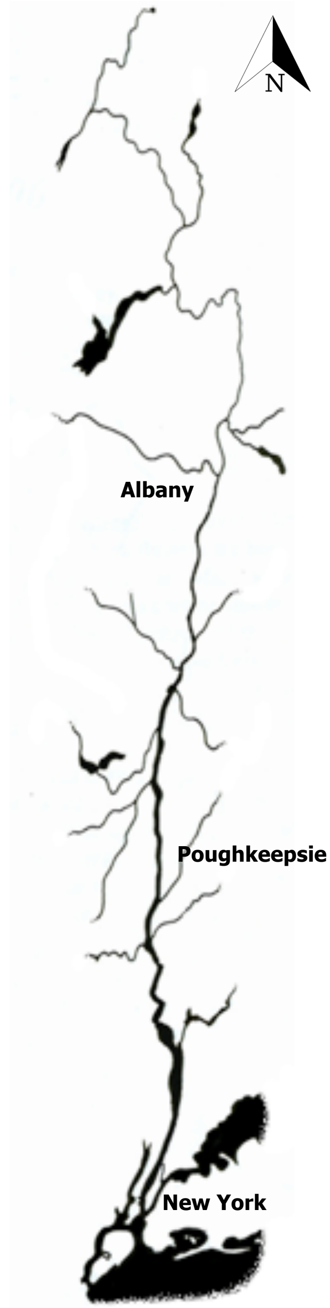
Lamont-Doherty Earth Observatory
COLUMBIA UNIVERSITY | EARTH INSTITUTE

Is the Hudson a River or an Estuary?
High School Version
The Background



Each of us has a *water address*. No matter where you reside on land, you are a part of a watershed. A *watershed* is a geographic area whose rainfall, snowmelt, streams, and rivers all flow or drain into a common body of water, such as an ocean, lake, river, stream, estuary, or reservoir. Ultimately, most watersheds eventually drain into the ocean.

At Lamont-Doherty Earth Observatory's Field Station, we are a part of the Hudson River watershed, one of particular importance as it expands across approximately a third of New York State and even into New Jersey, Vermont, Massachusetts and Connecticut! The freshwater input of the Hudson River starts at any location within the watershed. One drop of rainwater in the watershed could contribute towards the freshwater of the Hudson River, eventually draining into the Atlantic Ocean. The highest point of our watershed is at Mount Marcy in the Adirondacks. While the entire Hudson River spans an impressive 315 miles from Lake Tear of the Clouds to the Atlantic Ocean, our investigation will focus on the 153 miles stretch between the Troy Dam and the Atlantic Ocean.

In three activities, we will be investigating whether this section of the Hudson is an estuary or a river using the principles outlined by the National Oceanic and Atmospheric Administration (NOAA). We will use fish species diversity, salinity ranges, and water level change to help us in our investigation.

Above is an image of Bear Mountain Bridge looking north onto Manitou Marsh, an important nursery area for several Hudson River fish including striped bass.

START BY CREATING A MODEL!!

ON THE LEFT YOU WILL CREATE A MODEL OF WHAT DEFINES AN ESTUARY.

- **In your model you will include the critical pieces that make a body of water an estuary.**
- **Be sure to annotate how the pieces relate to each other**

ON THE RIGHT YOU WILL CREATE A MODEL OF WHAT DEFINES AN RIVER.

- **In your model you will include the critical pieces that make a body of water a river?**
- **Be sure to annotate**

Write down your thoughts using this chart and then discuss as a class! You can include phrases, diagrams and drawings but only use one color for your first drawing!

Estuary	River

Investigation #1: Let's Check in With Some Hudson Residents!

The biology of the Hudson can tell us a little more about whether the Hudson is a river or an estuary based on the environmental preferences/tolerances of the species that we catch. In order to catch fish in the Hudson, we suggest a couple of different fishing tools. If a site has access to the waterfront or beach, a *seine net* is a perfect tool to catch smaller fish by walking a net through the water and pulling your catch up on the beach. A *fish trap* is a great fishing tool if your site has a dock or pole to tie down the fish trap. *Rod and reel* is a more expert method of fishing that requires practice and skill, but has the ability to catch larger species of fish.

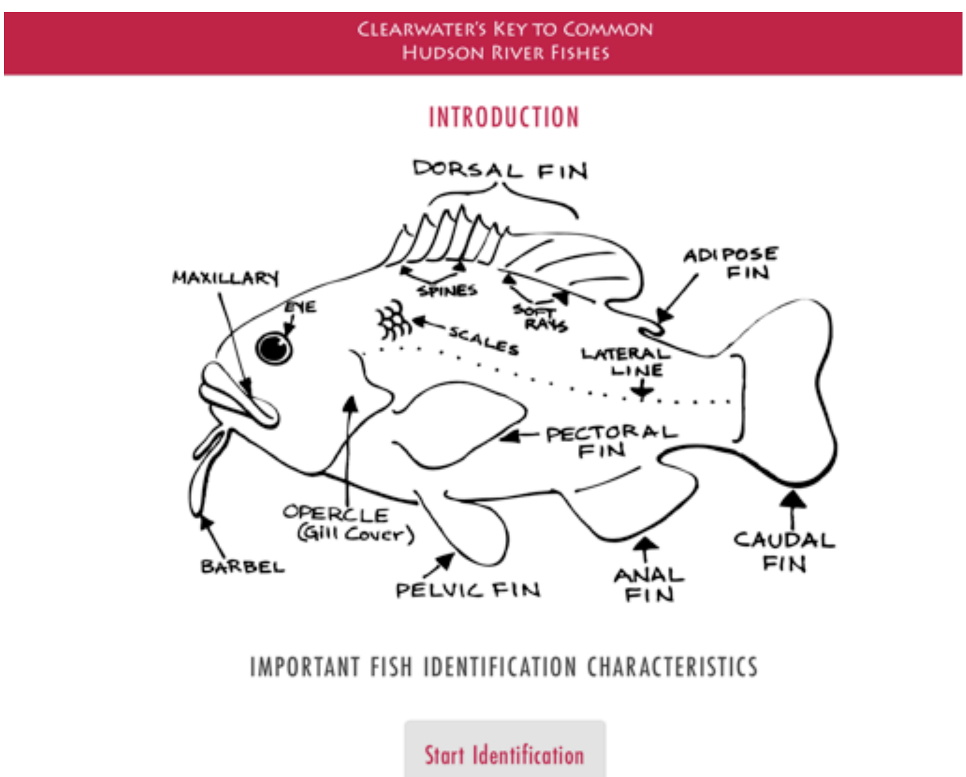
MATERIALS:

- Worksheet/packet
- Writing utensil
- Access to the internet and the Digital Version of Clearwater's Key to Hudson River Fishes via phone, computer, or iPad

Investigation #1:

Part 1: How can we tell what is caught in the Hudson River?

We can use a dichotomous key! Based on a series of questions about the species, this tool helps scientists or fishers identify the species that have been caught. Below are some key external anatomy features that the dichotomous key is based on. Each page in the key provides two options, A or a B, that describes a characteristic to examine and determine which option best describes what is being looked at. Based on these features, the key can narrow down to the genus, or in some case, the species.



Use the dichotomous key to identify the fish below. Record your answers on your worksheet to keep track of your pathway to identification.

Let's start with the first question for the key:

A. Eyes on same side of head; body lies flat on bottom
B. Eyes on opposite sides of head

For this fish, the eyes are on opposite sides of the head so we would click B.

NOW YOU CONTINUE:

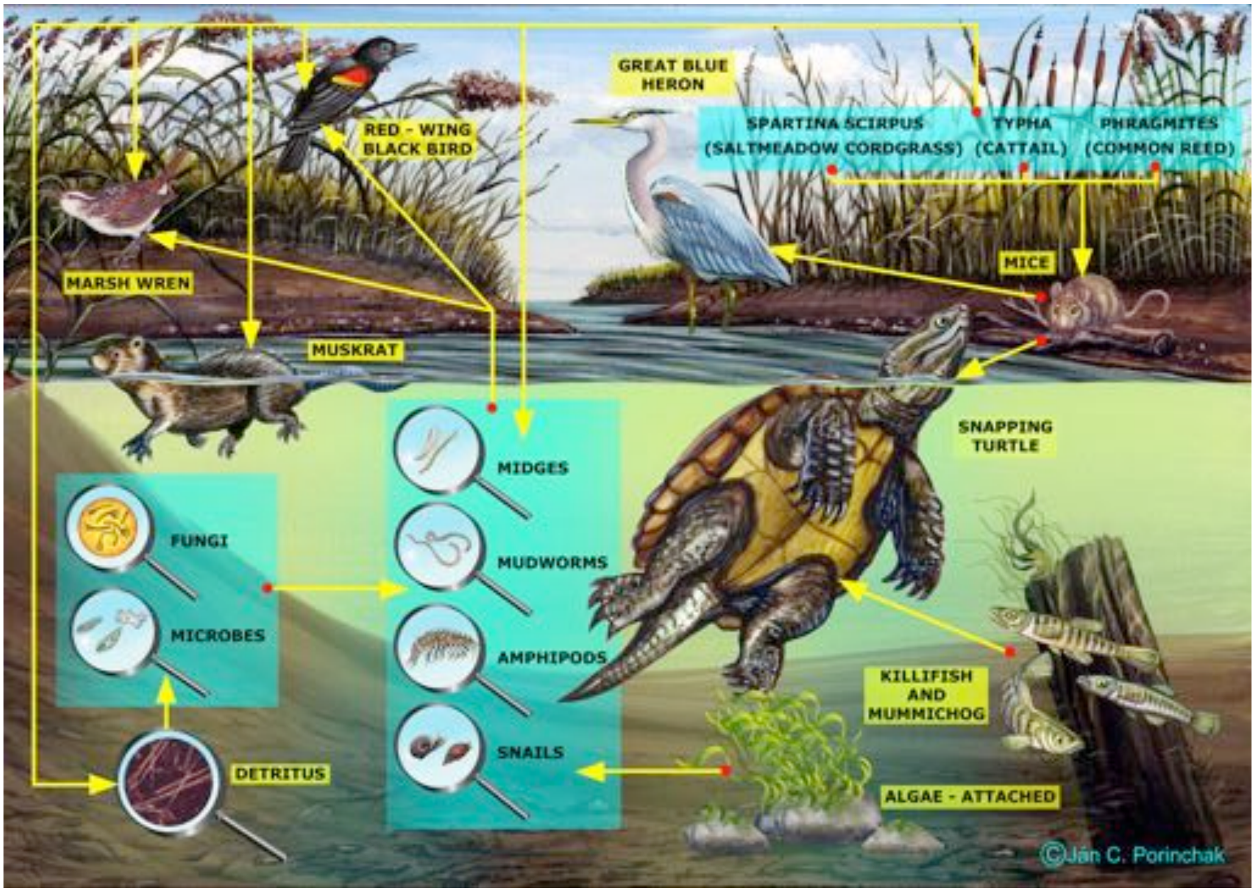
STOP: DO NOT PROCEED UNTIL PROMPTED BY YOUR TEACHER

The Hudson is home to over 200 species of fish, but we will focus on three types of **killifish**:

The **banded killifish** (Fundulus diaphanous) is the most slender of the three species with a squared tail and a head that is somewhat flattened on top. It has a small mouth that is turned up for surface feeding and they spawn in aquatic plant beds. During mating males will develop a bright blue patch and female eggs have adhesive threads to hold onto plants. Banded killifish live for 2-3 years and are 2-4 inches long.

The **striped killifish (**Fundulus majalis) has a round head and a tail with rounded corners. They are more tolerant of sandy environments than the other killifish species. During mating, the males will have black sides with golden orange and bright yellow fins. The average lifespan is 3-5 years and are 6-8 inches long.

The **mummichog** (Fundulus heteroclitus) is a killifish whose name is from the Algonquian Native American tribe meaning going in crowds. This species eats up to 2,000 mosquito larvae a day and are great for mosquito control. A plump fish with a rounded tail that burrows in mud and sediment, it is very tolerant of low oxygen environments. During mating the males will have yellow pectorals and blue and orange markings, sometimes with a bull's-eye on the dorsal fin. Mummichogs can live up to 3 years and are 5-6 inches long. This species of killifish has been sent to space and have a tremendous jumping ability!



An image of a Hudson food web. By Ján C. Porinchak

In observing the Hudson River food web and reviewing the PowerPoint as a class, answer the following questions:

1. **What are the similarities between these killifish?**

2. **How many centimeters are each killifish on average?**

3. **Notes about *banded killifish*:**

4. **Notes about *mummichogs*:**

5. **Notes about *striped killifish*:**

Investigation #1:

Part 2: Where do Different Species of Killifish Live in the Hudson?

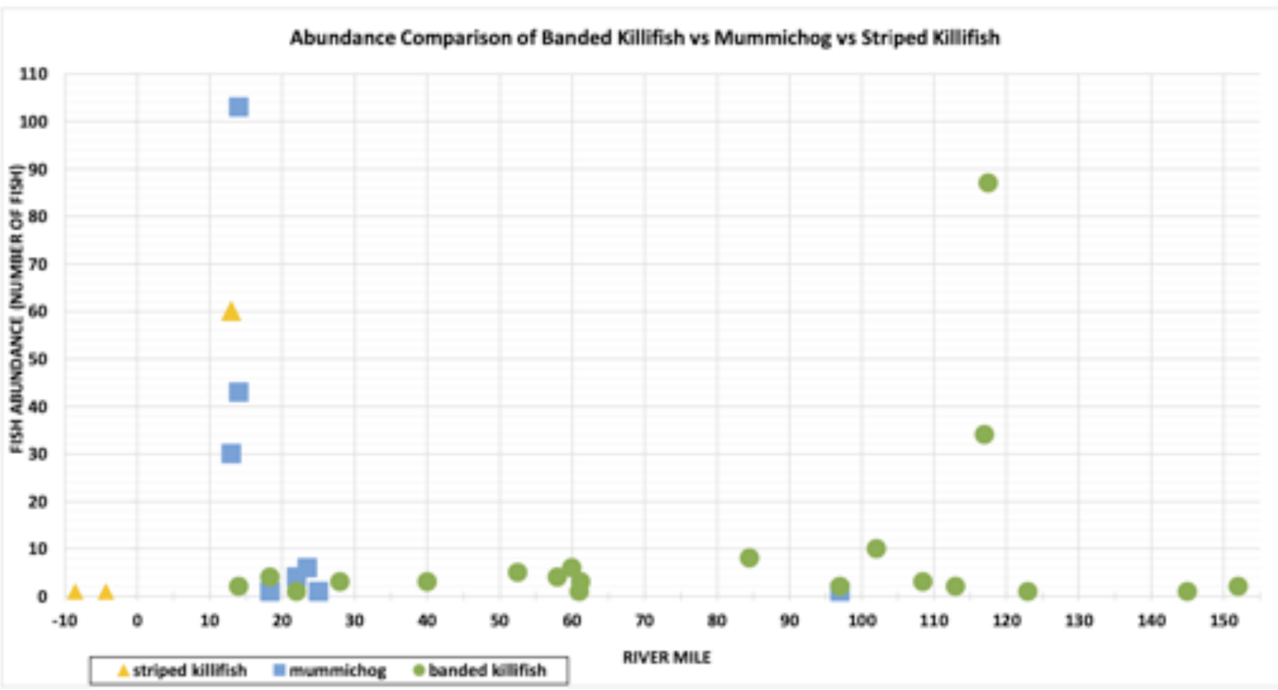
MATERIALS:

- Piece of paper
- Writing utensil

We are going to look at where the different killifish live throughout the Hudson. The Hudson is broken up into different River Miles (RM) with RM 0 located at the southern tip of the Battery in Lower Manhattan in the New York Harbor. We start the Hudson RM count at this point with RM numbers increasing as you travel northward. We begin by looking at the abundance of each killifish species caught at the noted RMs during a set of sampling events.

DIRECTIONS:

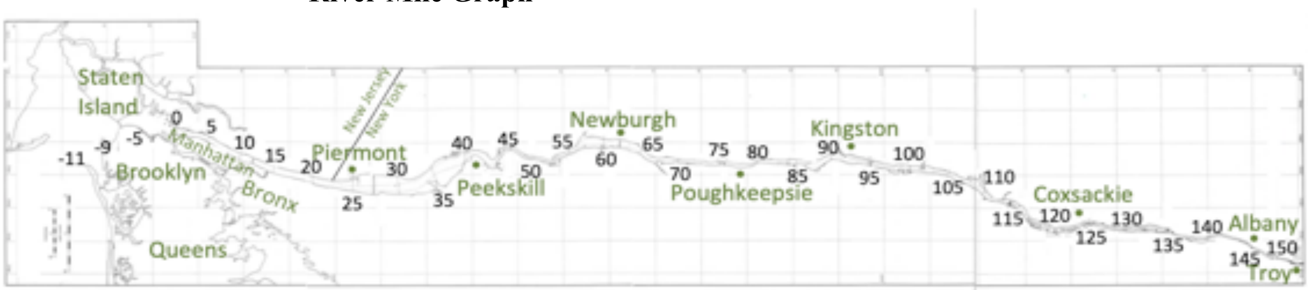
Look at the graph below. Based on the data provided in the Killifish Species Graph below, identify the range shown for each of the killifish species netted during our event. Next you will use the River Mile Map on the next page to show the species ranges shown in the data below.



Killifish Species Graph

Use the map and draw a line that represents the extent of the range of each Killifish species. Be sure to use a different color for each species. Then use the data to make observations, answering the questions below.

River Mile Graph



1. **Which species was found in the most locations?**

2. **Between what river miles did we find *striped killifish*?**

3. **Between what river miles did we find *mummichog*?**

4. **Between what river miles did we find *banded killifish*?**

5. **What do you think might influence where these fish are found in the Hudson?**

Remembering the estuary and river concepts, which ones have we covered so far?
Look back at your model on page 2. Using a different colored pen/pencil you can update your model or annotate it with the new information you have learned!

STOP: DO NOT PROCEED UNTIL PROMPTED BY YOUR TEACHER

THE ESTUARY VS. RIVER PRINCIPLES AND CONCEPTS

ESTUARIES	RIVERS
Connect directly to the ocean so water is both **salty & fresh**	A large body of **fresh** flowing water
Flow two ways due to tides	**Flow one way** –from higher to lower elevation
Depth determined by **tides**	**Depth** determined **by flow**
Ocean connection makes them **very dynamic**	Generally **consistent** water conditions
Highly complex with **varied habitats**	Less complex with **fewer habitats**
Species include freshwater, saltwater & estuarine (brackish)	**Species** are freshwater
People rely on them for the many things they provide	**People rely on them** for the many things they provide

Investigation #2: Let's Check the Salinity of the Water in Different Parts of the Hudson

MATERIALS:
- Worksheet/packet
- Writing utensil

A big difference between salt water and fresh water is the amount of dissolved salts or salinity of the water. Both salt and freshwater have salt, but the amount of salts in saltwater are significant higher. The amount of salt also influences the density of the water. Saltwater has a higher density than freshwater. That's why you can float or are more buoyant in saltwater than freshwater. Fresh water is water with a salt concentration of less than 0.01 percent as opposed to salt water that has an average salinity of 3.5 percent.

The amount of salt in a body of water, also known as the ***salinity**,* helps define the type of water we are looking at. In the Hudson, we have fresh, brackish, and marine sections. The **freshwater region** is defined as having < **100 ppm** (parts per million) salinity. The **brackish water** section has a salinity range that is **> 100 ppm and < 18,000 ppm (18 ppt). Marine waters** are defined as having a salinity that is **> 18,000 ppm (18 ppt).** For reference, the open ocean has approximately 35,000 ppm (35 ppt). The instrument that is used to measure salinity depends on your location on the Hudson.



Salinity is measured using *(from left to right)* a hydrometer, a refractometer, or quantabs.

A *hydrometer* is an instrument that measures salinity based on density. A hydrometer determines specific gravity by operating on Archimedes principle or the *principle of floatation* that states a solid suspended in a liquid/fluid will be buoyed up with a force that equals the weight of the fluid it displaces. In small plastic hydrometers like the one shown above it measures the buoyancy of the plastic lever/arrow as a way to find the relative density of a liquid. The lever will sink further into water with lower density (freshwater) than water with high density (salty or brackish water).

A *refractometer* is a tool that determines the concentration of a substance (salinity) in a given solution (water) based on the principle of refraction. When the rays of light pass from one medium into another, they are bent either toward or away from a normal line between the two media. Salinity causes light to scatter or refract. Therefore, the refractive light can be used to determine the sodium chloride (NaCl), concentration of salinity, in a solution. For each percent salinity value, there is a corresponding angle of refraction, and the angle of refraction is converted to percent salinity.

Salt is an ionic compound, with the majority of ions in seawater being sodium (Na^+) and chloride (Cl^-). *Quantabs* measure the amount of chloride in the water. When the quantab is placed in the sample of river water the fluid rises up the strip by capillary action. Each quantab contains a strip of silver ions, and when combined with chloride, a white column of silver chloride forms in the strip. The length of the white column is marked and proportional to the chloride ion concentration. The reading is then easily converted the total salinity.

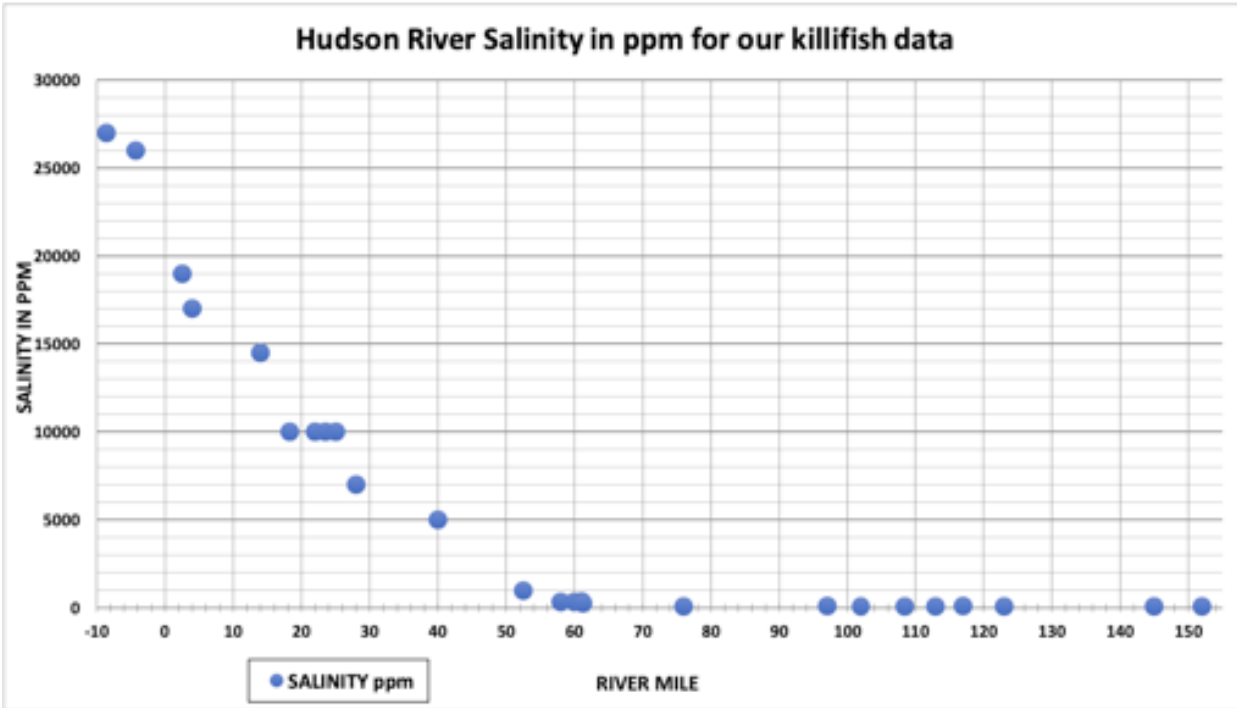
DIRECTIONS:

Identify the Marine, Brackish, and Fresh sections

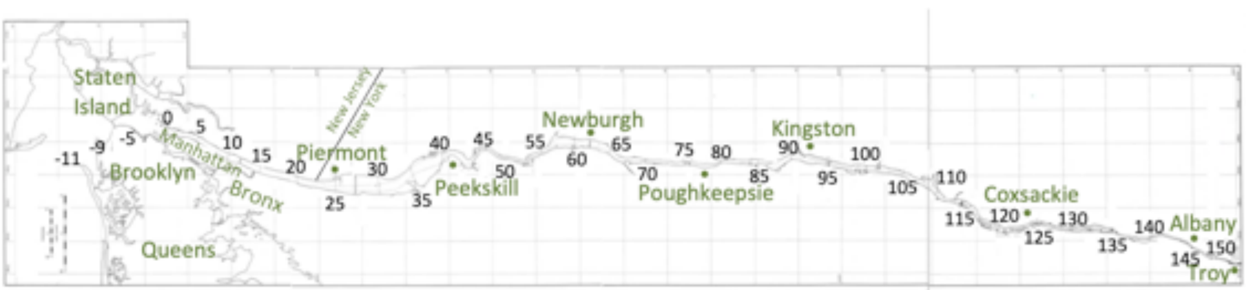
Recall that levels of salinity are used to identify whether water is Marine, Brackish or Freshwater. (You may want to go back to the start of this investigation if you need a refresher.) Examine the Salinity Graph below to see what salinity readings the samplers recorded. Then on the River Mile Map below the graph, mark on or above the map, the ranges where the samplers found the marine section, brackish section, and fresh water sections of the Hudson. Use different colored lines as you did for the fish ranges in Investigation #1.

Hint: It might be useful to add some salinity concentrations from the graph on the map to visualize how the salinity changes with river mile.

Hint Hint: You might want to start by identifying the salinity breaking points where the sections move from marine to brackish and brackish to fresh.



Salinity Graph



River Mile Map

REMEMBER, THE HUDSON IS A DYNAMIC WATER BODY!

The marine, brackish, and fresh sections of the Hudson vary daily, weekly, seasonally, and yearly based on tides, rain, snowmelt, and climate change. We are labeling the marine, brackish, and fresh sections of the Hudson based on the data collected in 2015 from the 'Day in the Life of the Hudson and Harbor' program.

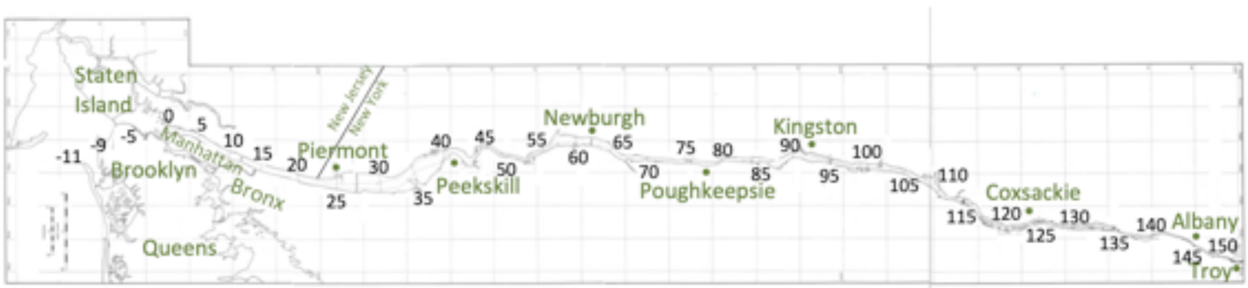
1. **Based on this data set, where are the marine sections in of the Hudson?**

2. **Based on this data set, where are the brackish sections of the Hudson?**

3. **Based on this data set, where are the fresh sections of the Hudson?**

Let’s put the biological and the chemical data on the same map!

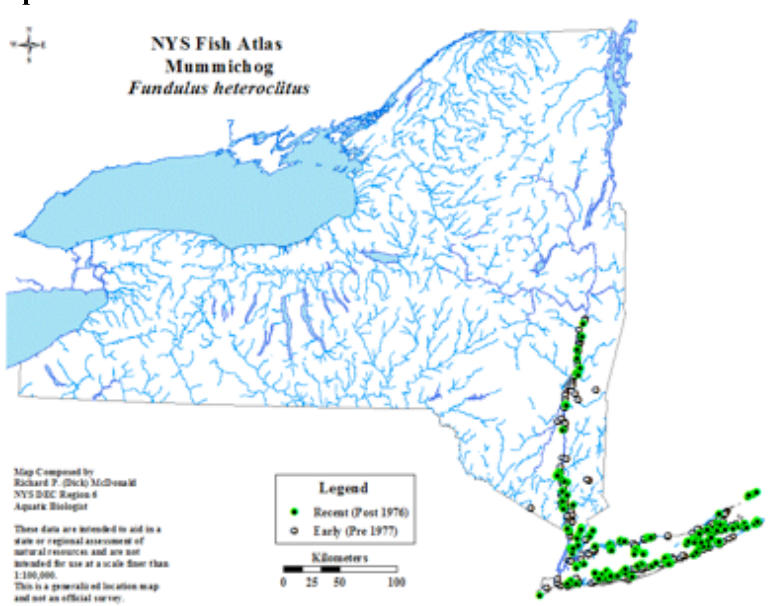
On the River Mile Map below combine the killifish ranges identified in *Investigation #1* with the salinity sections identified in *Investigation #2*. Now let’s make some observations. Are there any correlations?



1. **Can you say anything about the preferences of STRIPED KILLIFISH?**

2. **What about the preferences of a MUMMICHOGS?**

3. **Hypothesize! See if you can make at least 3 additional observations about MUMMICHOGS based on this map?**



Mummichog distribution in NYS. Source: NYS DEC

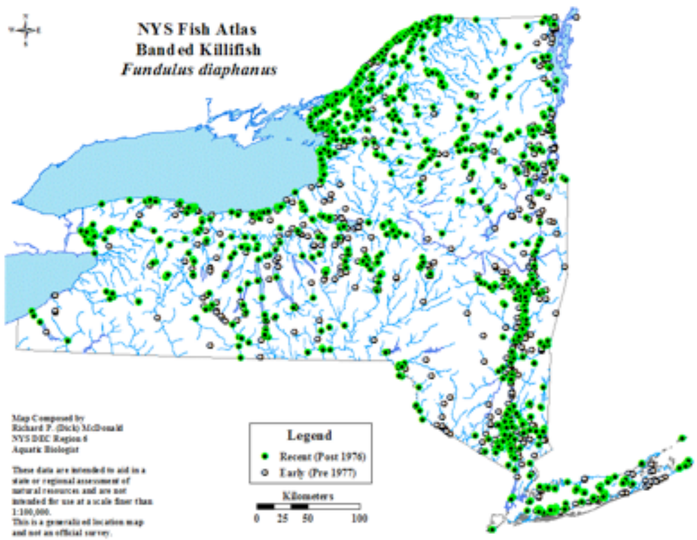
1.

2.

3.

4. What about the preferences of a BANDED KILLIFISH?

5. Hypothesize! See if you can make at least 3 additional observations about BANDED KILLIFISH based on this map?



Banded killifish distribution in NYS. Source: NYS DEC

1.

2.

3.

Remembering the estuary and river concepts, which ones have we covered so far?

Look at your model on page 2. Using the information we have discovered from *Investigation #1 and Investigation #2* about the Hudson, update your model or annotate it using a different colored pen/pencil with the new information we have talked about!

STOP: DO NOT PROCEED UNTIL PROMPTED BY YOUR TEACHER

THE ESTUARY VS. RIVER PRINCIPLES AND CONCEPTS

ESTUARIES	RIVERS
Connect directly to the ocean so water is both **salty & fresh**	A large body of **fresh** flowing water
Flow two ways due to tides	**Flow one way** –from higher to lower elevation
Depth determined by **tides**	**Depth** determined **by flow**
Ocean connection makes them **very dynamic**	Generally **consistent** water conditions
Highly complex with **varied habitats**	Less complex with **fewer habitats**
Species include freshwater, saltwater & estuarine (brackish)	**Species** are freshwater
People rely on them for the many things they provide	**People rely on them** for the many things they provide

Investigation #3: Let's Check the Water Depth of the Hudson

MATERIALS:
- Worksheet/packet
- Writing utensil

There is one additional piece of evidence that can help us determine whether the Hudson is a river or an estuary: measuring water level change! Water level or water depth can be measured in the field in a variety of different ways depending on your site.

Water level measured *(left to right)* from the surface of the water to the bottom of the Hudson, the distance the water has changed from where it hits the shore, the water level as marked on a tide stick.

1) If your site has a pier or dock, you can measure the water level by *measuring from the surface of the water to the bottom of the river.* If you are on a dock, you will have to do a couple measurements and some simple math to calculate the water's depth. First, measure from the top of the pier/dock to the bottom of the Hudson, and then measure the distance from the top of the pier/dock to the surface of the water. The difference between these two measurements will give you the depth of the water!

2) You could also use a *tide stick*. A meter stick gets placed in the water. Periodically, check back to measure the water level change in centimeters on the tide stick.

3) If you have access to the water via shoreline or beach, you can measure changes in the tide by measuring changes in *the water line on the beach.* Periodically, mark where the water line is on the beach to observe how the water line has changed.

DIRECTIONS:

At Piermont (RM 24.5) we used method #1 and #2 to observe the water level change over a 4.5 hour period during 'Day in the Life of the Hudson and Harbor'. You will use our data and complete the chart below.

1. **Calculate the time between the measurements. Then using the change in cms recorded you will complete the rate of change column for both the tide stick measurements and the measurements from the dock.**

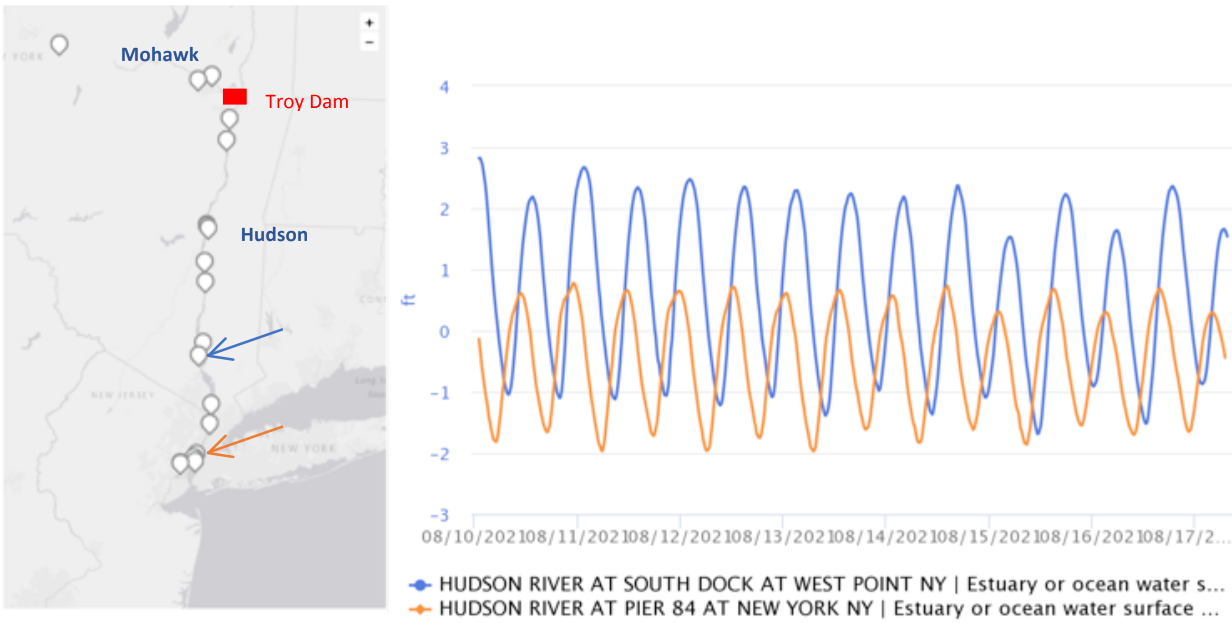
Piermont RM 25								
Time	Tide Stick cm	Change / cm	Rate of Change	Rising/ Falling	Measure to Water cm	Change / cm	Rate of Change	Rising/ Falling
9:00 AM	20				550			
9:30 AM	12	8	8cm/30 m	F	563	13		F
10:30 AM	25	-13	13 cm/60 m	R	555	-8		R
11:02 AM	41	-16		R	540	-15		R
11:23 AM	50	-9		R	535	-5		R
11:39 AM	60	-10		R	485	-50		R
12:30 PM	85	-25		R	436	-49		R
1:00 PM	92	-7		R	430	-6		R
1:20 PM	95	-3		R	411	-19		R

2. **Consider the two methods. Why are progressive measurements between the *Tide Stick* readings increasing, while the *Measure to the Wat*er are decreasing, yet the water level is 'rising' throughout the majority of the day?**

Another way to observe water level change is by using equipment like the [Hudson River Environmental Conditions Observing System]() (HRECOS). HRECOS is a network of high-frequency monitoring stations that are geographically distributed along the Hudson and Mohawk River, equipped with sensors that continuously record a suite of water quality and weather parameters every 15 minutes with most stations operating year-round. Below we graph the tides at the stations!

DIRECTIONS: Review the graphs and data below and answer the corresponding questions.

Graph 1 shows the water level changes at West Point, NY (blue) and Pier 84, NY (orange) from August 10th, 2021 through August 17th, 2021.



Graph 1: Comparing the water level change over a week at West Point, NY in **blue** and Pier 84, NYC, NY in **orange**.

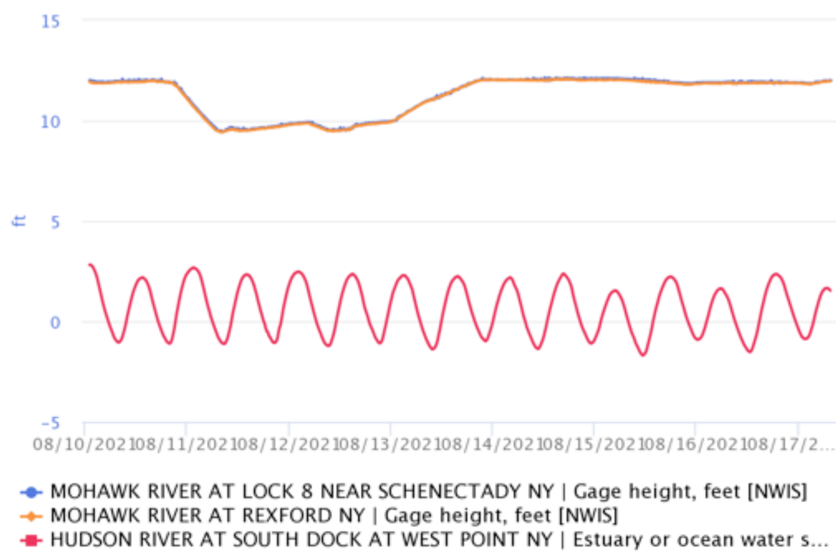
1. **List your observations about this data graph.**

2. **What might be the driver for the pattern that you see?**

3. **Why might the oscillation pattern between two sites not occur at the exact same time?**

4. **Why might the oscillation pattern between the two sites have a different range between high and low tide?**

Graph 2 demonstrates the water level changes at Lock 8 near Schenectady, NY in the Mohawk River (blue), Rexford, NY in the Mohawk River (orange), and West Point, NY in the Hudson River (red) from August 10th, 2021 through August 17th, 2021.



1. **Jot down some observations from this data graph.**

2. **The data collected from Lock 8 and Rexford, NY appears to follow the same pattern. Can you provide a hypothesis as to why?**

3. **What might be the cause of the difference in the data collected from Lock 8 and Rexford and that collected at West Point?**

4. **What do you think might drive the water level change in the Mohawk River? What about in the Hudson River at West Point?**

BASED ON THE INVESTIGATIONS, IS THE HUDSON A RIVER OR AN ESTUARY?

Look at your model on page 2. Using the information from *Investigation #1, #2, and #3*, update your model or annotate it using a different colored pen/pencil with the new information we have talked about!

STOP: DO NOT PROCEED UNTIL PROMPTED BY YOUR TEACHER

THE ESTUARY VS. RIVER PRINCIPLES AND CONCEPTS

ESTUARIES	RIVERS
Connect directly to the ocean so water is both **salty & fresh**	A large body of **fresh** flowing water
Flow two ways due to tides	**Flow one way** –from higher to lower elevation
Depth determined by **tides**	**Depth** determined **by flow**
Ocean connection makes them **very dynamic**	Generally **consistent** water conditions
Highly complex with **varied habitats**	Less complex with **fewer habitats**
Species include freshwater, saltwater & estuarine (brackish)	**Species** are freshwater
People rely on them for the many things they provide	**People rely on them** for the many things they provide

ALL ARROWS POINT TO THE ESTUARY!

BONUS QUESTION!

There are different types of estuaries around the world that we have defined below. Considering all that you know about the Hudson River, how would you define this estuary?

CIRCLE YOUR ANSWER FROM THE FOLLOWING:

1. **Fjord-** steep walled river valleys created by glacial advance (Example: Alaska)
2. **Drowned River Valley (or Coastal Plain Estuaries)-** rising sea levels flood existing river valley (Example: Chesapeake Bay)
3. **Tectonic-** Tectonic plate collide or fold together (Example: San Francisco Bay)
4. **Bar Built-** Barrier beaches, coastal parallel island, or barrier island create this estuary (Example: North Carolina)

EXPLAIN YOUR ANSWER CHOICE: