Tracking Invader Fish: Students and Scientists Working Together

For thousands of years, natural barriers like oceans, mountain ranges, deserts, forests, and rivers determined where plants, animals, and even microorganisms lived. Over time, natural ecological systems (ecosystems) were established, each made up a community of living organisms and the environment in which they lived. The plants, animals and microbes naturally living in an ecosystem (called native organisms) developed an ongoing balanced relationship with each other and with the environment around them, keeping the ecosystem productive and healthy.

However, as travel and trade have expanded around the world, human activities have helped spread plants and animals to areas where they are not naturally found, accidently or purposely expanding the range of many living things beyond their original locations. Sometimes organisms introduced into an area where they did not previously live (non-native organisms) will not be able to survive over time and will disappear with no ill effects. However, many times newly introduced organisms will live and reproduce, using up resources needed by native species that normally live in an area and destroying fragile ecosystems. In these cases, the invasive organisms can pose a serious threat to naturally occurring plants, animals, and microorganisms, and can disrupt the delicate balance of a natural ecosystem. Non-native organisms that damage the environment or disrupt existing ecosystems, or that result in economic loss or endanger human health are often called "invasive" organisms.

In lakes, rivers, and streams around the world, the introduction and spread of non-native fish presents a major threat to biodiversity (biodiversity, or biological diversity, is the variety of life found on Earth) by competing with the organisms that naturally occur in a stable natural aquatic environment. In addition to serious environmental problems, the loss of native fish can affect jobs and income. In this project we are going to look for the presence of invasive fish in waterways throughout New York State.

How do invasive fish get into local waters?

The introduction of invasive fish is a particularly difficult problem because non-native fish can easily be introduced into a body of water in many ways. Many different kinds of aquatic organisms, including fish, are often introduced into new areas as a result of the dumping of large amounts of **ballast water** by large ships (Ballast water is the water that is pumped into huge tanks to stabilize unloaded ships, and then discharged at the next port of call, along with all the organisms living in the ballast water). Around the world, millions of tons of ballast water are exchanged daily, carrying within it aquatic organisms from microscopic **plankton** (tiny marine and freshwater organisms that cannot swim against the current and live in a drifting, floating state) to fish. On a smaller scale, many economically important activities like aquaculture (aquaculture is water farming - the growing of plants and animals in water environments like ponds, rivers, lakes, or even the ocean), and buying and selling exotic aquarium fish can sometimes lead to the accidental or purposeful release of invasive fish into areas where they have never been found before.

In the past, well-intentioned plans to introduce non-native organisms to control biological problems have backfired and resulted in serious environmental damage. For example, the introduction of a fish called the grass carp to control the spread of unwanted aquatic plants has led to the destruction of native plant species in inland lakes, resulting in great damage to lake ecology and ecosystems at all levels. Boaters and fishermen can also contribute to the problem by transporting fish (even baitfish) between rivers and lakes, resulting in cross-contamination of previously unaffected waters.

Even people with home aquarium can contaminate a waterway simply by releasing their pet fish into a lake or stream. For example, a few pet goldfish released into Teller Lake in Colorado quickly reproduced, resulting in thousands of goldfish that destroyed many of the naturally occurring fish and plants in the lake.


Goldfish in Teller Lake. Courtesy Colorado Fish and Wildlife

What fish will we look for?

This research project will use the latest in scientific technology to check for the presence of the following three kinds of invasive fish, all of which pose a potential threat to New York waters.

Sea Lamprey (Petromyzon marinus)


NOAA Great Lakes Environmental Research Laboratory licensed under CC BY 2.0


NOAA Great Lakes Environmental Research Laboratory licensed under CC BY 2.0


"Boca de lamprea. Licensed under CC BY-SA 3.0 via Wikimedia Commons -

Sea lamprey naturally live in the Atlantic Ocean. They were introduced into the Great Lakes in the 1800s through a series of manmade locks and shipping canals. By the late 1940s all of the Great Lakes contained large populations of sea lamprey that caused serious damage to lake trout and other kinds of fish. For part of its life cycle, the sea lamprey feeds on the blood of host fish. Sea lamprey have a large sucking disc for a mouth, filled with sharp teeth and a file like tongue. They use the sucking disc and teeth to attach to prey fish, and rasp through the scales and skin to feed on blood and other body fluids, often resulting in the death of the prey. The lamprey attack causes so much damage that only about 1 out of 7 fish will survive an attack. During its life, which can last from an average of 6 to as long as 20 years, a single lamprey can kill large numbers of native lake and rainbow trout, whitefish, chubs, walleye, and catfish. The economic effect of this invasive species has been enormous. For example, before the spread of the sea lamprey invasion, the United States and Canada harvested about 15 million pounds of lake trout from the upper Great Lakes each year. By the 1960s the total lake trout catch had dropped to only about 300,000 pounds. In Lake Michigan alone the catch dropped from 5.5 million pounds in 1946 to 402 pounds in 1953 (data from the Great Lakes Fishery Commission). Today there is an ongoing sea lamprey control program that is helping to reduce sea lamprey populations in many areas, but vigilant monitoring is still a key factor in controlling this highly destructive invasive species.

Asian Carp (Several kinds of carp are collectively known in the United States as Asian carp)

Asian Carp Regional Coordinating Committee

Asian carp were originally brought to the United States in the 1970s to help control algae growth on catfish farms and in wastewater treatment ponds. Two kinds of Asian carp were released into the wild following flooding in the 1990s, and the Asian carp invasion has been spreading north along the Mississippi ever since. In some areas of the Mississippi River, Asian carp have become the most abundant type of fish, out-competing native fish. Asian carp have also been identified in the canals connecting the Mississippi River to the Great Lakes. Unfortunately, Asian carp, which can grow up to four feet long and weigh more than 100 pounds, have no natural predators in their new environment. A single carp can eat up to 5 -10% of their body weight in plankton each day. By consuming nearly all of the available plankton, the primary food source for most of the native fish, the Asian carp can rapidly wipe out entire populations of native fish. In an effort to decrease the spread of Asian carp into new rivers and lakes, the U.S. Fish and Wildlife Service has placed several species of Asian carp to the federal list of injurious wildlife, making it illegal to transport live Asian carp, including viable eggs, across state lines except by special permit for zoological, education, medical, or scientific purposes.

NOAA Great Lakes Environmental Research Laboratory licensed under CC BY 2.0

Round Gobi (Neogobius melanostomus)
Round Gobi were introduced into the Great Lakes through the ballast water from large cargo ships and were first identified here in 1990. Since their introduction, round

Gobi have caused significant ecological and economic problems. Round Gobi have spread throughout the Mississippi River drainage area, and into streams and rivers that flow into the Great Lakes. Round Gobi have even been sighted in Cayuga Lake, one of the New York Finger Lakes. Round Gobi, which are bottom dwellers, compete very successfully with native bottom dwelling fish like sculpins and darters for food, habitat, and egg laying areas, and can cause substantial decreases in local populations of native fish. Round Gobi also prey on small fish and eat the eggs and fry (baby fish) of larger native fish like lake trout. The increased presence of round Gobi has been shown to affect the food chain supplying recreationally important fish like walleye and smallmouth bass. It has been noted that round Gobi eat large amounts of zebra mussels, which in the short term may seem like an unexpected benefit. But, as with most environmental and ecological issues, it is important to look at the broad picture. Despite their large appetites, it is unlikely that round Gobi will have a significant impact on zebra mussel populations. Equally important, the zebra mussels eaten by round Gobi contain large amounts of various toxins that are found throughout the Great Lakes. Following intake of the zebra mussels, the toxins become concentrated in the Gobi, which are in turn eaten by a variety of sport fish, including smallmouth and yellow bass, walleyes, yellow perch, and brown trout. This food chain can lead to high concentrations of dangerous toxins in sport fish that are consumed by humans, increasing health concerns related to consuming sport fish.

How will we monitor for these invasive fish?

DNA in the environment

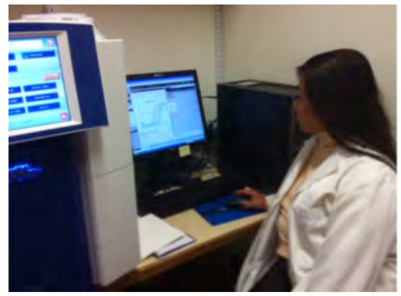
In this project we will test for the presence of invasive fish by looking at fish cells that have been shed into the water. Like all organisms, fish continuously shed cells containing DNA (<u>d</u>eoxyribo<u>n</u>ucleic <u>a</u>cid - a molecule that carries specific genetic information that makes each organism unique) into the environment in mucous, feces, urine, or blood, or even in flaked off skin cells. The DNA from cells released into the environment is called <u>environmental DNA</u> (<u>eDNA</u>). eDNA is found in environmental samples like water, soil, or air. When eDNA is collected, it is made up of DNA from all the different organisms present in the environment, including plants, animals, and singled celled organism like protozoa, and bacteria.

Since the eDNA from each kind of organism is unique, it is possible to test for the presence of different kinds of invasive fish by collecting a water sample and testing it for unique invasive fish eDNA. Testing a water sample for eDNA is a very sensitive method of determining whether a particular kind of fish is, or was recently, present in the area where the water was collected.

In this project, teachers and students and scientists at Cornell University will work together to collect and test water samples from waterways throughout New York state for the presence of cells from 3 invasive species - sea lamprey, Asian carp, and round Gobi. <u>Global Positioning System</u> (<u>GPS</u>) coordinates (latitude and longitude) will be used to identify the location of each site.

Students will collect a small amount of water and filter it through small filters that will retain any cells shed by fish in the collected water. The eDNA from the shed fish cells will last in the water for at least 4-6 hours following shedding, so a fish can be detected even if it swam by several hours earlier. Your teacher will go over the more detailed description of the collection process shown in the Water Collection Protocol, which is also on our website. The filters containing cells from the water sample will be placed into a vial containing a solution that will protect the DNA from further breakdown, and sent back to Cornell University for analysis. The cells collected on the filter will provide eDNA that will be analyzed by quantitative PCR (**qPCR**) analysis, which will be carried out in the laboratories of the Aquatic Health Program ((http://www.vet.cornell.edu/microbiology/FishDisease/AquaticProg/).

qPCR is a very sensitive test that can detect the presence of a single fish in a 50-acre pond 10 feet deep. The eDNA signal provides information about the presence or absence of invasive fish at the location tested at the time the sample was taken. The test does not provide information about the age or sex of individuals present at the time of sampling, and does not indicate whether the DNA came from a live organism or a recently dead one (for example a bait fish). If the qPCR test does not give a positive signal, that may mean that the invasive fish being tested for is not present, or that there are so few fish that an eDNA signal cannot be picked up. A weak eDNA signal could represent a few cells from a non-resident fish that has left the site or a fish that has just entered the site so there are not many shed cells in the water. A strong signal suggests a larger population.



A Cornell scientist using the qPCR machine

What happens to the samples that are collected?

Once the filters containing the samples you collect are sent back to Cornell, they will be analyzed for the presence or absence of eDNA from sea lamprey, Asian carp, and round Gobi. Samples will also be stored for possible further analysis.

The results of the testing on your samples will be sent back to you so you can discuss your results in class. Your findings will be added to our state map, along with a tag giving credit to your class and your school for your help in acting as citizen scientists for this project.

This work is supported by the USDA National Institute of Food and Agriculture HATCH project 2014-15-242