January

Atlantic salmon natural history

During the month of January, ***The Salmon Times*** takes an indepth look at the natural history of Atlantic salmon. A brief discussion of the anatomy and physiology common to most fish will provide the foundation for a deeper understanding of the **life cycles** of **anadromous** fish.

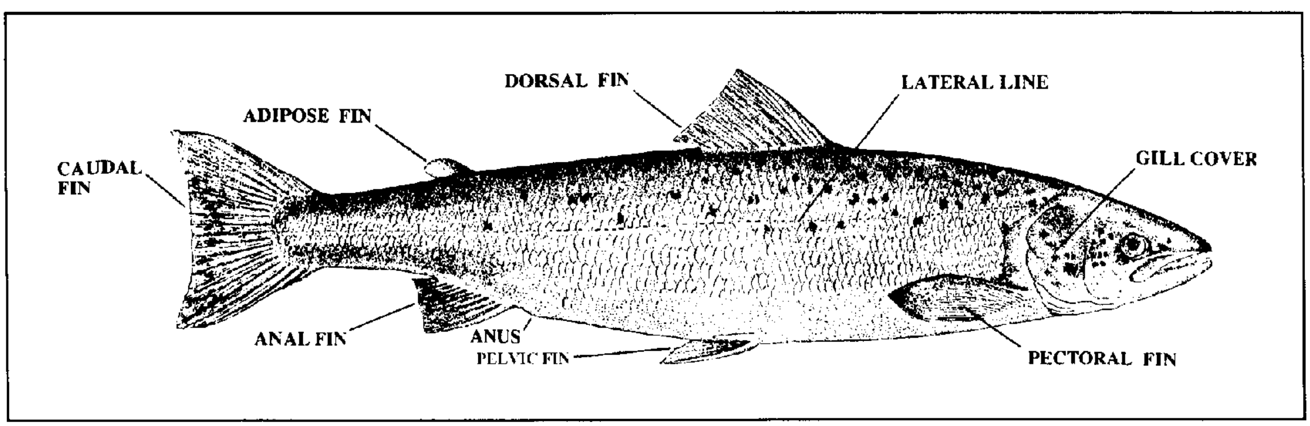
Fish Anatomy Basics

Students are likely to gain more from their exploration of the world of Atlantic salmon if they have a basic understanding of the anatomy and physiology of fish. The obvious difference between fish and land-based animals is the way in which they "breathe." Fish obtain oxygen from the water using **gills**. As water passes through the gills, oxygen molecules in the water diffuse across the **gill membrane** and enter the bloodstream. Carbon dioxide, a metabolic waste product, is expelled from the the fish's body through the gills.

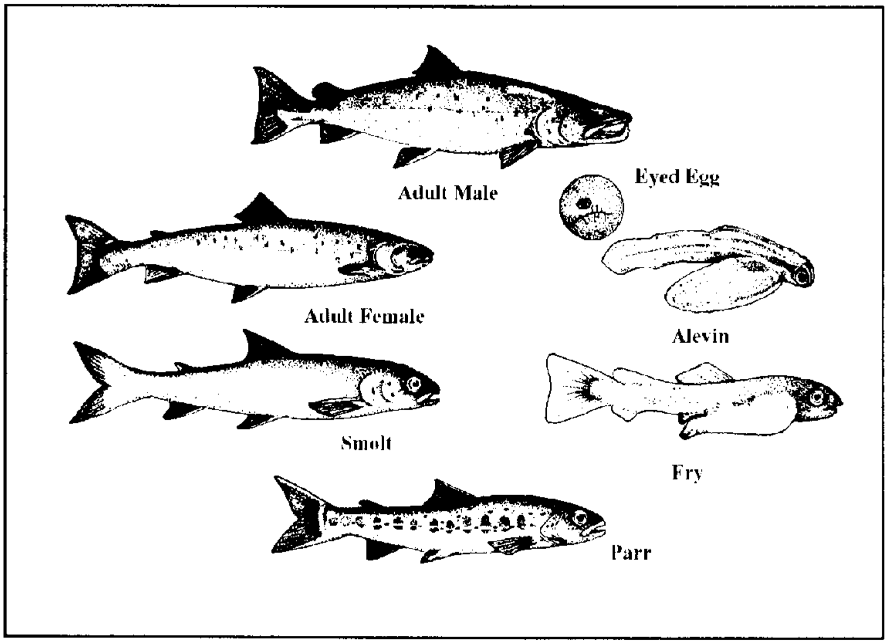
Fins are an important feature of fish anatomy. They come in different shapes and sizes and perform a variety of functions. The **tail fin** propels the fish through the water. The **dorsal fin** provides balance, allowing the fish to maintain an upright position in the water. The remaining fins are used much like the rudder on a boat, allowing the fish to "steer" or change direction.

Like most animals, fish have skin. Many, including the Atlantic salmon, have an additional outer covering of scales. **Scales** protect the fish, much like a suit of armor. Fish also have a protective film of mucous called a **slime coat**. The slime coat protects fish from some harmful, disease-causing organisms and reduces drag as they swim through the water.

Students often wonder how well a fish sees, smells, and hears? In fact, many of these senses are highly developed in fish. The fact that many biologists believe Atlantic salmon possess the ability to navigate in the ocean by following the stars is a strong indication of their keen eyesight. Likewise, the salmon's ability to sense the particular odor of their native stream while swimming upriver testifies to their acute sense of smell. A series



of cells arranged in a linear pattern along both sides of fish, called the **lateral line**, allow fish to sense vibrations in the water — including those caused by predators and prey. The lateral line is somewhat analogous to hearing.



Another unique feature of many fish is the **air bladder**. This "bag of air" changes the **buoyancy** of fish, enabling them to maintain a certain position in the vertical plane of a water column. The air bladder reduces the energy that fish must expend in moving their fins to maintain a certain position in the water. Fish can adjust the volume of air in the bladder.

Natural History of Atlantic Salmon *(Salmo salar)*

Having an anadromous life cycle, salmon are born in a cold freshwater stream and later **migrate** to the ocean where they mature. The life cycle is completed when the adult fish return to the streams of their birth to **spawn** and reproduce.

Adult salmon return to New England rivers to spawn from May through October. Swimming upriver, they locate their natal streams by smell. The specific stream odor they follow was **imprinted** when the juvenile salmon migrated downsteam to the sea. They do not feed after leaving the ocean and will not feed again until they return to salt water.

In October or November female salmon prepare a depression in the gravel of a stream using their tail fin. This depression or "nest" is called a **redd**. Hovering over the redd, the female salmon releases thousands of pea-sized eggs, up to 800 per pound of body weight. As the eggs settle to the bottom, the male fish releases a cloud of sperm, or **milt**, to fertilize the eggs. After spawning is complete, the female again uses her tail fin to sweep the gravel over the top of the eggs. In some redds, salmon eggs can be buried under up to 12 inches of gravel.

Post-spawn adult salmon are referred to as **kelts**. Following spawning, some salmon return immediately to the ocean. Others over-winter in the river, returning to sea the following spring. Atlantic salmon are not genetically programmed to die after spawning like the Pacific species, however, many do die as a result of the physical stresses related to the spawning migration. Some salmon spawn multiple times during a life in the wild that may span seven or eight years.

Salmon eggs hatch from late March to early April. The exact date is largely dependant on stream temperature. Newly hatched salmon are referred to as **alevin**. They somewhat resemble tadpoles because of the pendulous **yolk sacs** protruding from their underside. Alevin remain within the protective cover of the redd for several weeks, subsisting on the food supply provided by the yolk sac.

When the yolk sacs are nearly depleted, the young salmon emerge from the redd as **fry** and begin the rigors of survival in a stream ecosystem. After several weeks a series of dark vertical bands, called **parr marks**, begin to appear along the sides of the growing fish. Salmon remain in the **parr** stage until the time arrives to migrate to the ocean.

Juvenile salmon migrate to salt water in the spring after one to three years in their natal streams. Before doing so, their bodies undergo a transformation called **smoltification**. This prepares them to make the transition from fresh to salt water. Now called **smolts,** the young fish turn a bright silvery color - protective camouflage that will serve them well in the marine environment.

Upon entering the ocean, smolts begin a northerly journey that may cover 2000 miles. How do they find their way? Research has shown that salmon have the ability to find their way by following the stars and the earth's magnetic field. To what degree and in what combination Atlantic salmon employ these navigational abilities is still a mystery.

Spending the warmer months in the coastal waters of Newfoundland, Labrador, and western Greenland, salmon head for deeper ocean waters as winter approaches. The marine environment is nutrient-rich. A rapidly maturing juvenile may gain 10 to 20 pounds before returning to its native river as an adult in one to three years. Upon return to the river of their birth to spawn, the life cycle of the Atlantic salmon comes full circle and begins anew.

Predator-prey Relationships

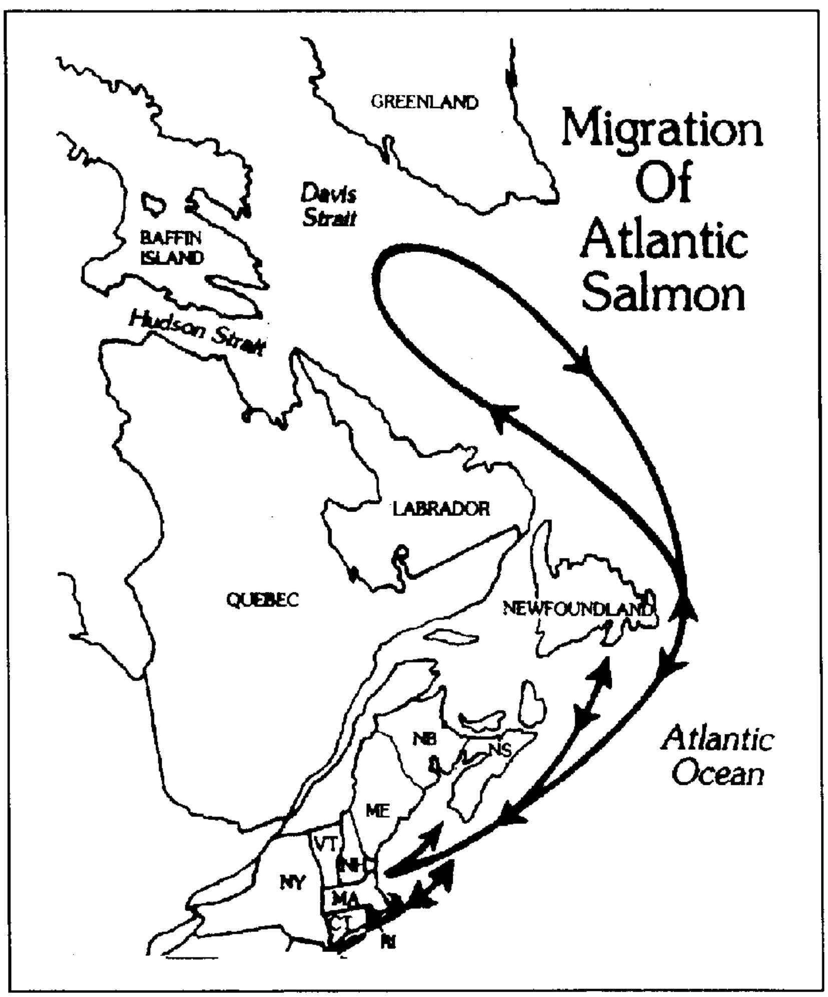
Atlantic salmon eat a diversity of **prey** species at different stages of their life cycle. **Opportunistic feeders,** salmon will eat almost any living aquatic animal they can grasp within their jaws. Newly emerged fry hover near the stream bottom and feed on **zooplankton** carried along on the current. Parr feed primarily on aquatic insects, small crustaceans (crayfish), smaller fish, and terrestrial insects that have the misfortune to fall into the water. In the ocean salmon feed primarily on shrimp, caplin, and herring. It is the shrimp in their diets that give salmon their color.

Salmon are themselves food for many aquatic, terrestrial, and avian **predators.** While in the river, salmon are hunted by larger fish, river otter, heron, and kingfishers. Sharks, cormorants, seals, tuna, ospreys, and sea lamprey are all important ocean predators. Needless to say, fishermen have had a demonstrable impact on Atlantic salmon populations, both historically and present day.

Salmon Decline and Restoration

Atlantic salmon live on both sides of the North Atlantic. Along the North American coast, wild salmon once ranged as far south as the Connecticut River. The onset of the Industrial Revolution in the early 1800s meant the beginning of the end for many wild salmon populations, particularly in central and southern New England. There, three factors caused the salmon's decline: construction of dams, overfishing, and water pollution.

Industrialists constructed dams to harness the power of New England's



rivers to support their burgeoning businesses. These dams prevented migrating salmon from reaching their spawning grounds. As a result, salmon were unable to reproduce and populations declined precipitously.

Since the time of the Native Americans, salmon have been an important part of the New England diet. As often happens, too much of a good thing turns out to be anything but. Overharvesting of Atlantic salmon, both within rivers and on the high seas, was a major factor in their decline.

As industry spread and watersheds swelled with new human inhabitants, rivers increasingly became waste streams. Water pollution got so bad that several of New England's rivers were among the dirtiest in the nation by the 1960s. Needless to say, water pollution is not good for any form of wildlife.

Some farsighted conservationists of the 1800s realized that Atlantic salmon were under serious assault. They began an effort to restore the salmon by constructing fish ladders at dams and rearing salmon in hatcheries. While these efforts proved somewhat successful through the late 1800s, interest in salmon restoration was waning. By 1900 salmon populations were extinct in several of New England's major river systems.

With passage of the **Anadromous Fish Conservation Act** in 1965, the effort to restore Atlantic salmon to New England's rivers was rejoined. Today, cooperative state and federal programs are in place to restore Atlantic salmon to the Connecticut, Merrimack, and Pawcatuck (R.I.) Rivers — as well as to many rivers in the state of Maine, including the Penobscot.

Male or Female?

Determining a salmon's gender during most of the year is, at best, dificult. However, as the spawning season approaches, the male begins to develop a pronounced hook, called a kype, on its lower jaw. The exact purpose of the kype is unclear. After spawning has taken place, the kype, comprised of cartilage, begins to disappear as gradually as it appeared.

At a basic level, today's efforts are remarkably similar to those of a century ago. Salmon continue to be raised in hatcheries. Providing fish passage over dams is a major focus. Research, public education, and law enforcement are important tools in the management arsenal. A management strategy unique to modern times has been the effort to reduce ocean fishing. The Canadian government has passed moratoriums for Atlantic salmon fishing in Labrador and Newfoundland. A buyout of the western Greenland fishery is presently in place.

While Atlantic salmon can certainly be considered a rare fish in many of New England's river systems, they are not protected under the federal **Endangered Species Act**. The U.S. Government is considering protection for several populations of Atlantic salmon found within seven small river systems in Downeast Maine. These fish comprise the only true wild stocks of Atlantic salmon remaining in New England.

Word Power

*aerate
*air bladder
*buoyancy
*chiller
*downstream bypass
*embryo
*fin
*fry
*gills
*lateral line
*magnetic field
*marine mammal
*molecule
*mucous
*osmosis
*parasitic
*parr
*predator
*prey
*propulsion
*redd
*smolt
alevin
dorsal fin
imprint
kelt
migrate
milt
parr mark
scales
smoltification
tail fin
yolk sac
zooplankton

Tale of a Scale

Concepts: Just like counting the rings of a tree, biologists are able to determine a great deal of information about an Atlantic salmon by looking at its scales under a microscope: age, time spent at sea and in the river, and the number of times it has spawned.

Objectives: By examining a scientifically accurate drawing of a salmon scale, students will be able to determine:

1. age of the fish;
2. number of years spent in the river before migrating to the ocean;
3. number of years spent at sea before first spawning migration; and
4. how many times the salmon has spawned.

Materials: student handout with fish scale graphic and instructions

Subjects: biology, math

Preparation and Procedure:

Distribute handouts and allow students enough time to completely label the scale diagram. The teacher may elect to prepare an overhead transparency of the handout as an effective way to review student results.

As an extended activity, students could view fish scales under a microscope and determine the same information that was gleaned from the scale drawing. A videomicroscope is best suited for this purpose. The teacher should check with the Adopt-A-Salmon Family facilitator about acquiring slide mounts of Atlantic salmon scales.

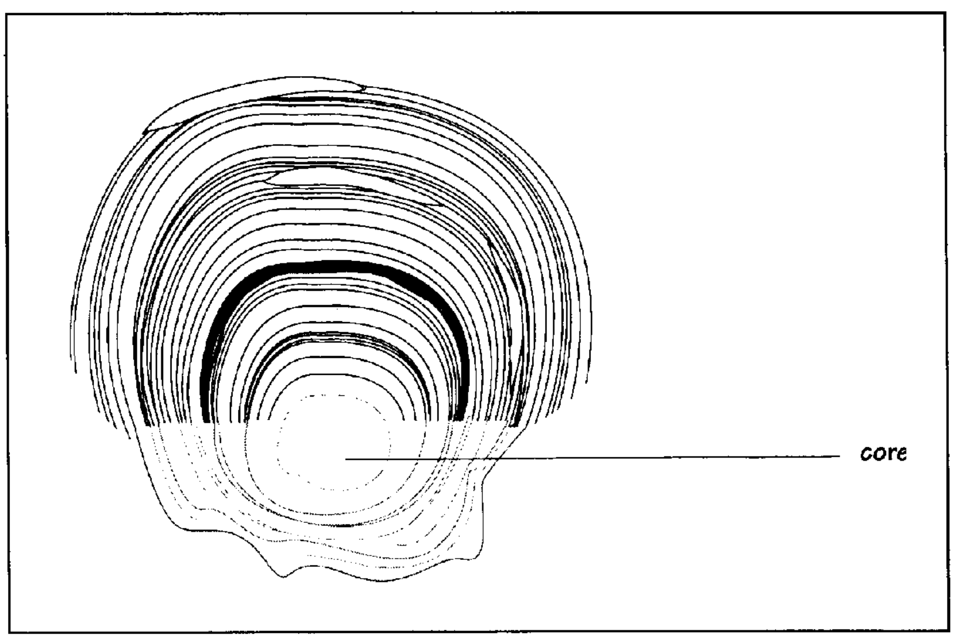
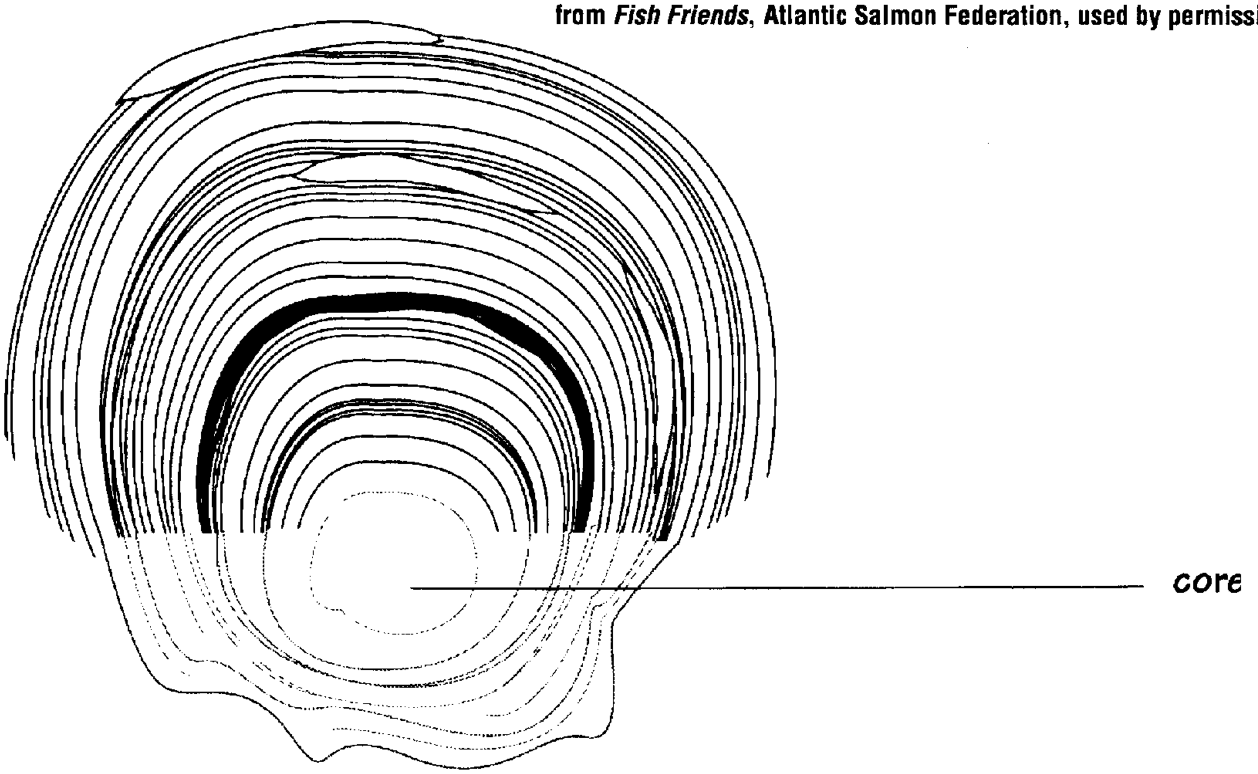


Illustration from *Fish Friends*, Atlantic Salmon Federation

from *Fish Friends*, Atlantic Salmon Federation, used by permission



The scales of a fish are like a book. They tell a story. They tell how old the fish is, where it has lived, and if it has been eating well. As a fish grows, rings form around the center of each scale. You can easily see the rings in this diagram.

Find the **core** or center of the scale (It's not in the middle!). This has been labeled on the diagram. The first rings form when the fish is in its early stages. If the water is warm and there's lots of food, the fish will grow well. The rings will be spaced far apart. This is **summer growth**. Label this section of the scale.

Next are some rings that are very close together. These grow during the fish's first winter. The water is cold and there's little food. The fish doesn't grow very much and the rings are close together. This is **winter growth.** Label this section on the diagram. At this stage, the fish was a year old.

The fish then spends another year in freshwater. Can you find the summer and winter growth rings for the second year? Label these sections **second summer** and **second winter**. Following the second winter, the fish feeds heavily and then starts its journey to sea. At this stage it is called a smolt. It goes through some major changes and the scales show a dark band. Find the **smolt mark** and label it.

The fish then spends its first summer at sea. There is lots of food and it eats and grows well. The growth rings are far apart. Can you find these? Label them **first summer at sea**.

This is followed by a winter at sea when the fish is not eating well and the rings are closer together. Find these rings and label them **first winter at sea**.

The fish then returns to freshwater to spawn. During this time it doesn't feed and the scales develop special marks or scars. They look like blank spots on the scale. Label these **spawning scars**.

The fish spends the winter in freshwater and then returns to sea the next spring. After another summer and winter at sea, it comes back to freshwater to spawn again. Label **second summer at sea, second winter at sea**, and **second spawning scars**.

Hooks and Ladders

Concepts: Students simulate Atlantic salmon and the hazards faced by salmon in an activity portraying the life cycle of these aquatic creatures.

Objectives: Students will be able to:

1. recognize that some fish migrate as part of their life cycle;
2. identify the stages of the life cycle of one kind of fish;
3. describe limiting factors affecting Atlantic salmon survival; and
4. generalize that limiting factors affect all populations of animals.

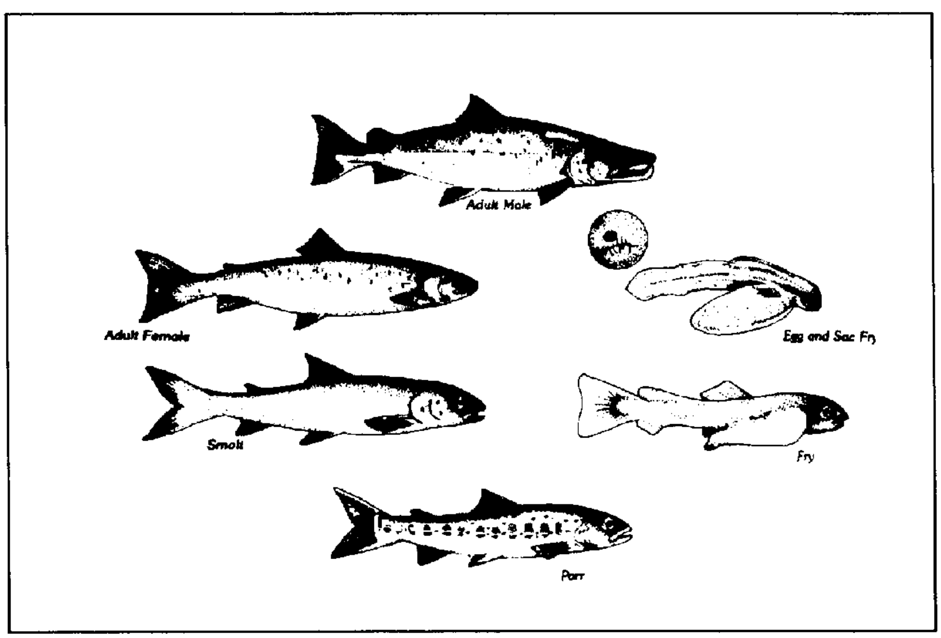
Materials: large playing area (100 feet x 50 feet); about 500 feet of rope or string, chalk, or six traffic cones for marking boundaries (masking tape may be used if area is indoors); two cardboard boxes; 100 tokens (3 x 5 cards, poker chips, etc.).

Subjects: science

Background:

Atlantic salmon are among a unique class of fish, called anadromous, that spend portions of their lives in freshwater and portions in salt water. In the case of salmon, such a life cycle requires a migration from the freshwater streams of their birth to the ocean — and back. It is the duration, distance, and limiting factors inherent in this migration that greatly influence the rate of salmon survival.

The factors influencing salmon mortality are multiple and varied. Predators are a fact of life (and death) for salmon in both freshwater and saltwater habitats. A variety of predacious birds, fish, and mammals (both marine and terrestrial) feed on salmon. Dams bar salmon from reaching spawning beds and flood important habitat. Churning hydroelectric turbines exact a toll during downstream migration. Overharvesting and water pollution are additional limiting factors.



The odds of an adult Atlantic salmon returning to its native river to spawn are a long shot. From approximately 7500 eggs deposited in a redd by a 10-pound salmon hen, about 50 fish can be expected to reach the ocean as smolts, with perhaps only two adults returning to the river to spawn.

The major purpose of this activity is for students to gain an understanding of some of the complex characteristics of the life cycle of the Atlantic salmon. Not all possible conditions are covered by the design of this activity. However, the activity does serve simply and effectively to illustrate three important concepts: life cycle, migration, and limiting factors.

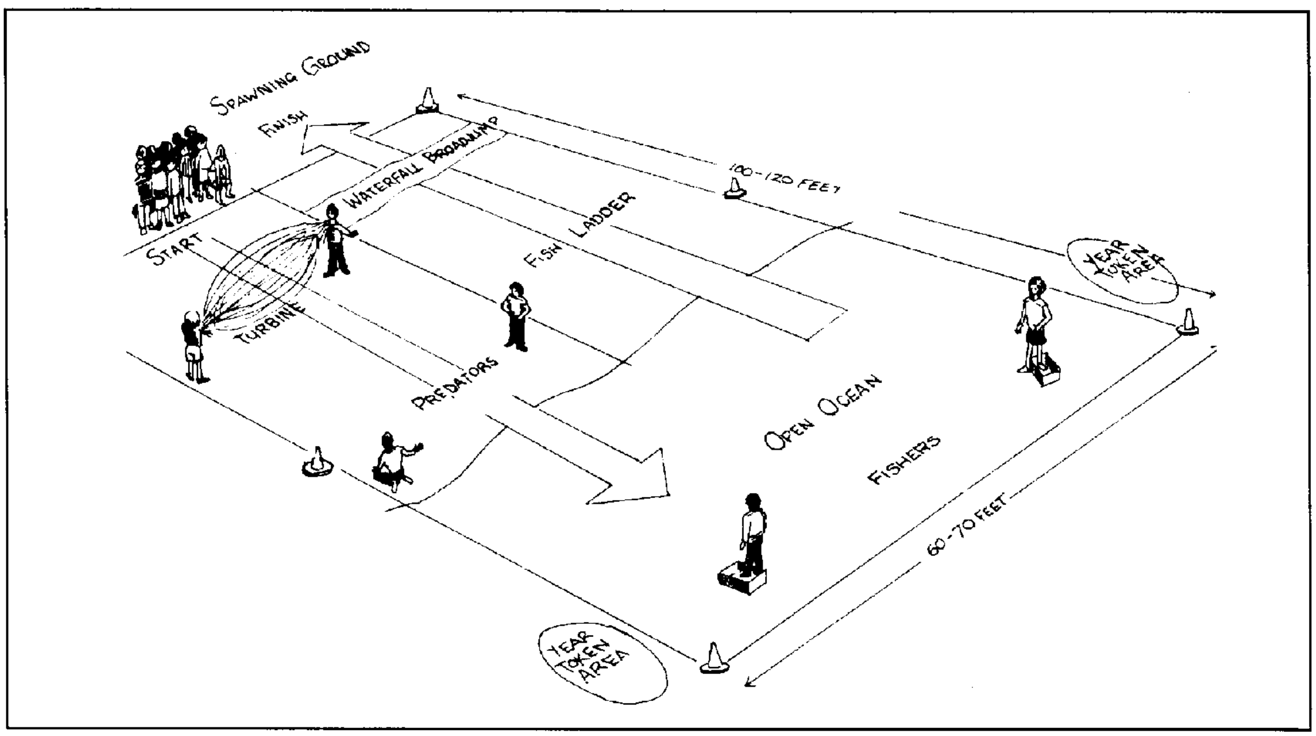
Preparation and Procedure:

1. Begin by asking the students what they know about the life cycle of fish that live in their area. Do any local fish migrate to spawn? If yes, which ones? (shad, lake trout, striped bass, suckers, carp, and salmon are examples of fish that migrate to spawn). In this activity, students will learn about some of the characteristics of one species of fish that migrates as part of its life cycle — the Atlantic salmon.

2. This is a physically involving activity! Set up a playing field as shown in the diagram, including spawning grounds, downstream, upstream, and ocean. The area must be about 100 feet by 50 feet. Assign roles to each of the students. Some will be salmon, others will be potential hazards to the salmon. Assign the students roles as follows:

- Choose two students to be the turbine team. These are the ones who operate the jump rope that represents the turbines in hydroelectric dams. Later in the simulation, when all the salmon have passed the turbine going downstream, these students move to the upstream side to become the waterfall broad jump monitors. (See diagram)
- Choose two students to be predatory wildlife. At the start of the simulation the predators will be below the turbines where they catch salmon headed downstream.
- Choose two students to be humans in fishing boats catching salmon in the open ocean. These students in the fishing boats must keep one foot in a cardboard box to reduce their speed and maneuverability. (**Note:** Teachers should point out that, because of recent ocean fishery buyouts, the commercial harvest of salmon in the North Atlantic has appreciably diminished.)
- All remaining students are salmon.

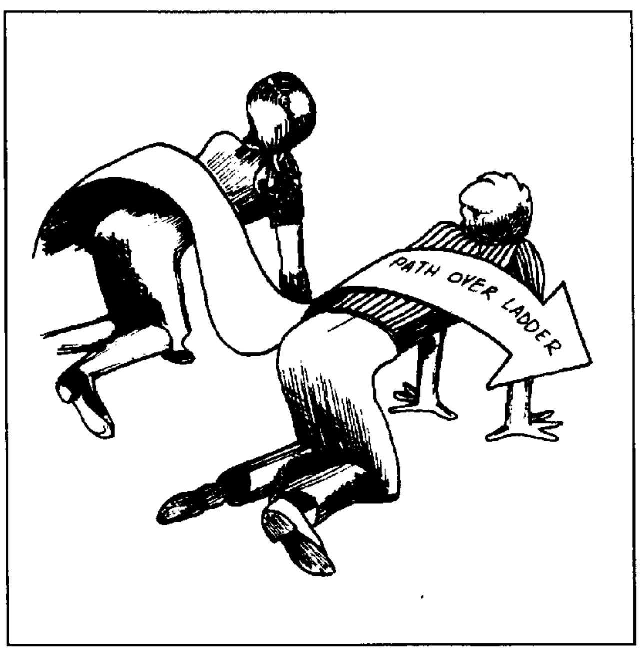
Note: These figures are based on a class size of 25 to 30. If the group is larger or smaller, adjust the number of people who are fishing and acting as predatory wild animals accordingly.



3. Begin the activity with all the salmon in the spawning ground. The salmon then start their journey downstream. The first major hazard is the turbines at the dam. At most dams there are escape weirs to guide migrating salmon past the turbines. The student salmon cannot go around the jump rope swingers, but they can slip under the swingers' arms if they do not get touched while doing so. A salmon dies if it is hit by the turbine (jump rope). The turbine operators may change the speed at which they swing the jump rope. **Note:** Any salmon that "dies" at any time in this activity must immediately become part of the fish ladder. The student is no longer a fish, but becomes part of the physical structure of the human-made ladders now used by migrating salmon to get past barriers such as dams. The students who are the fish ladder kneel on the ground, a body-width space between them (refer to diagram).

4. Once past the turbines, the salmon must get past predatory wildlife. The predators below the turbine must catch with both hands — tagging isn't enough. Dead salmon are escorted by the predator to become part of the fish ladder. **Note:** Later, the salmon who survive life in the open ocean will use the structure of the fish ladder — by passing through it — to return to the spawning ground. **Note:** Both the predatory wildlife in the last downstream area and the people fishing in the open ocean must take dead salmon to the fish ladder site. This gets the predators and fishing boats off the field regularly, helping to provide a more realistic survival ratio.

5. Once in the open ocean, the salmon can be caught by fishing boats. The salmon must move back and forth across the ocean area in order to gather two tokens. Each token represents one year of growth. Once each fish has two tokens (two years growth), that fish can begin migrating upstream. The year tokens can only be picked up one token at a time on each crossing. Remember, the salmon must cross the entire open ocean area to get a token. The "two years" these trips take make the salmon more vulnerable and thus they are more readily caught by the fishing boats. For purposes of this simulation, the impact of this limiting factor creates a more realistic survival ratio in the population before salmon begin their return migration upstream.



6. Once two of the year tokens are gathered, the salmon can begin upstream. The salmon must walk through the entire pattern of the fish ladder. This enforced trip through the fish ladder gives the students a hint of how restricting and tedious the upstream journey can be. In the fish ladder, predators may not harm the salmon.

7. Once through the fish ladder, the salmon faces the broad jump waterfall. The waterfall represents one of the natural barriers the salmon must face going upstream. Be sure the jumping distance is challenging but realistic. The two former turbine students will monitor the jump. The salmon must jump the entire breadth of the waterfall to be able to continue. If the salmon fails to make the jump, then it must return to the bottom of the fish ladder and come through again. NOTE: When playing indoors, the broad jump waterfall may be changed into a stepping stone jump defined by masking tape squares for safety on hard floors.

8. The waterfall is the last limiting factor the salmon faces before reaching the spawning ground. The activity ends when all the salmon are gone before the spawning ground is reached — or when all surviving salmon reach the spawning ground.

9. Next, engage the students in a discussion. Explore topics such as:

- the apparent survival-mortality ratio of salmon
- the students' feelings throughout the activity
- the role of the barriers
- the role of predatory wildlife and the people fishing
- where the losses were the greatest
- where the losses were the least
- what the consequences would be if all the eggs deposited made the journey successfully
- what seemed realistic about this simulation and what did not

10. Ask the students to summarize what they have learned about the life cycle of Atlantic salmon, the salmon's migration, and the limiting factors that affect salmon. Make sure the students have a clear working definition of limiting factors. Encourage the students to make the generalization that all animals — not just Atlantic salmon — are affected by limiting factors. Ask the students to give examples. They might mention the availability of suitable food, water, shelter, and space; disease; weather; predation; and changes in land use as well as other human activities.

Extensions

1. Write a report on the life history of Atlantic salmon. Create a mural showing the life cycle of the salmon.
2. Research and illustrate the life cycle of any local fish. If possible, look for one that migrates.
3. Compare how the life cycle of the Atlantic salmon is similar and different to the life cycle of one or more local fish.
4. Investigate similarities and differences in the migration and life cycles of Atlantic and Pacific salmon. Investigate the life cycle of salmon in the Great Lakes ecosystem.
5. Visit fish hatcheries that work with migratory species and investigate how they function.
6. Explore ways that dams can be modified to let fish safely pass downstream and upstream. Design the "perfect" fish ladder.
7. Find out about laws protecting migratory species, including fish.

Evaluation

1. List, describe, and illustrate the major stages in an Atlantic salmon's life cycle.
2. What are some of the factors that affect salmon as they complete their life cycle?
3. Identify and describe some limiting factors that might affect other animal populations.

Doing it by the Numbers

Concept: Hatchery managers use water temperature calculations to predict when salmon eggs will hatch and alevin will be begin to feed. Students can make similar predictions for their own "salmon family."

Objectives: By tracking incubator water temperature, students will be able to predict approximate dates for the onset of egg hatch and first feeding.

Materials: incubator with salmon eggs, water temperature data for eggs prior to placement in classroom, and daily percent development table (attached)

Subject: Science, Math

Preparation and Procedure:

There is a proven quantitative relationship between water temperature and the rate of Atlantic salmon egg/alevin development. From this relationship a table has been developed that lists the percent development of a salmon egg/alevin in a 24-hour period at different water temperatures, where percent development at time of egg fertilization equals 0% and first feeding equals 100%. By keeping a daily record of the water temperature in the incubator, it is possible to predict **approximate** dates for a number of developmental stages such as "eye-up," hatching, and first feeding. It is the cumulative sum (or running total) of percent development values that allows for specific predictions.

Starting from the day the eggs are fertilized and incubation begins, the water temperature is recorded daily. Weekend water temperatures are "guesstimated." For each temperature that is recorded, a corresponding percent development value, obtained from the percent development table, is also recorded and added to the previous day's sum of percent development values. It is this cumulative percent development that is used to predict the various developmental stages according to the following known values:

Stage:	Percent Development:
weakly eyed	29%
stongly eyed	47%
90% hatched	58%
first feeding	100%

For example, after two days (24 hours) in 42.2 degree (Fahrenheit) water, a salmon egg would have a cumulative percent development of 1.288% (.644 + .644). If the water temperature on the third day was 42.8 degrees, the **daily** percent development (from the table) would be .678%. Therefore the **cumulative** percent development after three days would be 1.966%. As shown above, eggs should begin to hatch as the cumulative percent development nears 58%.

Note: The program facilitator is responsible for providing the teacher with the percent development records for the period of time the eggs were in the hatchery incubator.

Daily Percent Development

Daily temperature Fahrenheit	+ 0.0	0.2	0.4	0.6	0.8
32	0.247	0.252	0.257	0.263	0.268
33	0.274	0.279	0.285	0.290	0.296
34	0.302	0.308	0.314	0.321	0.327
35	0.333	0.340	0.347	0.353	0.360
36	0.367	0.374	0.381	0.389	0.396
37	0.404	0.411	0.419	0.427	0.435
38	0.443	0.451	0.460	0.468	0.477
39	0.486	0.495	0.504	0.513	0.522
40	0.531	0.541	0.551	0.561	0.571
41	0.581	0.591	0.601	0.612	0.623
42	0.633	0.644	0.656	0.667	0.678
43	0.690	0.702	0.714	0.726	0.738
44	0.751	0.763	0.776	0.789	0.802
45	0.815	0.829	0.843	0.856	0.870
46	0.885	0.899	0.913	0.928	0.943
47	0.958	0.973	0.989	1.005	1.020
48	1.036	1.053	1.069	1.086	1.103
49	1.120	1.137	1.164	1.172	1.190
50	1.208	1.226	1.245	1.264	1.283
51	1.302	1.321	1.341	1.361	1.381
52	1.401	1.421	1.442	1.463	1.484
53	1.505	1.526	1.548	1.570	1.592
54	1.614	1.636	1.659	1.682	1.705
55	1.728	1.751	1.775	1.799	1.824

table source: U.S. Fish and Wildlife Service, Lamar Fish Technology Center

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