contaminants, eutrophication, and fishing.

Largemouth bass and white crappie require stable but high water levels in the spring for spawning. Without this habitat, numbers and health may decline in some areas.

Aquatic Habitat

PROTECTION & MANAGEMENT: GOVERNMENTAL, ACADEMIC & ORGANIZATIONAL EFFORTS

The Lake Champlain Basin Program completed the plan in 2002 and is now implementing its recommendations through monitoring programs, local projects funded by grants, research, watershed associations, outreach, and education.

Water quality legislation

National Environmental Protection Act (NEPA; 1969)

This Act was declared a national policy in 1969, which encouraged productive and enjoyable harmony between man and his environment. It promoted efforts that prevented or eliminated damage to the environment and biosphere and stimulated the health and welfare of man. Along with it came hopes of an enriched understanding of the ecological systems and natural resources important to the Nation. This Act lead to the establishment of the Council on Environmental Quality.

Clean Water Act (1972, 1977)

This Act established the basic structure for regulating discharges and pollutants into U.S. waters. It gave the Environmental Protection Agency authority to implement pollution control programs such as wastewater standards for industry. There are continued requirements to set water quality standards for all contaminants in surface waters. This Act made it unlawful for any person to discharge any pollutant from a point source into navigable waters without a permit. It also funded the construction of sewage treatment plants and recognized the need for plans to address nonpoint source pollution.

Lake Champlain Basin Program

This Program (LCBP) is a federal, state, and local initiative to restore and protect Lake Champlain and its surrounding watershed for future generations. Lake Champlain was designated a resource of national significance by the Lake Champlain Special Designation Act (Public Law 101-596) which was signed into law on November 5, 1990. The Act's goal is to bring together people with diverse interests in the Lake to create a comprehensive pollution prevention, control, and restoration plan for protecting the future of the Lake Champlain Basin. The Lake Champlain Basin Program completed the plan in 2002 and is now implementing its recommendations through monitoring programs, local projects funded by grants, research, watershed associations, outreach, and education.

Protection and restoration

Numerous federal and state agencies, local groups, universities, conservation organizations, and others are actively involved with Lake Champlain Basin protection and restoration. More than 25 watershed, river, and lake groups are active with efforts to restore riparian and wetland habitats.

Recent accomplishments include the protection of some 8,000 acres of wetlands by willing landowners in response to efforts by The Nature Conservancy with support from the Lake Champlain Basin Program. The initiative was enabled via $1.4 million in federal North American Wetlands Conservation Act monies. Other restoration/protection funding sources include: the U.S. Fish and Wildlife Service's Partners for Fish and Wildlife Program and the Natural Resources Conservation Service's Wildlife Habitat Incentives Program.

The Lake Champlain Special Designation Act of 1990 designated Lake Champlain as a resource of national significance and the act's goal was to bring together people with diverse interests to create a comprehensive pollution prevention, control, and restoration plan. The Lake Champlain Basin Program is the major portal of this work. Others programs or groups such as Lake Champlain Sea Grant, and the Lake Champlain Ecosystem Team represent good starting points for those interested in learning about restoration accomplishments and future challenges.

Smallmouth bass/Timothy Knepp, USFWS

Wash your car with non-phosphorus and biodegradable soap on your lawn rather than on your driveway so that excess water and detergents can soak into the grass.

Community involvement in controlling pollution

There are many things that the local citizen can do to contribute to the efforts to restore Lake Champlain to a healthy state. These are just a few:

- Disposal of oil, paint, and varnishes at a recycling center.

- Plant trees and vegetation to help hold soil in place and reduce erosion, particularly in areas next to surface water.

- Properly maintain your septic system, especially by pumping every few years.

- Wash your car with non-phosphorus and biodegradable soap on your lawn rather than on your driveway so that excess water and detergents can soak into the grass.

• Do not use unnecessary fertilizers; first, have your soil tested. If you must fertilize, use compost instead. Many varieties of compost are produced locally in the Lake Champlain Basin.

• Do not use anti-freeze or other chemicals to keep ice fishing holes open.

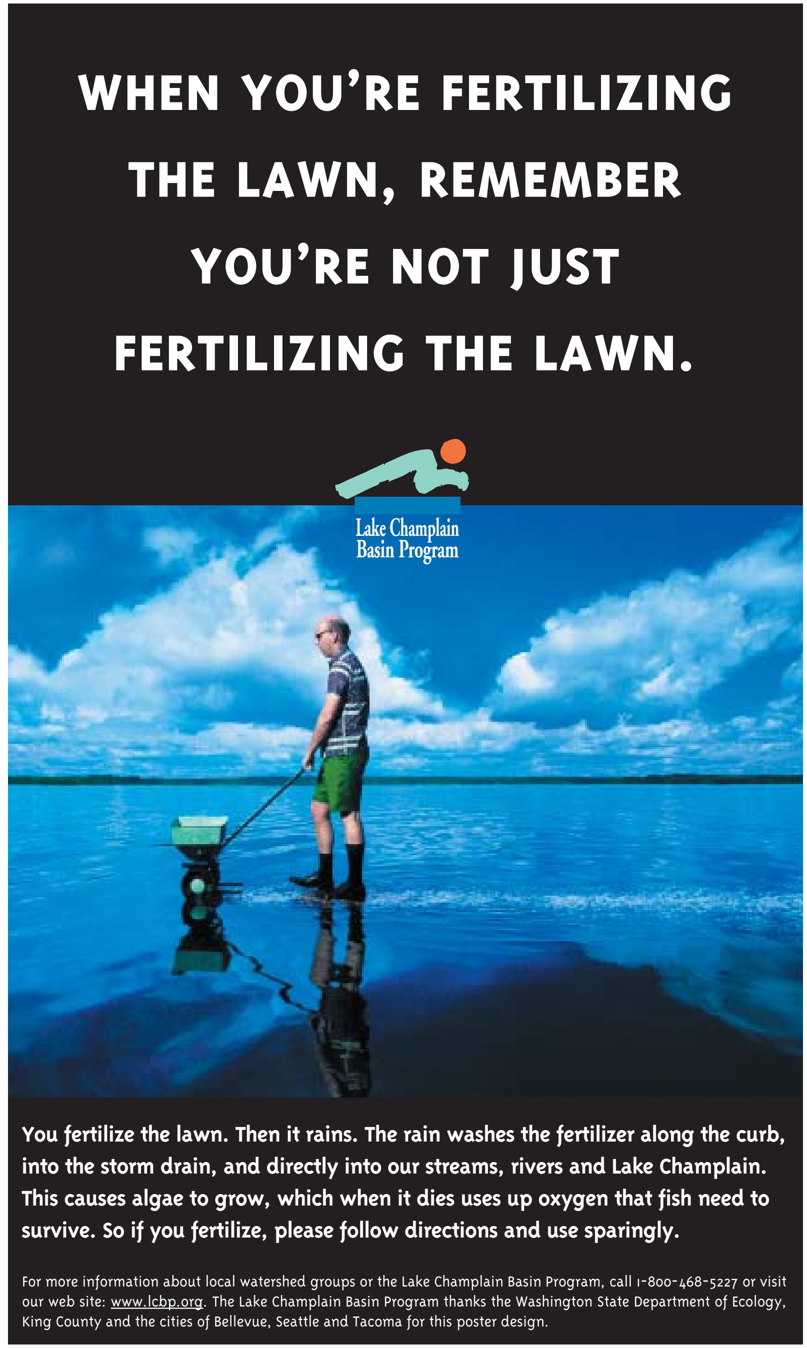
• Do not disturb ground cover unless absolutely necessary.

• Do not rake your yard waste into nearby streams, lakes, or stormwater gutters.

• Keep domestic animals out of sensitive habitats such as alpine areas and bogs.

• Fence livestock out of riparian zones.

• Use measures such as streambank fencing, constructed wetlands and buffer strips to control nonpoint source pollution that causes habitat degradation.



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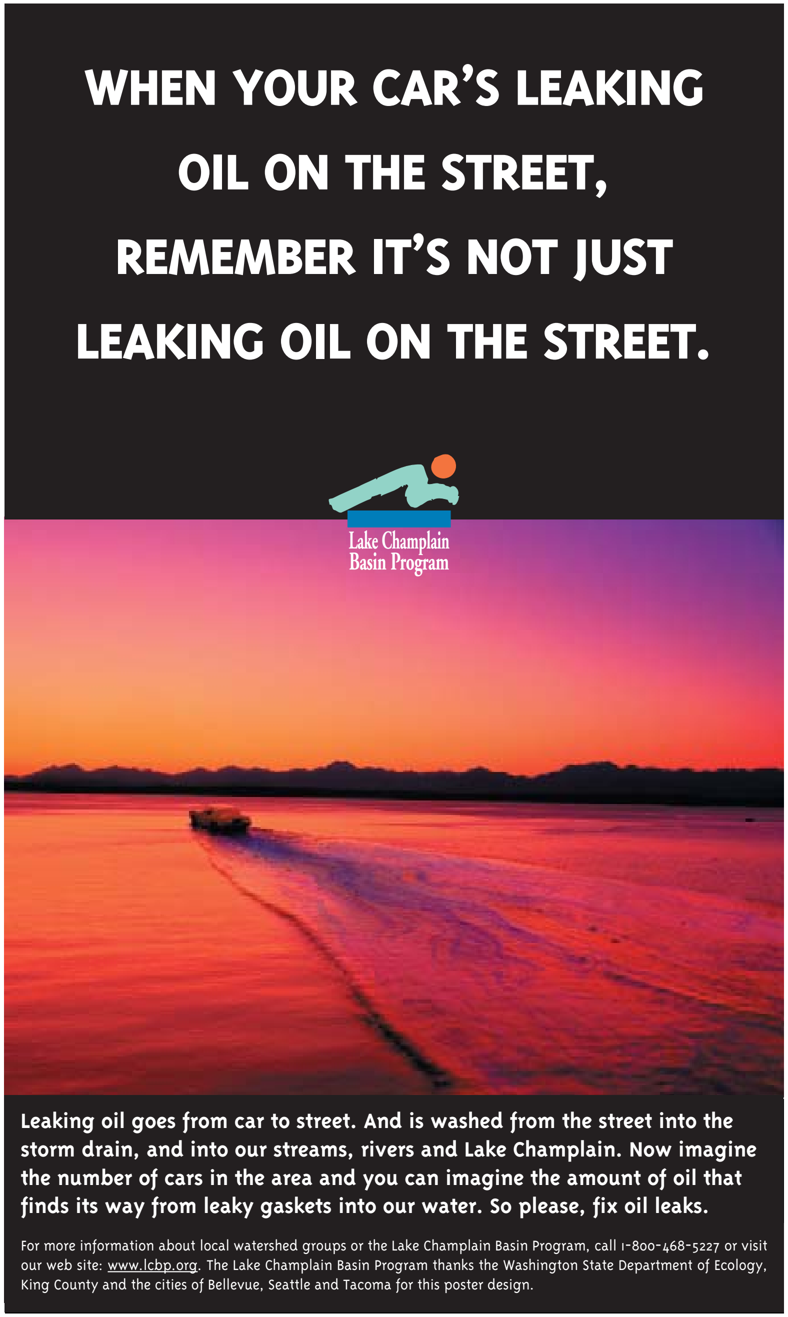

- Help limit the spread of water chestnut, zebra mussels, purple loosestrife, and other nuisance nonnative species that can have negative effects on native fish and wildlife species and their habitats.

- Drain all water from the boat, including the bilge, live well, and engine cooling system.

- Dry the boat and trailer in the sun for at least five days, or if you use your boat sooner, rinse it off, along with the trailer, anchor, anchor line, bumpers, engine, etc., with hot water or at a car wash.

- Leave live aquatic bait and bait used in infested waters behind—either give it to someone using the same water body, or discard it in the trash.

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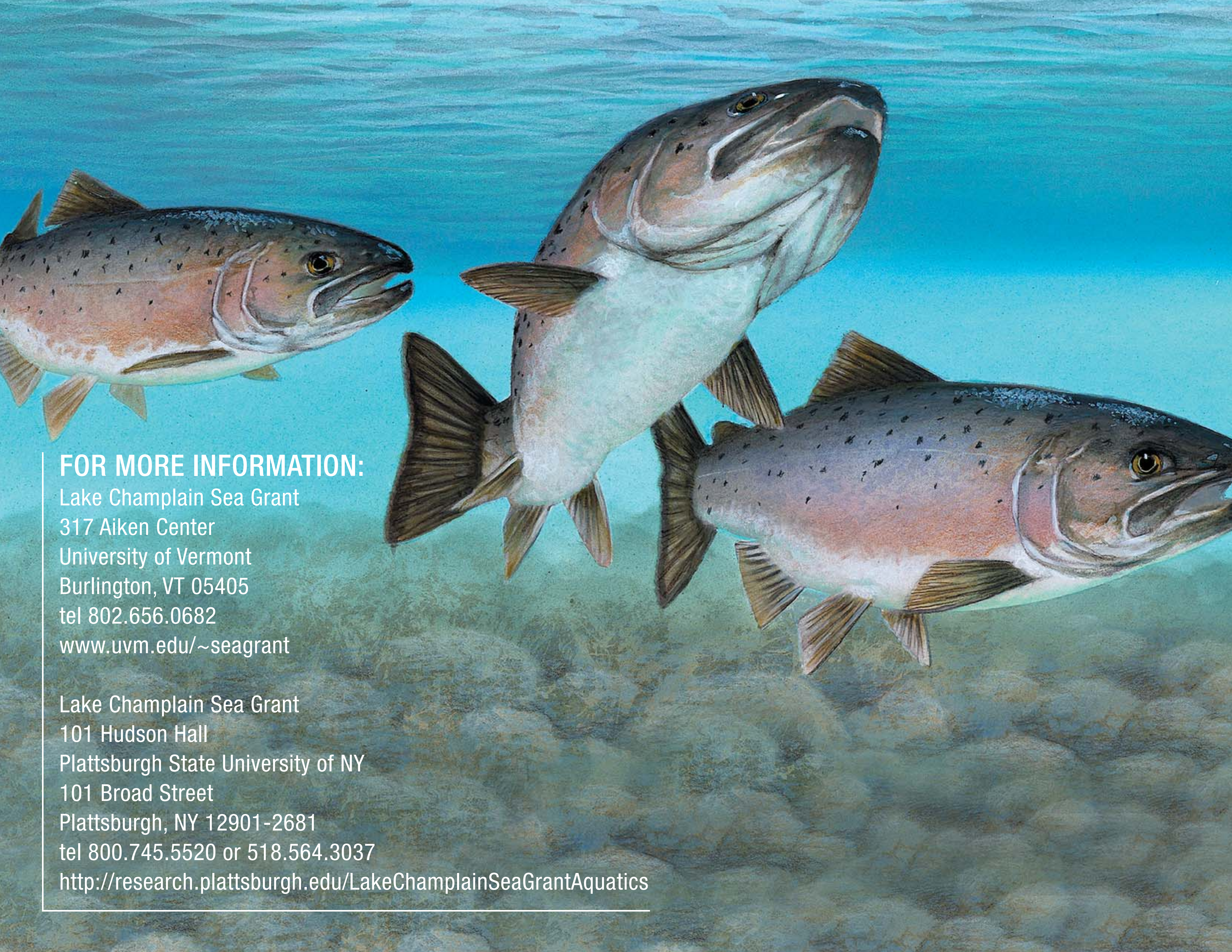

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