Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
2017 Volume II: Watershed Science

The Extraordinary Life and Journey of Migratory Fish, through the Connecticut Watershed, the Long Island Sound, and the Atlantic Ocean

Curriculum Unit 17.02.03
by Laura Carroll-Koch

Introduction

Dive into an ocean adventure with the extraordinary life and journey of migratory fish. The developmental stages and migration patterns of these remarkable marine creatures link our worldwide water systems and shine a light on our responsibility as global citizens to protect and defend our planetary water system and the life that depends on it.

In this unit, students will learn about multiple ecosystems and the human impact to these systems as they follow migratory fish through their life cycles. As students study these migratory fish, they will learn about the ecosystems of the rivers, Long Island Sound estuary, and the Atlantic Ocean. In this way, students will develop an understanding of the complex interactions between these ecosystems as well as their interdependent relationships in our global water system enabling the survival of these world travelers.

This engaging thematic curriculum unit is designed for students of 3 rd through 6 th grades to explore the more complex ecosystems of the Long Island Sound watershed. This unit builds upon a prior unit I wrote called, “Just Ask! Exploring Marine Life of Long Island Sound,” /curriculum/units/2013/4/13.04.02.x.html. Through this study, students will learn the fundamental principles and interactions between multiple ecosystems and the marine creatures that swim within them, through the eyes of the Atlantic Salmon, American Shad, Striped Bass, and the American Eel. As students develop an appreciation and deeper understanding of these marine creatures and each ecosystem, students will more fully understand the significance of the human impact of these systems and be inspired to invest in potential solutions. Lessons will build conceptual knowledge and language around the global water system and the life within it in outdoor classroom settings, hands on activities, and labs. These activities will build a deeper understanding of the abiotic and biotic features of Connecticut rivers, Long Island Sound estuary, and ocean ecosystems empowering students to analyze problems and begin to form potential solutions. With a sound understanding of these interdependent relationships, students will begin to recognize the threats to these ecosystems and address real world problems that are impacting the journey and health these migratory fish as they move through multiple ecosystems.

This problem based unit design allows students to identify real world problems in their neighboring waters, develop essential questions, and then form hypotheses. Using the scientific method to set up and conduct tests, students will work in the field to conduct tests and collect information about the state of the water at various locations of Long Island Sound watershed including the Mill River, Quinnipiac River, and Long Island Sound. This study will highlight fresh water and salt water ecosystems and the impact environmental factors within the watershed have on these systems. While developing a deeper understanding of the content through field studies, questioning, and research, students will cultivate the academic language of marine science along with the skills to gather and analyze data. Students will then draw conclusions about the effects of the varying aspects of the watershed on the marine environments. Through this study, students will develop a deeper appreciation and understanding of these migratory fish and the complex interdependence of these multiple ecosystems. As a result, students will seek to advocate, educate, and protect their existence in solution based problem solving. Finally, students will apply this knowledge to find solutions to identified problem(s), synthesizing knowledge of the content and using data to develop plans that will lead to solutions. In this way, students will have an opportunity to affect change as empowered citizens and stewards of our global environmental community.

Rationale

John S. Martinez Sea and Sky STEM Magnet School is part of the New Haven Public School district where eighty-five percent of our students are Hispanic and speak English as a second language. With the needs of our English Language Learners (ELL) in mind, this unit will provide students with authentic, meaningful learning that is culturally relevant, linguistically supportive, and connects students to the larger global community. Concepts will be taught through student centered, engaging hands on activities that facilitate inquiry, student discourse, and language acquisition. Bloom's hierarchy of cognition will guide the development of critical thinking. [1] The classroom culture will be transformed to one of student centered learning, where students are actively engaged, exercising higher order thinking while working collaboratively to solve real world problems. In this way, content will unify concepts, cultivate language acquisition, and develop depth of knowledge around the science of our global water system and the life that depends on it.

Unit Plan

This unit will focus on the study of fresh water and salt water marine ecosystems, developing the content related to the STEM curriculum. Students will explore the watershed systems of the Long Island Sound and the ways in which these systems interact with the migratory fish of the watershed. Students will research and conduct field studies investigating the health of fresh water and salt water ecosystems within the LIS watershed. Building upon this knowledge, students will examine specific pollutants through observations, water testing, and interviewing local businesses and government agencies. Additionally, students will conduct multiple on site field studies to collect data and make observations about the health of the watershed. Students will focus on the ways dissolved oxygen, salt, nitrogen and debris impact these environments. Using their data, students will look for trends and patterns, analyzing information in order to draw conclusions and

make predictions. These experiences will provide opportunities for students to learn content in a meaningful, relevant way, deepening their understanding of the human impact on ecosystems, and transferring conceptual knowledge in a comprehensible, engaging manner.

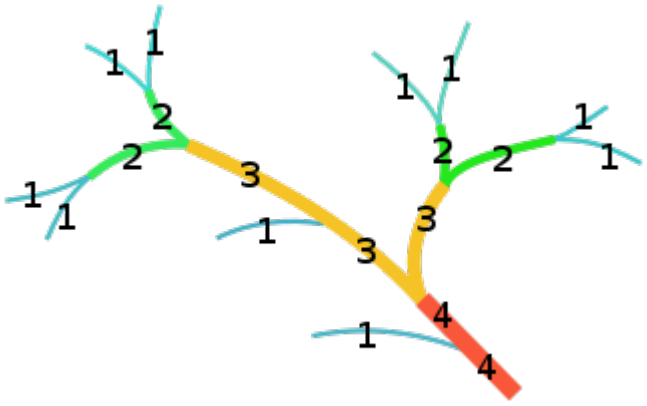
This interdisciplinary thematic curriculum unit will foster the understanding of the interrelated connections between the land, water, and organisms within the watershed. Students will develop an understanding of the relationship between the land and water within the watershed and their relationship looking outward from the fresh water rivers, estuary, and to the seas. Beginning with the rivers of Connecticut, the Long Island Sound estuary, and finally the open waters of the Atlantic Ocean, students will explore the relationships of these marine environments to the watershed and the ecology through the eyes of migratory fish. This problem based unit will build core knowledge of our global water system, watershed science, and the migratory fish that move through these marine environments as students ask questions, read, write and investigate these topics. With an understanding of these fundamental systems, students will identify real world problems effecting both freshwater and saltwater marine environments and then work in teams to design possible solutions. Through engaging hands on activities, field work, and on site testing, students will develop an understanding of the complexity of these relationships and consequential problems affecting the water systems of our planet.

What Is A Watershed?

A watershed can be defined as the drainage area that is determined by the topography of the area which causes the water to drain in a specific direction following elevation changes. A watershed is a unit of land that defines an area from which water flows through, over, and under on its way to a larger body of water such as a lake, river or ocean. A watershed can cover a vast expanse of land as in the Connecticut River watershed or a small area as in the drainage system for a headwater stream. A watershed can be a hundred square kilometers or a hundred square meters. In most areas, the path of the water through a watershed eventually leads to the ocean.

Stream Order

Our global water system grows and flows across the land in streams and rivers. The way in which streams form and build into larger rivers can be measured by stream order. Stream order demonstrates the order in which water collects as it flows downstream, defining the hierarchy of stream size as they intersect and unite with other streams to form tributaries and larger rivers. Stream order is an organized, mathematical formula to show the way water collects when it flows downstream. Stream order can be used to model or diagram the structure of a watershed, or other water systems. Site testing for biotic and abiotic features of a river’s water quality can be determined when analyzing the water quality at various points in its stream order.



https://en.wikipedia.org/wiki/Strahler_number

Figure1. Stream order

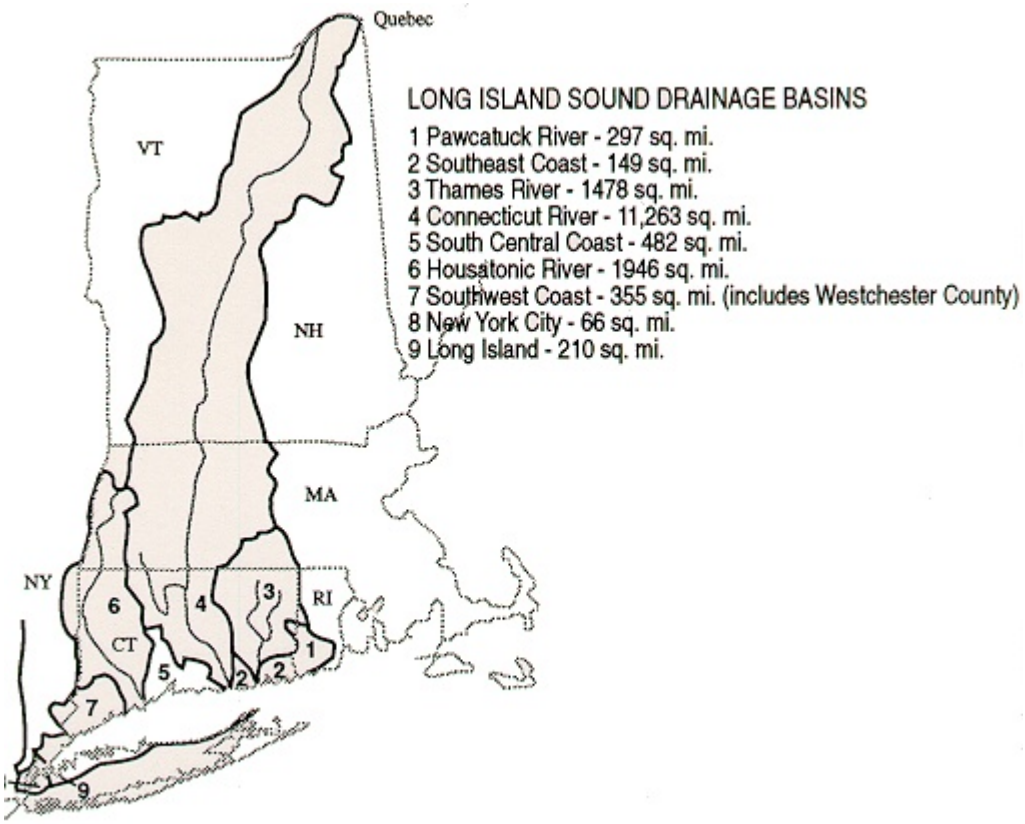
The concept of stream order can be compared to the order in which twigs connect to larger stems and then to larger branches which all flow into the truck of a tree to show how the flow of water moves through a tree. Another comparison to demonstrate a flow system is the way our capillaries connect to form veins and then arteries to show how blood flows through the body. [2]

Long Islands Sound Watershed

The Long Island Sound watershed includes the unit of land through which water flows and drains into Long Island Sound. This includes all the streams, tributaries, ground water, and rivers that ultimately drain into the Long Island Sound and then to the Atlantic Ocean.

The Long Island Sound watershed drains over ten million acres encompassing the four major rivers of Connecticut. These rivers are the Housatonic River, Connecticut River, Thames River, and Quinnipiac River which all drain into the Long Island Sound. The waters that drain into the Long Island Sound from these four major rivers hold the collective health and water quality of the land they swept over, under, and through as they moved toward the Long Island Sound. During the journey, the waters from these rivers have crossed farm lands, asphalt roads, parking lots, industrial areas, metal collection centers, salt piles, abandoned power plants, and water treatment centers. As the water moves through and over these areas, a variety of pollutants and debris are picked up and carried, thus entering the global water system. These pollutants affect both the fresh water and saltwater fish and ecosystems as they enter the rivers and are carried through estuaries and to the Atlantic Ocean. When the river waters drain into the Long Island Sound, saltwater marsh and estuary ecosystems are affected. As a result, marine creatures in both fresh water and salt water ecosystems are affected by what is carried with the water from the watershed. Thus the waters and life of Long Island Sound and the watershed can be impacted by activities as far away as Quebec, Vermont, New Hampshire and Massachusetts in addition to the neighboring states of New York and Rhode Island. Ultimately, as some contaminates move up the food chain, humans are affected by their own impact on the watershed when they consume plants and fish that have become contaminated by pollutants in these waters. Humans are also affected when they interact with water when boating, swimming and fishing. The water quality of the

Long Island Sound rests in the quality of water that is feeding into it from its watershed. Eventually, these pollutants enter our global water system when they mix with the large water system of the Atlantic Ocean, inevitably affecting a broader global community. [3]



https://en.wikipedia.org/wiki/Long_Island_Sound

Figure 2. Long Island Sound watershed

Migratory Fish of the Connecticut Watershed

The Connecticut watershed is host to four main migratory fish, the Atlantic salmon, American shad, Striped bass, and the American eel. These fish live in both fresh water and salt water during different periods of their life cycles. The ecosystems of the Connecticut Rivers, Long Island Sound estuary, and the Atlantic Ocean together support the health and survival of these migratory fish.

The Atlantic salmon, American shad, and Striped bass are anadromous fish which means they begin their lives in the fresh water rivers, pass through the Long Island Sound, and then spend their adult lives in the ocean. These anadromous fish then return to the Long Island Sound on their way back to spawn in the river of their birth as mature adults, thus completing their life cycle.

The American Eel is a catadromous fish. Conversely, the American eel's life cycle is the opposite of the anadromous Atlantic salmon, hatching in the Sargasso Sea, then riding the currents back to the Long Island

Sound, and then spending its adult life in the fresh water rivers and lakes of North America. When eels are mature adults, they return to the Sargasso Sea where they mate, spawn, and then die.

The study of these fish's remarkable life cycles and global migration patterns offers an engaging forum to study complex interactions of multiple ecosystems. The condition of these fish populations reflects the state of the marine ecosystems they live in. Subsequently, the fish are a vehicle that can be used to investigate the effects of the human impact on these ecosystems which impact the growth and survival of these majestic marine species. Additionally, following migratory fish though their life cycle demonstrates the way our global water system and the ecosystems within them are connected and interdependent. Rivers, lakes, streams, estuaries, oceans, and seas are home to these migratory fish during various parts of their lives. The collective health of our global water system is imperative to survival of these incredible migratory fish.

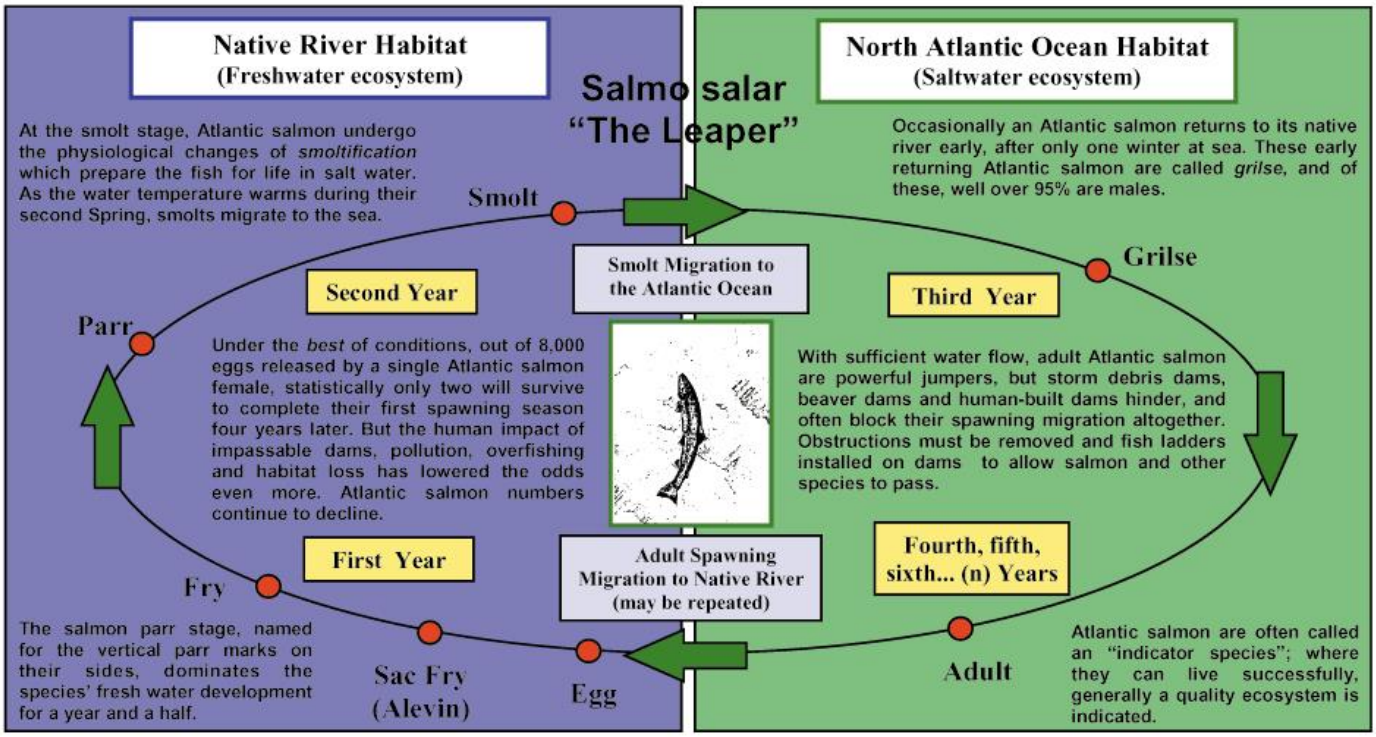
Atlantic Salmon

The Atlantic salmon is an anadromous fish. Anadromous fish spawn in fresh water, live most of their adult life in the open ocean, and then return to their birthplace in freshwater as mature adults to spawn.

The Atlantic salmon's life cycle can be organized into six stages. The life cycle begins in late fall when the mature male and female salmon begin their in a long journey home where they return to the river of their birth and spawn. Imprinted with the memory of the "smells" of their birthplace and journey to the ocean, Salmon are able to find their way back to the river of their birth using their sense of smell. After overcoming obstacles and challenges, the Atlantic salmon swim upstream, against the current, until they reach the place of their birth. Soon after they arrive, the female salmon digs a nest in the rocks and pebbles of the riverbed with her tail fin. This nest is approximately 6-8 inches deep and is called the redd. The female then lays up to 8,000 eggs. The eggs are about the size of a pencil eraser and fall safely into the rocks and crevices of the redd. Next, mature male salmon fertilizes the eggs by spraying sperm over the eggs. The fertilized eggs lay protected in the nest, or redd, in the benthic zone of the fresh water river. The Adult Atlantic salmon then return to the ocean to feed, and then repeat the cycle all over again when they journey back to their birth river to spawn again. [4]

Life Cycle of Atlantic Salmon

Sea Run Atlantic salmon (Salmo salar) inhabit two worlds, spending part of their lives in fresh water and part in salt. The life cycle begins in the fresh water ecosystem of their native stream, and two years later, as smolts, they migrate to the salt water ecosystems of the North Atlantic Ocean. After another two years migrating and feeding at sea, they return as four year old adults to spawn, most usually to the same river where they were hatched. Unlike Pacific salmon, Atlantic salmon may repeat the spawning migration.



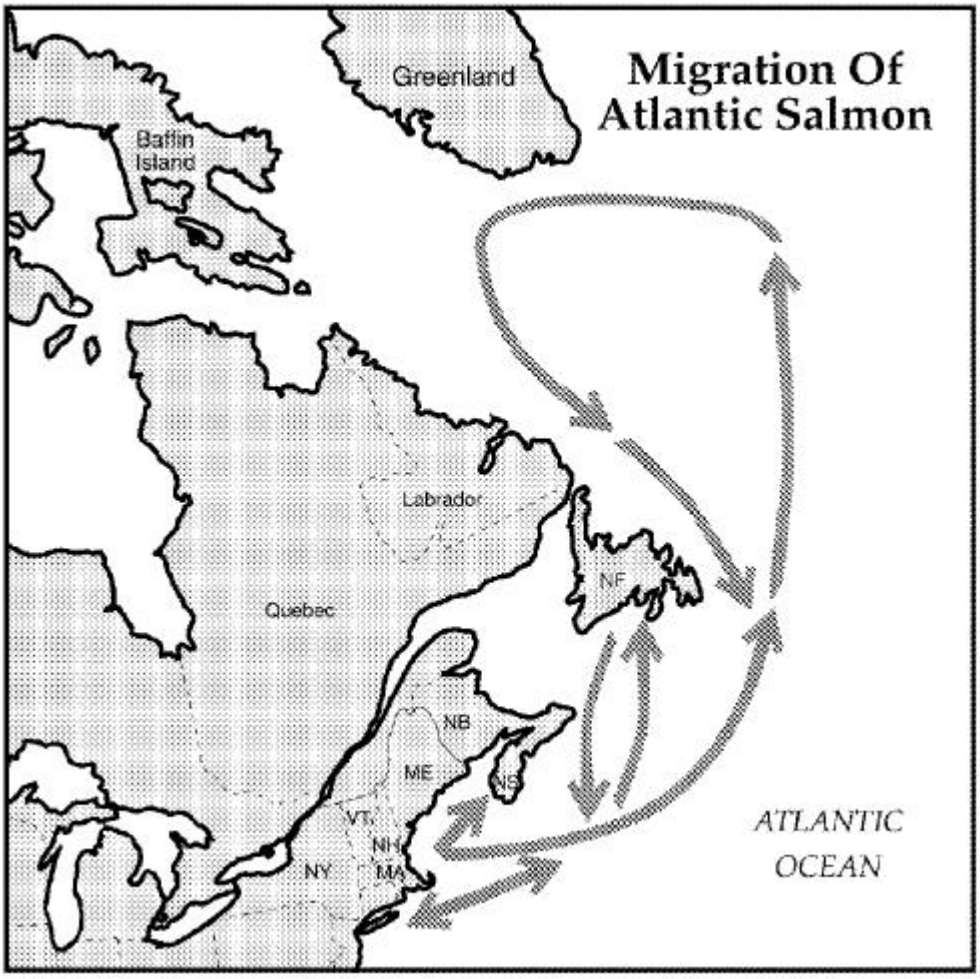
Used by permission of USFWS (United States Fish and Wildlife Services

Figure 3. Life Cycle of the Atlantic Salmon

The first stage of a salmon's life cycle is called the alevin. This phase begins when the salmon hatches from the egg. The alevin are born with a yolk sac attached to its belly. Since the yolk sac provides needed nourishment, the alevin do not need to search for food. For this reason, the alevin are able to stay safely within the rocks crevices of the redd for about 3 months. During this time, the alevin grow to about 2 cm. long. The second stage of a salmon's life cycle is called the fry. Once the yolk is absorbed, alevin become a fry. As a fry, salmon need to find their own food, thus the fry leave the redd, moving up from between the rocks and crevices of the riverbed to feed on microscopic insects and plankton. In this stage, the fry is considered a zooplankton because it is still too weak to swim against the current. The fry begin to drift with the current downstream toward the estuary. The fry continues to grow to 5- 7cm. and strengthen as it finds food and drifts downstream.

The third stage of the salmon's life cycle is called a parr. The dark vertical markings with one red dot between each vertical mark along its body indicate the parr stage. As the salmons more fully enters the ecosystem, hunting for food, these vertical markings serve an important purpose, camouflaging this young vulnerable

marine creature from its prey. Parr can remain in the river for 2- 5 years. This period depends on the water temperature and the availability of food.



https://en.wikipedia.org/wiki/Atlantic_salmon

Figure 4. Ocean migration of Atlantic salmon from the Connecticut River

The fourth stage of the salmon's life cycle is called a smolt. In this stage the salmon is adapting to the salt water. This is a complex transformation because the salmon is changing both internally and externally. Externally the smolt begins to look different. The smolt is 12 to 24cm. in length and the vertical striped markings of the parr stage disappear. Instead, when salmon are smolts, they take on a silvery shiny look. Internally the organs of the salmon are adapting to survive in the salt water. Additionally, during this stage and journey downstream, odors of their native river are being imprinted on their brain/memory for their return journey home. Smoltification is competed when the salmon has made physical changes in its kidneys, an internal metamorphosis that allows the smolt to live in the salt water of the open ocean.

The fifth stage is the adult stage. During this stage, the Atlantic salmon migrate to Greenland. They move into the Atlantic Ocean where they travel approximately 3000 kilometers north along the coast of North America, embarking on their long journey to the waters off southwestern Greenland to feed. Once they arrive, the Atlantic salmon feed on small fish, artic squid, sand eel, and crustaceans, growing rapidly. Adult salmon live and feed in the ocean for a year or more. During this time, they are growing and storing fat for the return

journey to the spawn in freshwater. They return to their native rivers between April and November. The Atlantic salmon stops feeding and live off their fat reserves when they travel through in the estuaries and arrive in the freshwater river.

The sixth stage of the salmon's life cycle is when the salmon matures to reproduce. After spending one to three years at sea, the Atlantic salmon returns to their native river to spawn. In this stage, they are called Grilse. Salmon look different when they are mature and ready to spawn. Salmon swim upstream against the current, jumping over waterfalls, climbing up fish ladders, and scaling dams in order to find their spawning ground where they lay and fertilize the eggs beginning the cycle all over again ensuring the survival of their species. [5] [6]

American Shad

American shad is the Connecticut state fish. Like the American salmon, shad are anadromous fish, which means they begin their life in fresh water rivers, travel through the Long Island Sound and then migrate out to the Atlantic Ocean where they spend most of their adult life in the open ocean before returning to the fresh water rivers to spawn. [7]

The life cycle of the shad begins in the freshwater where the mature adult female shad spawns 100, 000 to 600,000 eggs which are fertilized by several adult males. The larvae eggs develop and infant shad hatch between 4 to14 days after being fertilized. At this stage, the shad are zooplankton drifting with the current. After hatching, the juveniles spend their first summer in freshwater rivers of Connecticut. During the fall, shad gather in schools and begin swimming to the ocean. Like salmon, shad spend three to six years in the ocean and then return to spawn as mature adults in the rivers of their birth.

The number of shad returning to the Connecticut River to spawn has greatly diminished over the years. This has been attributed to land development and the use of dams to control water flow. These dams have blocked access to returning fish thus obstructing entry and routes to their spawning grounds. [8] [9]

The American Eel

The American eel is an extraordinary catadromous fish. The eel is born in salt water and then spends its adult life in freshwater until they migrate back to the Sargasso Sea of their birth. Connecticut freshwater rivers, streams, lakes, and estuaries are home to many American eel. They spend years feeding on zooplankton, frogs, insects, crustaceans, worms, and small fish in the Connecticut watershed and Long Island Sound, growing and maturing before they migrate back to the Sargasso Sea where they mate, spawn, and then die.

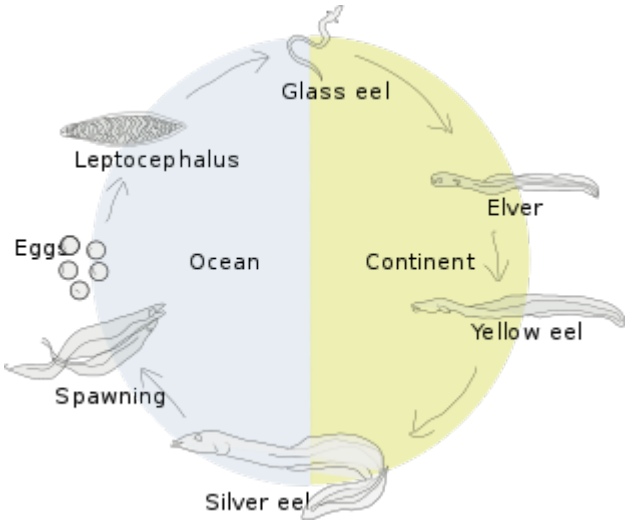
Eels are fin fish that look like snakes. They have two small fins behind their gills that help them swim and move over land. Eels can use their fins to move across, up, and though muddy, moist soil which enables them to "slither" around dams and obstructions. Incredibly, eels are known to move from ponds to rivers by the thousands using their bodies as bridges. [10] Furthermore, eels are able to absorb oxygen through their skin as

well as their gills which allows them to “breathe” out of water for short periods of time. [11] For these reasons, eels are able to inhabit inland lakes, rivers, and streams as far west as Kansas, Nebraska, and Oklahoma. [12]

The Life Cycle of the American Eel

The life cycle of the American eel is highly complex and cloaked in mystery. The American eel inhabits diverse habitats as well as transforms through several metamorphoses throughout its life cycle. The eel transforms physically and behaves differently during each stage of its life as it adapts to the diverse ecosystems it inhabits. Furthermore, the American eel journeys great distances over its lifetime, over 2000 miles from the Sargasso Sea as hatched larvae to the freshwater rivers and lakes of North American, and then back to the Sargasso Sea as mature adults. [13] Although mating, birth, and death of the American eel is believed to take place in the Sargasso Sea, there is no witness to these events. [14] [15] [16]

The life cycle of the American eel can be organized into six stages. The first stage is the when the egg is fertilized. Mature eels return to the place of their birth, migrating from rivers all along the Atlantic coast to the Sargasso Sea in order to spawn. The Sargasso Sea covers two million square miles in the Atlantic Ocean and contains enormous mats of Saragassum weed floating on the surface of the warm waters north of Bermuda in the Atlantic Ocean. [17] The Sargasso Sea is devoid of land boundaries. Instead, the North Atlantic, Gulf Stream, Canary, and North Atlantic Equatorial ocean currents form its borders . [18] After making the1000 mile journey from North America, to the Sargasso, mature eels mate. Next, the female eels lay between 10-20 million eggs. [19] These eggs are then fertilized by the mature male eels. Once fertilized the buoyant eel eggs float to the surface of the Sargasso where between February and March the eel hatch from the drifting egg to become larvae called leptocephali.



https://en.wikipedia.org/wiki/Eel

Figure 5. Life Cycle of the American Eel

The second stage of the American eel’s life cycle is the hatched larvae called the leptocephali. The newly hatched eel larvae look like a flat clear willow leaf. These little marine creatures ride the Gulf Stream currents

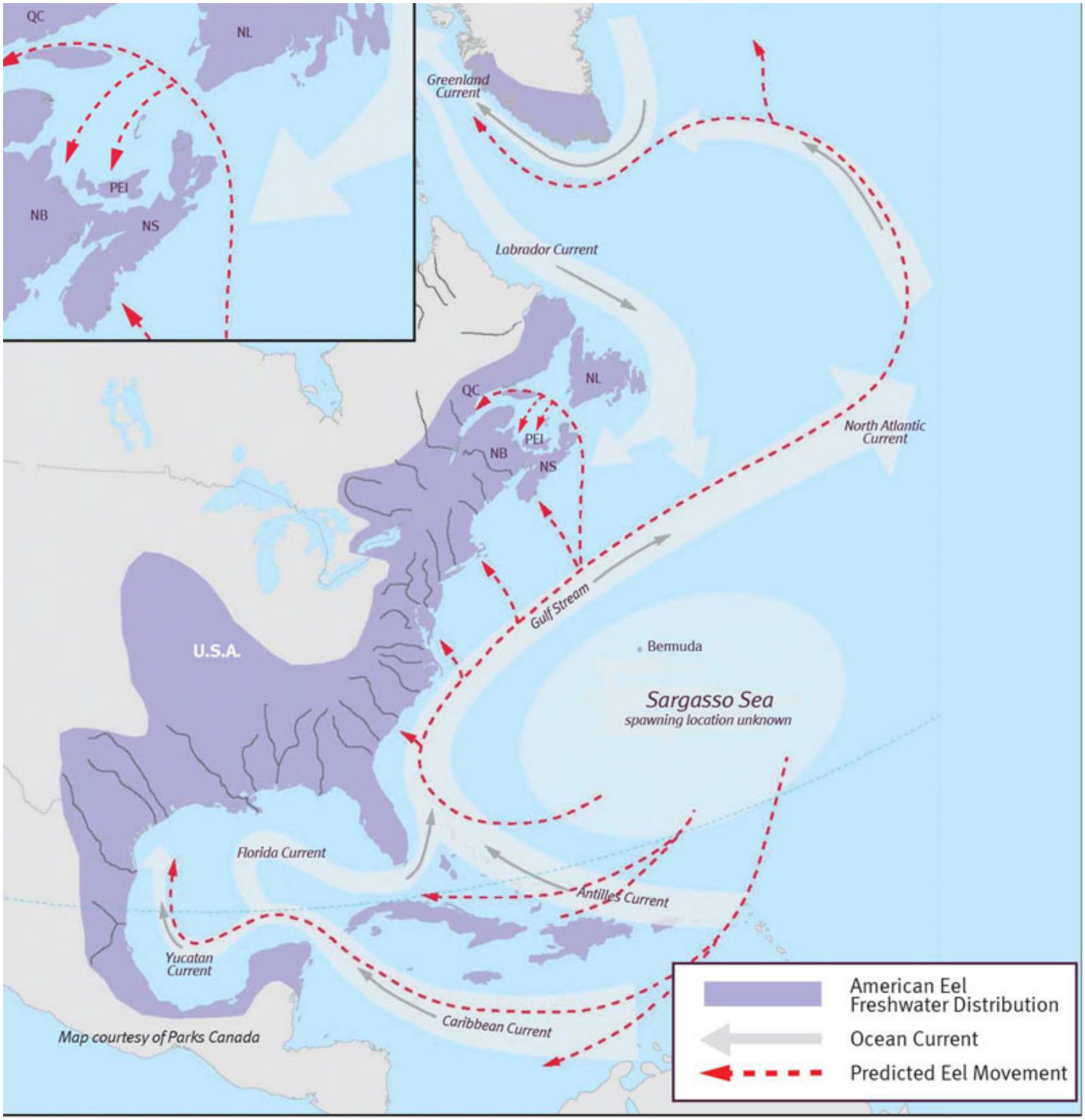
for about a year as zooplankton to the coastal waters of North American. Protected by their transparency, leptocephali, grow and feed on plankton of the rich ocean waters during the journey west.

The third stage of the eel's life cycle is the "Glass eel" stage. This is the next metamorphosis. After the leptocephi have fed and grown for about a year drifting on the Gulf current to North America, they begin arriving at the shores of Connecticut in late winter and mid-March. The glass eels begin to enter the brackish waters of the Long Island Sound estuary in addition to tidal creeks and inlets of Connecticut and Rhode Island . [20] At this stage, the Glass eels look like thin, transparent worms with a tiny black dot for an eye, literally as clear as glass. They are about 2-3 inches long and have grown two small fins on each side of their bodies. Glass eels are known to enter tidal creek by the 10s of thousands. [21]

In the fourth stage of their life, eels are called elvers. At this stage, eels grow to about 4 inches in length. As elvers, the young eels begin to migrate into the brackish waters of coastal estuaries as well as fresh water streams and ponds. During this time, their bodies under go another physical change. When elvers enter the fresh water, their bodies develop grey to greenish brown pigmentation and darken as they move inland. Elvers eat almost anything in their habitat, burrowing themselves in the mud during the day and hunting almost anything at night. [22]

The fifth stage of the eel's life cycle is called the yellow eel. This is the juvenile stage of the eel's life. When the elver reaches its inland destination, it metamorphoses to a yellow eel. During this phase, eels are dark olive green or brownish. They are bottom dwellers, living in fresh water rivers, lakes, and streams, sleeping in the mud, silt, or sand during the day. Eels are carnivores feeding on insects, mollusks, worms, smaller fish, crustaceans, and dead animal matter at night. Female eels grow to four to five feet in length which is twice the size of adult male eels.

The sixth stage of the eel's life cycle is called Silver eel. In this stage, the eel metamorphoses again, physically maturing to spawn and prepare for the migratory journey to the salty spawning grounds of the Sargasso Sea. Silver eels are mature adults with an average life span of five years but many live to 15-20 years. In preparation for their journey to the Sargasso, the Silver eel's body coloration changes to a dark grey with a white underside which offers predatory protection in the open ocean. Additionally, their eyes and pectoral fins enlarge. Furthermore, the eel stops eating when it is in the silver stage because its digestive system stops functioning. The sexually mature Silver eels leave inland fresh water rivers in the fall (September and October), and begin their journey to the Sargasso Sea. James Prosek, author of "Eels", describes their yearly journeys to the Sargasso as, "the greatest unseen migrations of any creature on the planet." [23] Moreover, once in the Sargasso, the entire eel population mate and spawn together. This is the first and last time the American eel will spawn. They spawn just once in their life time and then die. The life of the American eel begins and ends in the Sargasso Sea. [24] [25] [26]



http://www.dfo-mpo.gc.ca/species-especes/profiles-profils/eel-anguille-eng.html

Figure 6. Map of American eel migration routes

Source: Parks Canada

The Human Impact on Migratory Fish of the Watershed

Pollution

As the population has increased, land areas have developed with housing, schools, shopping malls, power plants, dumps, dams, roadways, cars, and waste treatment centers. The impact of this growth and development has a far reach effect on multiple ecosystems. This development has greatly affected the ecosystems of the Long Island Sound watershed.

A variety of pollutants enter the water system through both point sources, specific locations and non-point sources, broader sites. Rain water washes over farms, parking lots, city builds, salt piles, roadways, out dated dilapidated electric power plants, dumps(a plethora of surfaces) picking up and carrying with it a multitude of substances as the water travels to the Long Island Sound. These pollutants include salts, nitrogen, oil, detergents, plastics, pesticides, and chemicals, pharmaceutical, and micro fibers. [27]

Salt

Salt naturally occurs in estuaries and oceans, but when the salt levels in the waterways exceed normal levels, problems follow within the ecosystem. The delicate balance of the ecosystem can be tipped with road salts flooding water systems.

The salt in the estuaries and oceans come from the rocks. When it rains, the water droplets pick up carbon dioxide as the water droplets fall to the land. The carbon dioxide makes the rain slightly acidic which wears down the rocks which releases salt into the water. [28] [29] Unfortunately, there is a lot of salt placed on roadways during the winter to make driving safer. This salt is highly mobile and easily enters into streams and rivers. Freshwater organisms in these systems are not used to such high levels of salt and are adversely impacted.

Overfishing

Maine's fishermen are trying to address the over fishing of eels with a lottery system. Overfishing is having a huge impact on the eel population. As elvers return to the shores of Maine from the Sargasso, they are being harvested and sold for over $2000.00 a pound to Asia. They are then exported and farmed in Asia where they are sold for an even higher price. [30]

Additionally, overfishing of the sand eel and krill is having a significant impact on migratory patterns and health of Atlantic salmon. As a result, Atlantic salmon is returning to their native rivers thinner and earlier. Concerns are arising about the kind of impact the early return will have on the spawning patterns because the salmon will need to survive in the rivers until January when they spawn. [31]

Dams and Loss of Habitat

Another problem facing migratory fish is the blockage to watershed spawning grounds. Land development has created obstacles such as the construction of dams and habitat loss with landfills which blocks access to the spawning grounds of migratory fish. Hydroelectric dams have posed a catastrophic effect to the eel population. When adult eel journey back to the Sargasso, a hydroelectric dam kills and injures the eel when they are caught in the turbines. [32] Unable to reach spawning grounds, the populations of American Shad,

Atlantic salmon, and American eel are being severely impacted. [33] [34]

Oxygen & Nitrogen

A healthy stream and river has balanced levels of oxygen and nitrogen levels. Marine creatures need appropriate levels of oxygen, carbon, nitrogen, and phosphorus in the ecosystem to survive. The marine creatures in these ecosystems depend on healthy levels of dissolved oxygen to breath. Hypoxia can become problematic in the summer because water stratifies and bottom waters can effectively be separated from oxygen replenishment from the atmosphere.

Another situation that can cause hypoxia to occur is when there are excess rain storms and run off into the watershed. The runoff carries extra nutrients into the water to the phytoplankton. These microscopic marine plants grow and reproduce vigorously under these conditions. There quick growth also has a short life cycle. The tiny marine plants, phytoplankton, die quickly. When the phytoplankton die, and are decomposing, the process uses the dissolved oxygen in the water. This depletes the levels of oxygen for other marine creatures that depend on the oxygen in the water. A low oxygen level, or hypoxia, stresses fish and other marine creatures. Fortunately, fin fish are able to swim away from the affected areas, but benthic creatures such as clams, mussels, and oysters are not.

In conclusion, there is an interconnected relationship between oxygen and nitrogen levels in marine environments. Levels of nitrogen often have a direct relation to the amount of dissolved oxygen available. Excess nitrogen can cause algae blooms. After the large numbers of algae multiply and grow, or “bloom” they die off quickly. The decomposition of the dead algae is what depletes oxygen levels. When the algae, or phytoplankton dies, its decomposition by bacteria, animals, uses up the dissolved oxygen in the water. These algae blooms deplete oxygen levels in the water because algae uses oxygen as it decomposes resulting in lower levels of dissolved oxygen in the water [35] which in turn causes hypoxia, or low levels of dissolved oxygen. Hypoxia stresses marine creatures in such environments.

Solutions

One way to address the problems facing the migratory fish populations is to connect with community resources and educate the citizens to raise community awareness about the problems facing migratory fish. In this way, students can ignite enthusiasm in order to motivate citizens and community members to get involved and become part of the solution.

In April of 2016, the community of New Haven did just that when they tackled the problem of Pond Lily Dam. Although there was a fish ladder built at the West River Fish way, the Pond Lily Dam continued to cause flooding and obstruct migratory fish from access to spawning grounds. Consequently, the community mobilized, working together to successfully removed the Pond Lily dam on the West River restoring stream access to migratory fish, such as the eel and shad. In addition to correcting the neighborhood flooding issue, the removal of the dam successfully restored important stream access to native migratory fish such as the shad, eel, and herring and re-opening habitats for spawning. [36]

Teaching Strategies

Universal Design for Learning, (UDL).

Question Formulation Technique(QFT)

Problem Based Learning (PBL)

Outdoor Classroom/Place Based Learning

Cooperative Learning:

Learning Activities

Guest Speakers: Peter Raymond- PhD Yale School of Forestry and Environmental Science;Stephen Gephard: Fish biologist with the CT Dept. of Energy & Environmental Protection; James Prosek: Author of Eel

Field trips to New England Science and Sailing, Hammonasset State Park, Light House Point Beach, area rivers, and area salt marshes, Whitney Water Center: Project Water

Students will create a map of Long Island Sound watershed labeling states, rivers, and oceans.

Students will use Google map to map our watershed and then label the streams and rivers growth and development using “stream order” in order to identify the hierarchy of stream development in the watershed.

Students will create a map of our global water system. Label oceans and water cycle process.

Students will map the migration patterns of the Atlantic salmon and American Eel.

Students will research salt and fresh ecosystems and the marine life that depend on the water quality of the watershed.

Students will read, research, and write about the stages of the life cycles of migratory fish: books, essays, reports, brochures, scripts for plays, podcasts, and slideshows

Students will create an infographic of a migratory fish American Salmon/ American Eel:

- Map the migration patterns
- Label oceans, rivers, seas, and estuaries
- Label States and Countries
- Label ocean currents and movement
- Illustrate and label life cycle stages at specific locations and ecosystems
- Describe habitats and ecosystems – prey predators, abiotic & biotic feature
- Illustrate and label environmental hazards and obstacles along the migratory routes.

- Write captions to describe and explain concepts.

Students will research, explore, visit, design and restoration projects related to migratory fish.

Students will use resources and state data bases to collect information about the health of Connecticut Rivers: http://www.connecticutriver.us/site/content/sites-list

https://ecoreportcard.org/report-cards/long-island-sound/health/

Students will develop questions, research and identified businesses and industries in the neighborhood that compromise the water quality and life in the watershed, map the area to include waste treatment centers, salt piles, oil containers, metal collection centers, and Ball Island English Station power plant.

Students will then test water for dissolved oxygen, nitrogen, bacteria, salt, and metals to identify point source pollutants. Students will develop a plan to address these problems and meet with local government and business in order to ascertain their help.

Students will research and write fishing policy related to the American Eel population and or Atlantic salmon population.

Students will connect with the global community to create a project for the celebration of World Migration Day 2018, on April 21, 2018. Happy Fish Symbol

Standards

LS2.A: Interdependent Relationships in Ecosystems

MS-LS2-1 Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

MS-LS2-2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

LS2.B: Cycle of Matter and Energy Transfer in Ecosystems

CCSS.ELA-Literacy.W.6.2 Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.

CCSS.ELA-Literacy.W.6.2.a Introduce a topic; organize ideas, concepts, and information, using strategies such as definition, classification, comparison/contrast, and cause/effect; include formatting (e.g., headings), graphics (e.g., charts, tables), and multimedia when useful to aiding comprehension.

CCSS.ELA-Literacy.W.6.2.b Develop the topic with relevant facts, definitions, concrete details, quotations, or

other information and examples.

CCSS.ELA-Literacy.W.6.2.c Use appropriate transitions to clarify the relationships among ideas and concepts.

CCSS.ELA-Literacy.W.6.2.d Use precise language and domain-specific vocabulary to inform about or explain the topic.

Resources

Atkin, John and Bangser, Jennifer, et al. *The Sound Book* , Norwalk, Ct.: The Long Island Soundkeepers Fund, 1990.

Prosek, James. *Eels.* New York, New York: Harper Perennial, 2010.

Van Patten, Peg, Moore, Milton, and O'Muin, Eamon. (2009) *Sound facts, fun facts about long island sound* . Groton, CT: Connecticut. Sea Grant.

Wahle, Lisa and Balcom, Nancy. (2002 *) Living treasures: the plants and animals of long island sound* . Groton, CT.: Connecticut. Sea Grant College Program.

Website Resources

http://www.hws.edu/fli/lessons_teach_oxygen.aspx

https://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/indiana/journeywithnature/incredible-journey-american-eel.xml

https://oceanservice.noaa.gov/facts/sargassosea.html

https://www.fws.gov/northeast/americaneel/pdf/American_Eel_factsheet_2015.pdf

http://www.dfo-mpo.gc.ca/species-especes/publications/sara-lep/eel-anguille/index-eng.html

https://www.researchgate.net/figure/280726611_fig1_A-schematic-diagram-of-the-life-cycle-of-anguillid-eels-illustrating-how-the-different

https://www.fws.gov/hurricane/sandy/projects/PondLilyDam.html

What is the Sargasso? https://oceanservice.noaa.gov/facts/sargassosea.htmlDepartment of Environmental Conservation, Atlantic Ocean / Long Island Sound Watershed, http://www.dec.ny.gov/lands/48375.html

Eli the eel: A Mysterious Migration - James Prosek, https://www.youtube.com/watch?v=BR1enXROmgA

NATURE | The Eel Life Cycle | The Mystery of Eels | PBS ,https://www.youtube.com/watch?v=5n8TNPilw6s

http://soundbook.soundkeeper.org/chapter_SectionID_7.htm

https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/

World Migration Day 2018, https://www.youtube.com/watch?v=Rx9udu_p2QY, An excellent video explaining the significance of migratory fish globally and the efforts to create global community to build awareness around safe passage of fish through multiple habitats

A River Flows Free in New Haven, CT, U.S. Fish and Wildlife Service
https://www.youtube.com/watch?v=38-IIhXdHLo&feature=youtu.be-, Removal of Pond Lilly Dam and community restoration project, lowering the water levels to stop flooding, ensuring the free passage of migratory fish and restoring natural habitat

Millions of Salmon Return Home | National Geographic , https://www.youtube.com/watch?v=ZR4_LhPCgbo

Salmon Eggs Hatching at Seymour Hatchery, https://www.youtube.com/watch?v=px1KOZjvm44&t=68s, Great visual of salmon hatching as alevin with attached yolk sac

Salmon Life Cycle, Marine Institute, https://www.marine.ie/Home/site-area/areas-activity/fisheries-ecosystems/salmon-life-cycle

A Tale of Shad, the State Fish , https://connecticuthistory.org/a-tale-of-shad-the-state-fish/

American Shad, https://www.fws.gov/chesapeakebay/shad.htm

Migratory Fish in Trouble, Connecticut River, https://www.ctriver.org/river-resources/about-our-rivers/migratory-fish/

http://www.hws.edu/fli/lessons_teach_oxygen.aspx

https://water.usgs.gov/edu/dissolvedoxygen.html

http://www.dec.ny.gov/chemical/74997.html

http://www.dec.ny.gov/docs/water_pdf/linapscope.pdf

The Sound Book, http://soundbook.soundkeeper.org/chapter_ContentID_210_SectionID_6.htm

Maritime Aquarium at Norwalk. Retrieved from, http://www.maritimeaquarium.org/long-island-sound

Printable Living Treasures Tour: Long Island Sound Study. Retrieved from, http://longislandsoundstudy.net/wp-content/uploads/2010/05/LivingTreasuresBlue_Full_Lores.pdf

Fact Sheets, Long Island Sound Study, http://longislandsoundstudy.net/category/media-center/fact-sheets/ , Facts related to the current health of Long Island Sound , including hypoxia, chemical contaminants, waste treatment, septic systems, floatables, pathogens

Endnotes

1. https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/
2. http://www.cotf.edu/ete/modules/waterq3/WQassess4b.html
3. http://soundbook.soundkeeper.org/chapter_ContentID_210_SectionID_6.htm .
4. https://www.ctriver.org/river-resources/about-our-rivers/migratory-fish/#Sturgeon
5. https://www.marine.ie/Home/site-area/areas-activity/fisheries-ecosystems/salmon-life-cycle-http://www.asf.ca/life-cycle.html
6. https://www.ctriver.org/river-resources/about-our-rivers/migratory-fish/#Sturgeon
7. https://connecticuthistory.org/a-tale-of-shad-the-state-fish/
8. https://www.fws.gov/chesapeakebay/shad.htm
9. http://soundbook.soundkeeper.org/chapter_ContentID_209_SectionID_6.htm
10. James Prosek, Eels, p.4.
11. https://www.fws.gov/northeast/newsroom/pdf/Americaneel9.26.11.2.pdf
12. https://www.fws.gov/northeast/americaneel/pdf/American_Eel_factsheet_2015.pdf
13. Peg Van Patten, Milton Moore, and Eamon O'Muin, Sound Facts, p.30.
14. http://www.dfo-mpo.gc.ca/species-especes/publications/sara-lep/eel-anguille/index-eng.html
15. https://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/indiana/journeywithnature/incredible-journey-american-eel.xml
16. James Prosek, Eels, 3.
17. James Prosek, Eels, 3.
18. https://oceanservice.noaa.gov/facts/sargassosea.html
19. Peg Van Patten, Milton Moore, and Eamon O'Muin, Sound Facts, p.30.
20. James Prosek, Eels, 115.
21. James Prosek, Eels, p 116.
22. James Prosek, Eels, pp.252-255.
23. James Prosek, Eels, p 4.
24. http://www.chesapeakebay.net/fieldguide/critter/american_eel
25. https://www.fws.gov/northeast/newsroom/pdf/Americaneel9.26.11.2.pdf
26. http://www.dfo-mpo.gc.ca/species-especes/publications/sara-lep/eel-anguille/index-eng.html
27. http://soundbook.soundkeeper.org/chapter_SectionID_7.htm
28. http://oceanservice.noaa.gov/facts/whysalty.html
29. http://www.lakesuperiorstreams.org/understanding/impact_salt.html
30. http://www.pressherald.com/2017/02/08/maine-fishermens-group-backs-lottery-for-elver-fishery/
31. http://www.telegraph.co.uk/news/earth/environment/10994071/Salmon-stocks-at-risk-as-sand-eels-are-overfished.html
32. James Prosek, Eels, p252
33. http://longislandsoundstudy.net/indicator/shad-blueback-herring-long-island-sound/
34. https://www.ctriver.org/river-resources/about-our-rivers/#river_renewal
35. http://soundbook.soundkeeper.org/chapter_ContentID_215_SectionID_7.htm
36. https://www.fws.gov/hurricane/sandy/projects/PondLilyDam.html