CLIMATE CHANGE AND AQUATIC INVADERS

What do scientists know about aquatic nuisance species of the Great Lakes and effects that climate change will have on them?

(Background and Teacher Guide)

The Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 defines an **aquatic nuisance species (ANS)** as a nonindigenous species that "threatens the diversity or abundance of native species or the ecological stability of infested waters, or commercial, agricultural, aquacultural or recreational activities dependent on such waters." A **nonindigenous species** is an organism (plant, animal, microbe) found living beyond its historic native range, which is usually taken as the area where it evolved to its present form.

Since the early 1800s, some 184 species of aquatic plants, algae, fish worms, mollusks, and other organisms have invaded the Great Lakes. Likewise, some North American species such as the green sunfish (*Lepomis cyanellus Rafinesque*) have migrated westward and have become pests in Europe. Biologists worry about these intrusions, because each new species in the Great Lakes alters the region's ecosystem. Any environment has a fixed amount of energy that must be divided among all the species present. When a nonindigenous species invades an ecosystem, it often has no enemies. This allows the species to increase rapidly, displacing native organisms by filling their niches. This change allows the once biodiversified region to lose some of its genetic diversity.

It is estimated that 24 of the 175 species of fish in the Great Lakes are nonnative species that were introduced accidentally or intentionally. Eighty-six aquatic nuisance species are plants, although plants have received less attention as invaders. How these non-native species get into the region varies, but many have been shipped in unintentionally.

When ships are not loaded with cargo, they take on ballast to balance and stabilize them as they travel. The use of water as a ballast material has replaced the use of sand and stones. Ballast tanks are filled with water from the harbor where ships are loaded and then dumped, along with any aquatic organisms present, when ships reach their destination. It is estimated that in the history of the Great Lakes, 34% of aquatic nuisance species entered in solid ballast and 56% through ballast water. As shipping times between continents becomes shorter, the threat of introducing live aquatic nuisance species becomes greater.

The United States and Canada have requested that all ships entering the Great Lakes discharge their water ballast while still in the ocean, replacing it with salt water in order to reduce the introduction of new aquatic nuisance species. About 90% of the ships currently comply with the request.

Invasive Species in this Activity

Alewife (*Alosa pseudoharengus*)
Asian Carp (*Ctenopharyngodon idella* or *Hypophthalmichthys molitrix* or *Hypopthalmichthys nobilis*)
Eurasian Water Milfoil (*Myriophyllum spicatum*)
Purple Loosestrife (*Lythrum salicaria*)
Quagga Mussel (*Dreissena rostriformis*)
Sea Lamprey (*Petromyzon marinus*)
Round Goby (*Neogobius melanostomus*)
White Perch (*Monrone americana*)

Teacher Activity: What do scientists know about aquatic nuisance species of the Great Lakes and effects that climate change will have on them?

Objectives: Students manipulate cards to identify aquatic nuisance species and explain the effects of global climate change on these species. After completing this investigation, students will be able to:

- Name and visually recognize some nonindigenous and invasive species of the Great Lakes.
- Locate on a world map the origins of the Great Lakes aquatic nuisance species.
- Explain the ways in which aquatic nuisance species are introduced into the Great Lakes.
- Explain the impacts of aquatic nuisance species on the Great Lakes ecosystem.
- Analyze the effects of global climate change on aquatic nuisance species of the Great Lakes.

Materials, per group:

Printed copies (or the accompanying electronic version to be projected) of *What's wrong with this picture?* Copies can be requested from Illinois-Indiana Sea Grant at ***http://www.iisgcp.org/catalog/ed/7way.htm***.

Printed copies of or computer access to ANS fact sheets

- Alewife - ***http://www.in.gov/dnr/files/ALEWIFE.pdf***
- Asian Carp - ***http://seagrant.psu.edu/publications/fs/asiancarp2007.pdf***
- Eurasian Watermilfoil - ***http://www.seagrant.psu.edu/publications/factsheets/EWM2012trialreduced.pdf***
- Purple Loosestrife - ***http://www.seagrant.psu.edu/publications/factsheets/loosestrife2012red.pdf***
- Quagga Mussel - ***http://www.seagrant.psu.edu/publications/factsheets/ZebraQuaggaFactsheet2012reduced.pdf***
- Round Goby - ***http://www.seagrant.psu.edu/publications/factsheets/roundgoby2012reduced.pdf***
- Sea Lamprey - ***http://www.seagrant.umn.edu/downloads/x106.pdf***
- White Perch - ***http://www.iisgcp.org/exoticsp/white_perch.htm***
  (This is a longer document. It is sufficient to print pages 1 - 3 to conserve paper.)

Great Lakes Aquatic Nonindigenous Species Information System (GLANSIS) ***http://www.glerl.noaa.gov/res/Programs/glansis/glansis.html*** This website allows students to search for all ANS in this activity. Note that information on Asian carp can be accessed though the watch list and not the main search engine.

Printed copies of or computer access to ANS background information sheet *Exotic, Invasive, Alien, Nonindigenous or Nuisance Species: No Matter What You Call Them, They're a Growing Problem* ***http://www.glerl.noaa.gov/pubs/brochures/invasive/ansprimer.pdf***

Copies of the included 32 information cards should be made for each group of students. Each of the four card categories (ANS picture, introduction, ecosystem impact, climate change effects) should be copied onto a different color of paper or cardstock. Cards can be laminated for repeated use.

Time required: 1 class period for reading ANS fact sheets and answering preliminary questions (or this could be done for homework)
1 class period for jigsaw and matching cards

ALIGNMENT

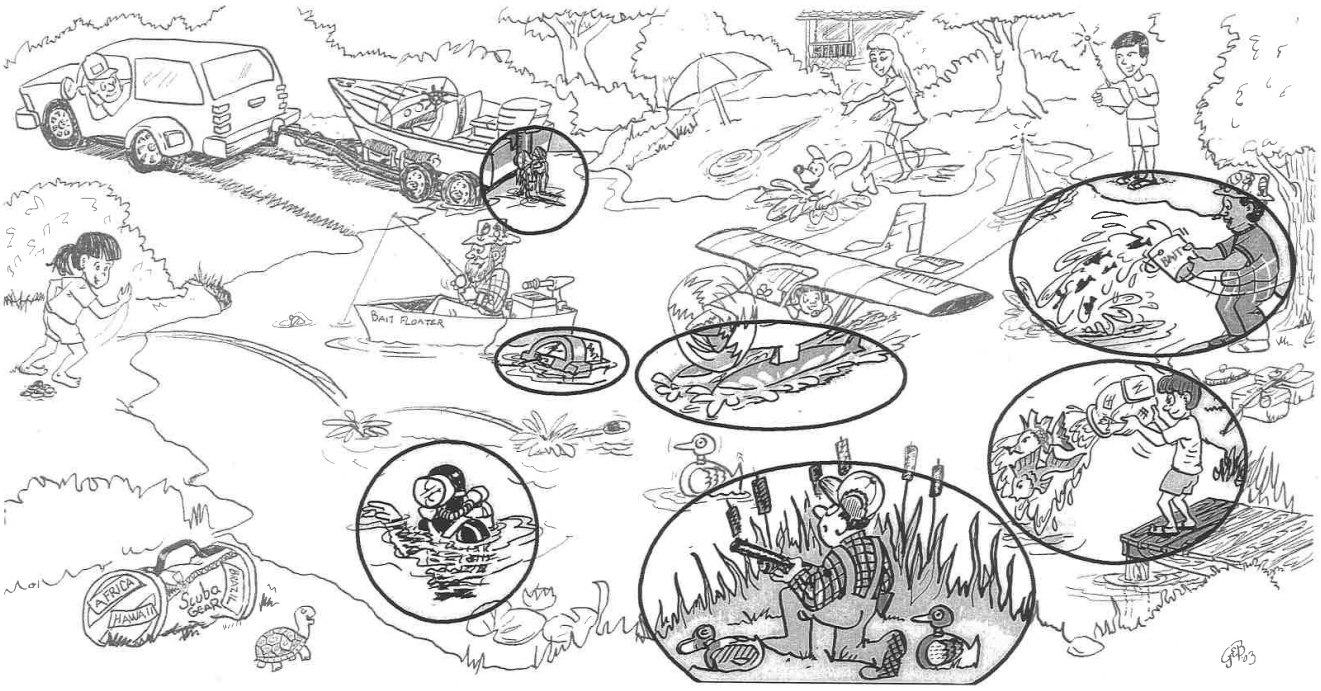
National Framework for K-12 Science Education:
CC 2: Cause and effect: Mechanism and explanation
CC 7: Stability and change
Core Idea LS 2: Ecosystems: Interactions, Energy and Dynamics
Core Idea LS 4: Biological Evolution: Unity and Diversity

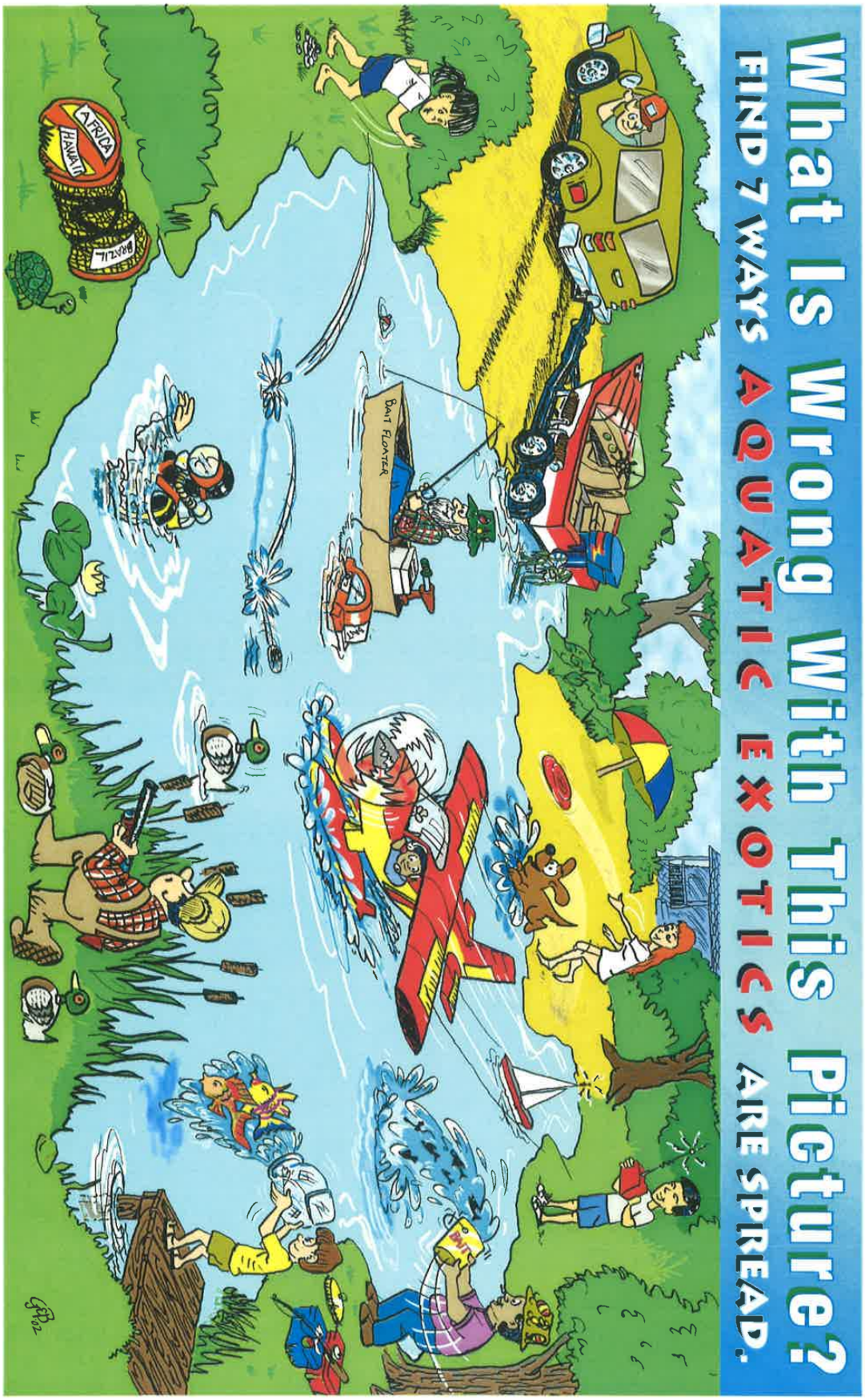
Great Lakes Literacy Principles:
#5i: The Great Lakes support a broad diversity of life and ecosystems.
#8d: The Great Lakes are socially, economically and environmentally significant to the region, nation and planet.

Climate Literacy Principles:
#3a: Life on Earth depends on, is shaped by and affects climate.

ENGAGE

Show students the image "What is wrong with this picture?" Have students identify at least seven ways aquatic nuisance species are spread. [The answer key is included below, but all reasonable suggestions should be entertained.]

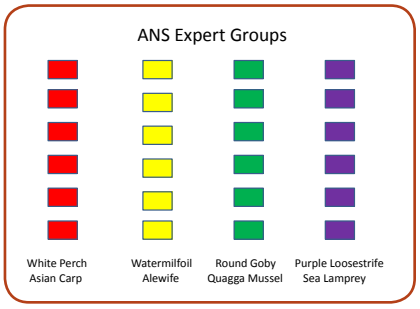



What Is Wrong With This Picture?
FIND 7 WAYS AQUATIC EXOTICS ARE SPREAD.
AFRICA
HAWAII
BAIT FLOATER

EXPLORE

This lesson begins with a teaching strategy called a jigsaw. In a jigsaw, students are first assigned an expert group (small group) and then reorganized into different groups (larger group) that will contain at least one member from every expert group.

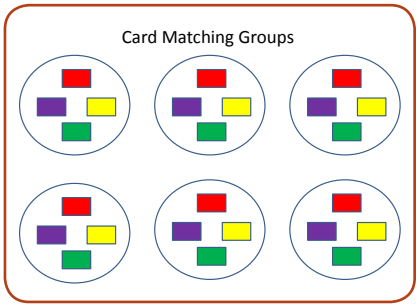
1. Divide the class into eight groups and assign each group an aquatic nuisance species to read about and then answer background questions. The students in each aquatic nuisance species group will become experts on the particular species assigned to them.



Teacher's Notes:

If the class is small (or if you prefer smaller groups than described in step 2 below), divide students into four groups; each group is now responsible for answering background questions and becoming experts on two aquatic nuisance species.

This task could be done by students individually as homework so that they come prepared to class the next day. Alternatively, expert groups could use class time to work together to answer the background questions before reorganizing groups.



Answers to student questions in Part 1:

Chart:
All nonindigenous species are invasive species. DISAGREE
An alien species is the same thing as an exotic species. AGREE
A nonindigenous species is native to an area. DISAGREE
All nuisance species are invasive species. AGREE
All invasive species are nonindigenous. AGREE

1. Answers will vary.
2. A nonindigenous species "threatens the diversity or abundance of native species or the ecological stability of infested waters, or commercial, agricultural, aquacultural or recreational activities dependent on such waters."
3. ballast water of cargo ships; travel through man-made canals as new connecting waterways; unintentional dumping of bait or aquaria organisms; transfer of ANS on boats between bodies of water; intentional introduction by humans because they wanted a particular organism in the ecosystem
4. $1.4 M + $13 M + $1.5 M + $10 M = at $25.9 M

EXPLAIN

2. Reorganize students so that each group contains at least one expert on each aquatic nuisance species. These new groups should have at least eight students in them. Students should have their completed worksheets with them.
3. Give each group a complete set of 32 shuffled cards.
4. Beginning with the picture of the aquatic nuisance species, each group should match the cards to determine which introduction, ecosystem impact and global change card goes with each nonindigenous species. For each picture, there should be one matching card of each other color.
5. When group members agree that they have matched the cards to the best of their ability, they may check their answers on the answer sheet. **Answers to card matching:** 1BUd, 2HWh, 3CSe, 4AZb, 5GYf, 6DVc, 7FXg, 8ETa
6. Facilitate a whole class discussion where groups share their findings about how aquatic nuisance species may be affected by climate change.

EXTEND

1. Have students draw a humorous cartoon or write a song or poem depicting the problem of aquatic nuisance species. (Example: A zebra mussel looking for a place to attach on an already-overcrowded lake bottom, a white perch nudging out a yellow perch, purple loosestrife choking other plants, etc.)
2. Have students explore *Nab the Aquatic Invader* (***http://www.iisgcp.org/NabInvader/great_lakes.html***), an interactive website where students acts as private investigators to help other detectives "book the bad guys." Students read ANS profile sheets, uncover more clues by solving the case files on each species, and collect evidence and background information to help "book a bad guy."

EVALUATE

1. Why should people be concerned about nonindigenous species? [Non-native species threaten to change present ecosystems, often in unpredictable ways. Because nonindigenous species frequently do not have predators, they often have the ability to disrupt the existing ecological balance and dominate an area. Consider the effects of European humans after their introduction to North America. Consider other species humans have displaced.]

2. How can the transfer of aquatic nuisance species be controlled or stopped in the Great Lakes or elsewhere in the world? Draft a piece of legislation that could be enacted to stop non-native species from invading the Great Lakes. [Ballast water is critical to the spread of aquatic nuisance species. Rules on ballast dumping are crucial to limit the spread of aquatic nuisance species.]

3. Explain what effects global warming may have on any of the aquatic nuisance species discussed – which species will benefit by the change and which will be negatively impacted? [Most aquatic nuisance species will be able to adapt to warmer water temperatures, higher precipitation and lower lake levels. They will likely outcompete native species as the climate changes.

4. Identify as many Great Lakes jobs as possible that are impacted by aquatic nuisance species. (Some impacts may be positive, that is, new jobs may be created by the newcomers.) [Increased numbers of researchers are needed to study the potential impact and spread of the aquatic nuisance species. There could be new public water systems and industry jobs to keep pipes clean. Fishers will be affected because the type and quality of catch (fish size and health) will be different. Beach cleaners would be needed to get rid of dead fish and boat cleaners will be in great demand to protect boats from aquatic nuisance species (potentially by developing and applying special toxic paints that will prevent quagga mussels in particular from adhering to boat hulls). Recreation facilities will most likely also experience some increased business because of the added water clarity that quagga mussels cause by filtering water, but may also lose some business because of decreased fishing opportunities. Park systems and gardeners must be concerned because aquatic nuisance species will compete with the native vegetation and wildlife.]

ADDITIONAL RESOURCES

Archived Webinar - Climate Change & Invaders: Sources of Uncertainty in Managing the Great Lakes Region
http://changingclimate.osu.edu/webinars/archives/2012-03-20/

Exotic, Invasive, Alien, Nonindigenous or Nuisance Species: No Matter What You Call Them, They're a Growing Problem
http://www.glerl.noaa.gov/pubs/brochures/invasive/ansprimer.pdf

Ballast Water and Aquatic Nuisance Species Introduction to the Great Lakes ***http://www.glerl.noaa.gov/pubs/brochures/ballast.pdf***

Great Lakes Aquatic Nonindigenous Species Information System (GLANSIS) ***http://www.glerl.noaa.gov/res/Programs/glansis/glansis.html***
This website allows students to search for all ANS in this activity. Note that information on Asian carp can be accessed though the watch list and not the main search engine.

Nab the Aquatic Invader interactive student website ***http://www.iisgcp.org/NabInvader/great_lakes.html***

REFERENCES

Exotic, Invasive, Alien, Nonindigenous or Nuisance Species: No Matter What You Call Them, They're a Growing Problem.
http://www.glerl.noaa.gov/pubs/brochures/invasive/ansprimer.pdf

What's wrong with this picture? ***http://www.iisgcp.org/catalog/ed/7way.htm***

Updated from the activity in *GLIMCES* © The Ohio State University, 1995

Student Activity: What do scientists know about aquatic nuisance species of the Great Lakes and effects that climate change will have on them?

Your task is to become an expert on an aquatic nuisance species (ANS). Completing the questions below will prepare you for your next group task.

PART 1

Before you go any further, place a check mark in the correct box on the LEFT to show if you agree or disagree with the sentence.

BEFORE READING		STATEMENT	AFTER READING	
Agree	Disagree		Agree	Disagree
		All nonindigenous species are invasive species.		
		An alien species is the same thing as an exotic species.		
		A nonindigenous species is native to an area.		
		All nuisance species are invasive species.		
		All invasive species are nonindigenous.		

Your teacher will provide background information on aquatic nuisance species, or you can access it electronically at the site listed below:
Exotic, Invasive, Alien, Nonindigenous or Nuisance Species: No Matter What You Call Them, They're a Growing Problem
http://www.glerl.noaa.gov/pubs/brochures/invasive/ansprimer.pdf

After reading the fact sheet above, place a check mark in the correct box on the right to show if you agree or disagree with the sentence.

1. For how many statements did you change your check marks? _____ / 5

2. Write your own definition for an aquatic nuisance species:

3. Briefly describe four ways in which aquatic nuisance species might enter the Great Lakes watershed.
   a.

   b.

   c.

   d.

4. Approximately how much money has been spent across the Great Lakes region to control the spread of the sea lamprey, zebra mussels and Asian carp?

PART 2

Your teacher will provide a fact sheet on your assigned ANS, or you can access it electronically at the site listed below:

Great Lakes Aquatic Nonindigenous Species Information System (GLANSIS)
http://www.glerl.noaa.gov/res/Programs/glansis/glansis.html

Note that information on Asian carp can be accessed though the watch list and not the main search engine.

1. What is the ANS's scientific name?

2. Circle any words that describe how the ANS might be classified.

   vertebrate invertebrate plant animal crustacean mollusk fish

3. Write a brief physical description of the ANS.

4. Where was the ANS originally found? What is its native range?

5. How was the ANS introduced into the Great Lakes?

6. In which Great Lakes is the ANS currently found? (circle)

   Erie Huron Michigan Ontario Superior

7. How is the ANS currently impacting the Great Lakes ecosystem? What specific organisms is it affecting?

8. How might warmer water temperatures in the Great Lakes affect this ANS?

9. How might lower water levels in the Great Lakes affect this ANS?


INVADER #2
Sea Lamprey (Petromyzon marinus)


INVADER #4
Asian Carp

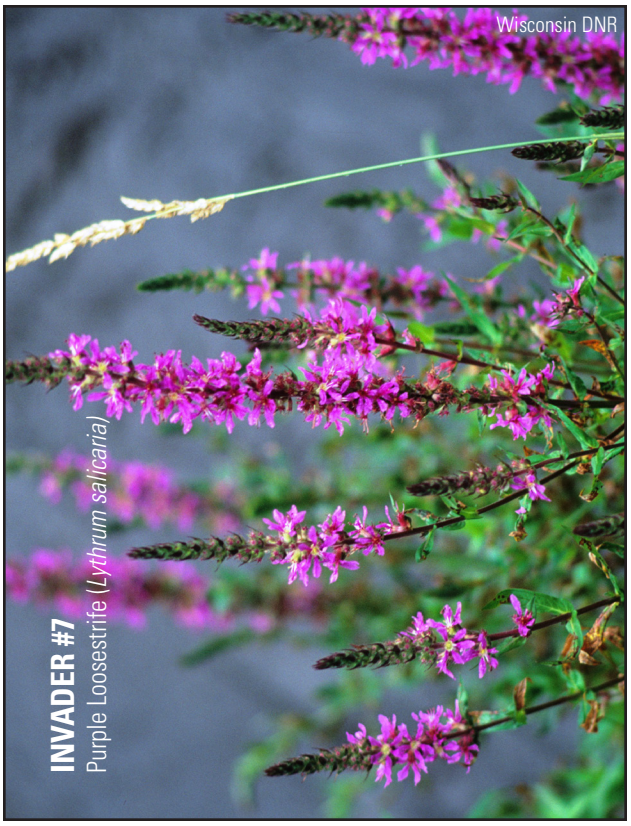

Wendy S. Smith
INVADER #1
Quagga Mussel (Dreissena bugensis)


Pennsylvania Sea Grant
INVADER #3
Round Goby (Neogobius melanostomus)


INVADER #6
White Perch (Monrone americana)


Chesapeake Bay Program
INVADER #8
Eurasian Water Milfoil (Myriophyllum spicatum)


INVADER #5
Alewife (Alosa pseudoharengus)
Brian Zimmerman


Wisconsin DNR
INVADER #7
Purple Loosestrife (Lythrum salicaria)

INTRODUCTION

Originally, it came from the Caspian Sea region of eastern Europe and western Asia. Canals built during the early 1800s allowed it to spread throughout Europe. First introduction into the Great Lakes was about 1989, when one or more transoceanic ships discharged ballast water into Lake St. Clair. Freshwater ballast from a European port likely contained larvae and possible yearlings. Being a temperate, freshwater species, it found the plankton-rich Lake St. Clair and Lake Erie to its liking.

B

INTRODUCTION

Originally it came from the Atlantic Ocean, the St. Lawrence and Hudson Rivers, and their tributaries for spawning. It swam from Lake Ontario into Lake Erie through the Erie and Welland Canals, gaining entry into the upper Great Lakes by attaching to boat hulls.

H

INTRODUCTION

A native of northern Europe, it made its way into the Great Lakes watershed in 1990. It is believed to have been brought over in fresh water or mud in ballast water of European freighters from eastern Baltic ports. They are currently spreading inland via rivers and canals.

C

INTRODUCTION

This ANS actually consists of a number of species, collectively known by a common name. It was introduced to the United States for aquaculture and fish farming, but is thought to have escaped farm ponds and entered the Mississippi River system and its tributaries as early as the 1970s. This group is currently considered on the cusp of invading the Great Lakes, as they have been found in shipping channels connecting Lake Michigan to the Mississippi River watershed.

A

INTRODUCTION

Coming from the salty Atlantic Coast, this species migrated through water routes, including canals in New York State and the St. Lawrence River. It swam into the upper Great Lakes through the Welland and/or Erie barge canal before 1931.

G

INTRODUCTION

From saltwater areas of the Atlantic coast, this invader moved up the Hudson River and via various canal systems into Lake Ontario and Lake Erie. Because of intentional stocking, it can now be found in all five Great Lakes.

D

INTRODUCTION

This species was intentionally imported from northern Europe over 100 years ago, because its hardiness and beautiful flowers were popular with landscapers, florists, and gardeners.

F

INTRODUCTION

It came from Europe, Asia, and North Africa and was introduced into North America as an aquarium plant. It also spreads when it gets entwined on boats, fishing equipment or waterfowl. It is now found in 37 states and 3 Canadian provinces.

E

ECOSYSTEM IMPACT

Like its better-known cousin, it filters plankton from the water; this allows sunlight to reach greater depths resulting in an overgrowth of aquatic plants. It accumulates on objects such as boat hulls and underwater pipes, clogging valves of both industrial and municipal water intake sources.

U

ECOSYSTEM IMPACT

It destroys valuable fish, especially lake trout, by attaching with its sucker-like mouth to suck out blood and body tissues. It upsets the ecological balance by removing top predators, allowing for explosion of populations of smaller fish such as alewives. It had great economic impact on the commercial fishing industry of the Great Lakes during the 1950s. Current control measures are able to keep populations in check, but the ANS still impacts fish species in the Great Lakes today.

W

ECOSYSTEM IMPACT

This aquatic nuisance species spawns from April to September, longer than many other fish, and producing a large number of offspring quickly. Males ferociously defend the nests, reducing the reproductive success of native species by denying them access to spawning habitat. This fish feeds on the eggs and young of native species, including many important sport fish like yellow perch, damaging an important industry for many Great Lakes states.

The species has also become a primary food source for the previously endangered Lake Erie Watersnake, demonstrating that some invasive species can have a beneficial impact on some areas while acting as a damaging influence in others.

S

ECOSYSTEM IMPACT

This species loves to eat plankton, mussels and snails, and can consume 5-20% of its body weight each day, easily outcompeting native species in the search for food. The fish is also less popular for recreational and sport fishing than the native species it would replace, potentially damaging a Great Lakes fishing industry valued at $7 billion per year.

Z

ECOSYSTEM IMPACT

Feeding primarily on zooplankton, this vertebrate competes for food with juveniles of almost all fish species. Large numbers die off in spring and summer because of electrolyte imbalance from living in fresh water. These die-offs clog municipal and industrial intake pipes and foul beaches. In 1967 bulldozers had to remove 50,000 tons of the rotting fish from the southern shores of Lake Michigan.

Y

ECOSYSTEM IMPACT

This aquatic nuisance species is suspected to be partially responsible for the decline of Lake Erie's yellow perch because of competition for food resources. It is also detrimental to walleye and white bass population because these species' eggs can be a primary food source.

V

ECOSYSTEM IMPACT

It is called "the beautiful killer" because its dense roots choke waterways as it competes with other vegetation. It spreads quickly, crowding out valuable plants that provide food for migrating waterfowl, and destroys habitat for almost all other forms of wetland life.

X

ECOSYSTEM IMPACT

It forms thick mats on the water's surface that choke out native aquatic vegetation. The mats alter the nutrient composition and flow of water, which in turn affects the amount of oxygen available to fish. It also disrupts all forms of water recreation—boating, swimming and fishing—because plants get caught in boat rotors, and swimmers and anglers are blocked from access to the water.

T

EFFECT OF GLOBAL CLIMATE CHANGE

It is very likely that this bivalve will be a permanent part of the Great Lakes environment. It prefers waters with a temperature between 4°C and 20°C, but tolerates temperatures up to 30°C. As global warming increases the temperature of the Great Lakes, it will spread farther north into warmer waters. Because it can grow on both hard and soft substrates, this ANS is likely spread deeper into the lakes as well, tolerating depths of up to 130 meters as well as the lower oxygen conditions present there.

d

EFFECT OF GLOBAL CLIMATE CHANGE

Warmer stream temperatures create a more favorable environment for this parasitic organism, enabling it to spawn successfully at more locations throughout the Great Lakes basin. This could result in a new increase in population that may further upset the ecological balance of the Great Lakes. Their favored prey are cold-water fish, such as lake trout, salmon and rainbow trout, that may migrate to regions where temperatures remain cold—both greater depths and more northern lakes.

h

EFFECT OF GLOBAL CLIMATE CHANGE

Increased summer water temperatures are likely to allow this species to spread farther north into the Great Lakes, and could even help the population grow more quickly. However, the lower oxygen concentrations found in warmer water could limit the fish's habitat, potentially shifting its range northward instead of spreading out over a wider area.

e

EFFECT OF GLOBAL CLIMATE CHANGE

Because climate change is expected to increase precipitation and severe weather in the Great Lakes region, additional and higher flooding is likely to allow this aquatic nuisance species to cross barriers into the Great Lakes. As higher water temperatures are predicted to decrease available plankton, competition for food will increase, putting native fish at a disadvantage because the species effectively strips the aquatic environment of food sources.

b

EFFECT OF GLOBAL CLIMATE CHANGE

These herring-like fish need deep water with moderate temperature to overwinter. A rise in water temperature would probably result in fewer die-offs and would enable the fish to be more abundant in Lake Superior, where they currently are scarce. This would certainly alter local fisheries, but the specific impacts are not yet clear.

f

EFFECT OF GLOBAL CLIMATE CHANGE

As waters warm, walleye and yellow perch may seek cooler waters in the deeper areas of the Great Lakes, leaving the shallower areas to this competing fish. Without the competition of the other species, this ANS will be able to reproduce into an even larger population, competing with still more species.

c

EFFECT OF GLOBAL CLIMATE CHANGE

As water levels decrease, this aquatic nuisance species will find new wetlands in which to spread, choking out more and more vegetation as it follows the receding waterline.

g

EFFECT OF GLOBAL CLIMATE CHANGE

This plant thrives as waters warm each summer, increasing in volume in relation to the increased water temperature. If this is any indication of its temperature requirements, as waters in the Great Lakes region warm, this species will thrive in the new climate, spreading rapidly to become an even bigger problem.

a