Atlantic salmon (Salmo salar)

Background:

Historically, Atlantic salmon were plentiful in the Northeast U.S. However, they are currently at 1-5% of those historical estimates and consequently are listed under the Endangered Species Act (ESA). This act was put in place in 1973 and mandates conservation measures for species that are in danger of extinction throughout part or all of their range and conservation measures for the ecosystem they depend on.

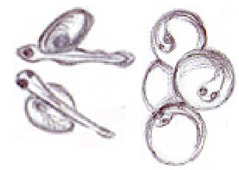
As anadromous fish, Atlantic salmon face many challenges during their initial hatching and two years in freshwater nursery rivers; journey through the estuaries and development of seawater tolerance; and two year feeding migration that covers 4,000 miles of marine habitat before they return to their natal (birth) streams to spawn. Some of the pressures that Atlantic salmon face include fresh water predators, warming water, dams or barriers in the stream, and marine predation. Current data suggests that only 40% of the migrating fish survive the journey to the ocean.

Scientists with the Northeast Salmon Team (NEST) are part of NOAA's Northeast Fisheries Science Center (NEFSC) and are tasked with gathering as much information as they can on the critically endangered Gulf of Maine Atlantic salmon population. These data on the critical habitat, threats, and optimal conditions required for sustainability and recovery of the species are collected to inform the team making management decisions in the hopes that the population will recover and eventually become self-sustaining.

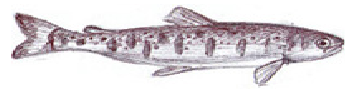
Salmon were once native to almost every river north of the Hudson River. Historic numbers are estimated at 500,000 adults annually returning to spawn in the rivers. Remnant wild populations are now found in only 11 rivers with a few hundred returning annually to spawn. Atlantic salmon have always had to negotiate environmental pressures as they migrate downstream. Seasonal flooding of their rivers as well as drought conditions, predator/prey interactions, storm related runoff into their streams, and warmer years when oceanic conditions may not be ideal.

However, as humans have shaped their environment and the climate has changed, salmon are facing more pressures than ever. These pressures include water quality degradation (e.g. pollution, changes in water flow, loss of shade), over fishing, barriers to migration and spawning, and climate shifts causing changes in water temperature that affect prey abundance. These alterations have led to massive declines in Atlantic salmon stocks as well as extinction in some historic salmon streams.

It is important to understand the salmon life cycle. Atlantic salmon are anadromous, or "sea-run". Fishes are called such because adults return from sea to "run" up their natal river to spawn. Atlantic salmon adults that have returned from sea to spawn do so in flowing stretches in late autumn. Fertilized eggs are buried under 5-8 inches of gravel in redds (an area of disturbed gravel containing one or more nests). Due to the Northeast's cold winters, eggs incubate slowly and do not hatch until March or April. Sac fry, or alevin, remain hidden in redds until they deplete their yolk sac reserves (mid-May).



They emerge as fry and begin feeding on invertebrates, including small aquatic insects. Now at greater risk from predators, fry develop lateral "parr" markings as a form of camouflage and thus enter the parr life stage. Parr typically remain in freshwater riffle areas for a couple years until they undergo a physiological transformation (smoltification) to develop a tolerance for saltwater. As smolts, they migrate from their natal rivers from late April to early June. Smolts reach Newfoundland and Labrador by mid-summer as postsmolts. They spend their first winter at sea south of Greenland, taking advantage of the North Atlantic's productivity and entering adulthood at sea. A small percentage of adults return to spawn after one sea winter; however, the majority of adults spend a second year at sea, feeding in the waters located to the southwest of coastal Greenland and returning to Maine after their second winter to spawn in November. Only a small number of adults return the following year as three sea winter fish to complete their life cycle. Unlike their semelparous counterparts, Pacific salmon that spawn only once and die thereafter, Atlantic salmon are iteroparous (capable of spawning more than once).



The first activity will focus on the perilous journey salmon smolts must take as they travel downstream from their juvenile habitat. NEST collects valuable information about this journey downstream using ultrasonic telemetry. VEMCO ultrasonic telemetry tags or "pingers" (about the size of a pencil eraser) are surgically inserted into the smolt's abdominal cavity. Naturally raised smolts are released shortly after surgery and hatchery raised smolts are released based on previously collected migration data for their river of release. The smolts then make their way down the river toward the ocean. Each salmon smolt pinger has a unique ID that is emitted every 25-40 seconds in a random pattern. Fixed location telemetry receivers moored to concrete blocks at various points along the river record these "pings" when the smolt passes within a detectable range. Data that are recorded with each detection include the unique ID, date and time. Depending on the width of the river at a given site there may be one receiver or an array or line of receivers across the river to ensure each fish is detected. A salmon smolt swims about 2 body lengths per second so each receiver collects 3-5 detections per fish.

This telemetry data provides valuable information about salmon migration and some insight into what influences smolt behavior. We get information on the timing and duration of migrations, the route that is typically traveled and where high levels of morality occur. This information allows us to develop strategies to contribute to salmon conservation and recovery.

In activity one, we focus on the journey the salmon smolts take as they migrate “downstream” to the ocean. We will work with real telemetry data and see the various challenges these fish face on their perilous journey, the information we can get from telemetry data and how we can use that information in salmon conservation. These fish are released below any dams within the system.

In activity two, we focus on the challenge of obstructions such as dams or roads. Not only do the fish have to either swim around the obstacle or through turbines but also artificially created pools in the river can disorient the fish and lead to increased predation as larger fish “lay in wait” for the salmon. A dam may prevent them from getting past and reaching rich spawning areas. Even if they make it past the dam they may have expended critical energy on bypassing the obstruction and be less “fit” to traverse the rest of the river. Additionally, a dam can impact water quality and stream flow. This activity focuses on the issues with dams and the current solutions being utilized.

Printed materials for this lesson can be found on this website. They will be *italicized* to indicate the label used on the website.

This lesson relates to the following Next Generation Standards:

5th and MS - ESS3 - Earth and Human Activity

Students will learn how human actions have affected salmon habitat and how individuals and communities have responded to the problem to protect salmon and their habitat. They will design a method for monitoring and minimizing a dam’s impact on salmon migration.

5th and MS - ETS1 – Engineering Design

The students will define the problem caused by dams in the river ways, define criteria for a successful bypass, try out multiple solutions as a group and as a class, and then evaluate the effectiveness of each design.

MS-LS1 – From Molecules to Organisms: Structures and Processes

Use empirical evidence to show how salmon behavior impacts the probability of successful reproduction.

MS- LS2 – Ecosystems: Interactions, Energy and Dynamics

Construct an argument supported by empirical evidence that changes to the physical and biological components of the riverine ecosystem have affected Atlantic salmon populations.

Lesson:

Objectives:

- Describe how Atlantic salmon migrate as part of their life cycle
- Describe some of the limiting factors on the salmon smolt's ability to migrate downstream to the ocean and the limiting factors on the salmon's ability to migrate upstream to spawn
- Describe human impacts on salmon populations and habitat

Concepts:

- Most Atlantic salmon migrate from their natal stream to the ocean, feed in the ocean for 1-2 years, and then return to their river of origin to migrate up and spawn.
- As smolts migrate down the river they face predation, unsuitable water temperatures, and lack of food.
- Adult Atlantic salmon must navigate barriers such as dams and roadways as they head "upstream" to spawn

Activity 1

SALMON TELEMETRY ACTIVITY – Follow that fish

Materials:

- 30 laminated river maps with telemetry stations
- 30 salmon worksheets
- 30 laminated salmon data sheets – each sheet has unique data for one salmon
- 30 salmon survival cards
- Salmon survival answer key
- 30 rulers- supplied by the classroom
- 30 dry erase markers
- 30 pencils –supplied by the classroom

*Teaching tip – try to limit your introduction to 5-10 minutes and then get materials in the students hands. Ask the students questions about what you want to cover, generate answers, and then show them the slide with the information.

1. Introduce yourself as a representative of NOAA, PSB, and NEST. Show students (**slide 1**) where we are located in Woods Hole and Orono.
2. **Slide 2 –** Today we are going to talk about Atlantic salmon. Ask the students: What do you know about Atlantic salmon? Make a list of what they say on the board. Things to make sure you or they mention:
    a. They are anadromous fish – they are born in fresh water, must travel to salt water and their bodies must change so they can survive in salt water, feed in the ocean, and then return to the freshwater to spawn. Feel free to share any interesting salmon information/facts you think the students would find interesting.
3. **Slide 3** – Why do you think we study Atlantic salmon and their ecosystem?
    a. These fish are endangered (ask what that means and define it).
    b. What dangers do the salmon population currently face (ask and list)? We know there are not many of these fish left and they have a long journey down the river from where they spawn to the ocean. They also face many dangers in the ocean before they return to their natal river.
    c. How can we study and address the dangers Atlantic salmon face? We look at what is causing mortality, what cumulative impacts dams have and use telemetry, marking, trapping, and models to gather data to aid in policy decisions. Our group (Northeast Salmon Team – NEST) is working on bringing salmon back to a healthy, sustainable population.
4. **Slide 4-** What is telemetry? Explain what a telemetry tag is in your own words, show how we insert them using the model salmon smolt and telemetry transmitter, and then use the telemetry receiver to demonstrate how they are distributed in the water. Make sure you pass all the materials around so that the students can hold each item.
   *********You may continue with this activity or do the alternate spinner activity. Skip to alternate activity 1 if you are doing the spinner activity. The spinner might be easier for 6th graders early in the year (they are closer to 5th graders).**
5. **Slide 5** – Today you will be assigned an Atlantic salmon to follow down the river. Your job is to plot their course, look for any anomalies in their track (and try to explain those behaviors), and figure out if your fish made it to the ocean or if not, what happened to them. We will be comparing our results as a class. Each student gets their own map to plot their data on and a worksheet so that they can discuss their fish's behavior and path. Hand out the maps, worksheets, data sheets and dry erase markers. Each student should pull out a pencil and ruler.
   **Material distribution tips:
    a. When handing out data sheets make sure you use the answer key so that you hand out the proper sheets to give the class a ratio of 40% survival and 60% mortality.

   b. One way to save time and get the students moving is to place the materials in piles around the room. For example, maps in the corner, dry erase markers on the table, worksheets in the front, etc. Leave slide 5 up and have everyone get their materials.
   c. Another strategy is to use student helpers to pass out all your materials
6. Ask the students to guess what percentage of the salmon will survive and make it to the ocean. Write down several guesses on the board.
7. **Slides 6-9** – Demonstrate how to plot their data.
   a. Explain that the latitude and longitude data we are using today is expressed in UTM rather than degrees. UTMN is north and UTME is east. **Slide 6**
   b. Everyone has the same data point for their salmon release. As a class look at the first point and plot it on the map. Use **Slides 7-9** to walk through the explanation.
   c. **If you are adapting this lesson for younger children you can use the grid system on the map rather than having them plot UTM data. You can convert the data points into their corresponding A-Q and 1-12 grid location.
8. Give the students about 25-30 minutes to plot their data and fill out their worksheet.
   a. **If you would like access to the raw data which may include additional points, please contact one of the NOEPS staff**
9. If the students do not look like they will finish plotting their data in the time allotted have them skip to the last 3 data points and plot them so that they get see if their salmon survived the journey to the ocean.

****Discussion – Refer to the worksheet**

10. How many students had fish reach the ocean (raise your hand)? How many did not?
    a. Calculate the percentage that made it and tell them that in the real world only about 40% of the fish make it to the ocean. Of that 40%, how many do you think make it back to the river from the ocean? How did the percentage match up to their earlier guesses? Remind them of the dangers faced in the ocean and the dangers faced when the fish go back upstream.
    b. If your fish did not make it – What do you think happened? **(Question 1 on the worksheet)**
11. Did your fish go straight down the river? (**Question 3 on the worksheet)** If not, what did they do and why do you think they did that?
    a. Someone should have a fish that made a reversal
    b. Someone should have had a fish that spent some time in an array (row of receivers)
12. What important information were we able to gain from our telemetry data? (example answers might include: the route the fish follow, how many fish made it to the ocean, when the fish

migrate and how long it takes them to get down the river) and how can we use these data to promote recovery and sustainability? **(Question 5 on the worksheet) Slides 10-14**

   a. Timing of the migration is important when deciding when to build structures on the river such as piers. You may limit permits to non migration timeframes. **Slide 10**
   b. Duration of the migration is key to understanding predation pressures. If salmon are migrating at the same time as other fish species then there are larger numbers of fish for predators to prey on. For example, say a cormorant eats 10 fish. If there are 1,000 fish of various species migrating at the time that is very different than a cormorant eating 10 fish out of 100 salmon migrating by. **Slide 11**
   c. The route taken helps us understand where to build underwater structures. If salmon typically migrate down the east side of an island then you may want to place your underwater turbine on the west side. **Slide 12**
   d. If there is a location with high salmon mortality then research can be focused on that spot to investigate the causes. **Slide 13**
   e. **Slide 14 –** summary.

13. Have the students clean off their map with a paper towel and return all their materials (they keep their worksheet).
14. Give each student a salmon survival card. This either congratulates them on surviving and reaching the ocean or gives the reasons they may not have made it. They can read the appropriate side.

Activity 1 Alternate Activity

Materials:

- 8 laminated spinner river maps with telemetry stations
- 30 salmon worksheets
- 30 goldfish
- 8 spinners
- 30 salmon survival cards
- 8 laminated Atlantic salmon migration game instruction sheets
- 30 pencils –supplied by the classroom

5. **(Skip Slides 5-9)** – Today you will be an Atlantic salmon traveling down the river. Your goal is to make it down the river and out to the ocean safely. We will be comparing our results as a class. Each student will get 4-5 goldfish to play with. The migration game sheet tells you what to do when you spin a certain number. If you reach a red station you MUST STOP and spin to see if you get eaten. If you do not get eaten you get to spin on your next turn and move on. You only stop at each red station once. If a student gets eaten right away encourage them to play again

and see what happens. They should keep track of how many times they died/made it for the class results.

6. Hand out the maps, worksheets, goldfish, spinners, and migration game instruction sheets. Each student should pull out a pencil.
    a. **Material distribution tips:
    b. One way to save time and get the students moving is to place the materials in piles around the room. For example, maps in the corner, dry erase markers on the table, worksheets in the front, etc. Leave slide 5 up and have everyone get their materials.
    c. Another strategy is to use student helpers to pass out all your materials
7. Give the students about 15-20 minutes to play and fill out their worksheet.

****Discussion – Refer to the worksheet**

8. How many students had fish reach the ocean (raise your hand)? How many did not?
    a. Calculate the percentage that made it and tell them that in the real world only about 40% of the fish make it to the ocean. Of that 40%, how many do you think make it back to the river from the ocean? How did the percentage match up to their earlier guesses? Remind them of the dangers faced in the ocean and the dangers faced when the fish go back upstream.
    b. If your fish did not make it – What do you think happened? **(Question 1 on the worksheet)**
9. What important information were we able to gain from our telemetry data? (example answers might include: the route the fish follow, how many fish made it to the ocean, when the fish migrate and how long it takes them to get down the river) and how can we use these data to promote recovery and sustainability? **(Question 5 on the worksheet) Slides 10-14**
    a. Timing of the migration is important when deciding when to build structures on the river such as piers. You may limit permits to non migration timeframes. **Slide 10**
    b. Duration of the migration is key to understanding predation pressures. If salmon are migrating at the same time as other fish species then there are larger numbers of fish for predators to prey on. For example, say a cormorant eats 10 fish. If there are 1,000 fish of various species migrating at the time that is very different than a cormorant eating 10 fish out of 100 salmon migrating by. **Slide 11**
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    d. If there is a location with high salmon mortality then research can be focused on that spot to investigate the causes. **Slide 13**
    e. **Slide 14 –** summary.

10. Have the students return all their materials (they keep their worksheet).
11. Give each student a salmon survival card. This either congratulates them on surviving and reaching the ocean or gives the reasons they may not have made it. They can read the appropriate side.

Activity 2

DAMS, BYPASSES, AND SALMON, OH MY

Materials:

- 6 building brick base plates with the river and banks built on it
- 6 bags of building bricks including:
  Gray dam pieces
  Blue for water
  Toy truck
  Miscellaneous pieces to represent whatever you can imagine
  At least 3 turbines
- 24 wooden fish - 4 per group
- 30 dam worksheets
- Bag of extra building pieces for the class to pick from

1. Now we are going to discuss barriers in the river and how they affect salmon migration. What barriers are found in the river? **Slide 15** The natural waterfall is to remind students that there have always been natural barriers to migration as well. **Slide 16** shows various dams. (They should come up with dams and culverts)
2. How might dams impact salmon migration? (Make a list on the board before telling them the answers)
   a. It might keep them from getting past either downstream or upstream. This may prevent them from reaching rich spawning areas.
   b. If they get caught in the turbines they may be hurt or killed
   c. Above dams, a lake like area may form and predators may lay in wait for them
   d. They may use a lot of energy trying to bypass the dam and then be less able to traverse the rest of the river
   e. Dams can impact water quality and stream flow
3. Your challenge is to build a dam that includes 3 turbines (their dam is generating hydroelectric power by blocking the water and then allowing the blocked water to turn the turbines) and has a safe way for salmon to travel both down and up the river. **Slide 17**
   a. Each person should be able to explain your bypass solutions.
   b. As you build your dam the water piles up behind it. Don't forget to fill in the water.
4. Divide the class up into groups of 4-5 depending on your class size. Each group gets a bag of building pieces, fish, a worksheet for each person, and a platform with the river and bank on it.

   a. **Hints – Some groups may need help getting started. Walk around and give them a little help getting their first blocks in place if needed.
   b. Make sure all the group members are engaged.
   c. It may help to have a gender mix in each group. Have the teacher help you pick groups as they know their students best.
5. Tell the students to take at least 5 minutes to design and plan before starting to build. The design portion is just as important as the actual building.
6. Give the students about 20-25 minutes to design/build their dam and fill out their worksheet.
7. When everyone is done have each group divide in half. Half the students should stay with their dam and explain their structure and bypasses. The other half should walk around the room and find out their classmate's solutions.
8. After a few switch groups so that those students who were explaining their dams are now walking around.

Discussion:

1. What solutions did you see?
   a. Tell us about one solution you saw at ANOTHER group's dam. Share some of the solutions you saw to supplement what the students say (if needed).
   b. Were there different solutions for salmon traveling upstream vs downstream? **(Question 2 on the worksheet)**
2. What solutions have been utilized in real life? **Slide 18**
   a. The fish lift is like an elevator for fish.
   b. Fishways – Manmade passage for fish to get past the dam
   c. Howland Dam bypass - example of a fishway that is designed to mimic a natural stream. There is a before and after picture. This bypass is being evaluated for effectiveness and in the middle of a 3 year study (as of 2017).
3. What innovative ideas exist? **Slide 19**
   a. Salmon Cannon – A hydraulic tube used to move salmon over a dam. You must catch the salmon and then safely send them through the tube. You can click on the image to see a video of this process. Stress that we are not endorsing this product but wanted to show one innovative technique that is being evaluated for efficacy.
   b. Truck Transport – You must catch the salmon and then drive them around the dam
4. How do these engineering changes help us with salmon conservation? **(Question 5 on the worksheet)**

Conclusion:

1. The type of science we did today is an example of what NEST does to promote salmon recovery. I like to highlight one of our scientists that does the same research you did today.

Our scientist in the spotlight is Jim Hawkes. **Slide 20** He is on our telemetry team and works with the same data you worked with today. **Encourage the students to think about careers in marine science.

2. What can you do? (Ask them before you show them **Slide 21**)
    a. In ME you can go out to the river and see the salmon migrating. Some classrooms raise salmon for release. Do your part to keep the rivers clean by organizing a clean up or making sure you are not contributing to the litter problem. Spread the word to your parents and friends that these fish live in our rivers.
    b. In MA you can familiarize yourself with our local fish species. Do your part to keep the rivers clean and help care for the fish in Buzzards Bay. A healthy ecosystem relies on all the species. Spread the word to your parents and friends that we used to have these fish in MA streams and now we only have them in ME rivers. Humans have a far reaching impact on the ecosystem.
3. Hand out a salmon sticker sheet to each student and encourage them to spread the word. Tell the adults they live with what they learned today. They can also visit the NOEPS website listed on the sticker sheet to find more information about our salmon research.