Lesson 1: Exploring Hudson River PCB Data

Objectives:
Students will know how to answer the question, “How likely is it that a striped bass caught near where the students live on the Hudson River will be above the FDA supermarket standard of 2 ppm?” and be able to provide evidence to support their answer.

Overview:

1. Students will gain background knowledge about PCBs and will be able to explain how fish get PCBs in their bodies.
2. Students will understand where PCBs in the Hudson River came from, and how they move in the river.
3. Students will brainstorm what they would need to know in order to decide if they should eat Hudson River striped bass.
4. Students will “sample” Hudson River striped bass.
5. Students will share their results and discuss the implications for consumption.

Time: Three 40 minute periods
Setting: classroom
Key Concepts: bioaccumulation and biomagnification, pollutants, data sampling and variability, frequency histograms

Materials:

- Formative Assessment Handout - one per student
- Hudson River PCB classroom map – one per classroom
- Envelopes with Hudson River fish data from Catskill in 2008 – consider laminating for longevity
- Student worksheets - one per student
- Student reading - one per student
- Computers w/internet OR Advisory Map Handout

Preparation:

1. Decide how to break up your class for groups in the Explore section; students can work in pairs or in larger groups, as they will then share their findings with the rest of the class.
2. Create one envelope of Hudson River fish data per group.

Background information:

PCBs build up in fat or lipid and some fish species are much higher in lipids than others species. Catfish are very “fatty” and have one of the highest PCB levels of any fish species. An individual fish that accumulates a lot of fat over the course of its life will have more PCBs than another fish who has less fat. Lipid levels are an important factor in how much PCBs will be found in a fish, but many other things affect the amount of PCBs in Hudson fish.

We can think about:

- Where does the fish live? Does the fish live near the source of the PCB contamination, or at a location in the river with a lot of PCBs? How big is the fish's "home range"?

Some locations have more PCBs in the sediments than other locations on the river. The distance from the source of the contamination influences the amount of PCBs in the sediment at any specific place, but the river bottom is not perfectly smooth - the shape of the river bottom, water flow, how sediment is deposited in the river, and storm events all affect the movement of the PCBs. The river has some tidal action from New York City to the large dam at Troy 150 miles upstream! Some fish may stay in a small area for most of their lives, but others travel more. A few species, like striped bass, live in the ocean or outside the Hudson most of the year and come back to the Hudson for part of the year to breed. Individual fish of the same species can behave differently. DEC fish biologists radio-tagged sixteen fish, walleye, from the tidal Rondout Creek in Ulster County in 2013/2014. Six stayed in the tidal Rondout year round and the other ten moved from 5 to 25 miles into the main river after spawning in April. Most of these fish returned to the tidal Rondout Creek to spawn the following year.

- What does the fish eat?

A fish that eats a lot of insects may have less PCBs that one that eats fish.

- How old is the fish?

A younger, smaller fish will usually have a lower concentration of PCBs, than an older, larger fish of the same species.

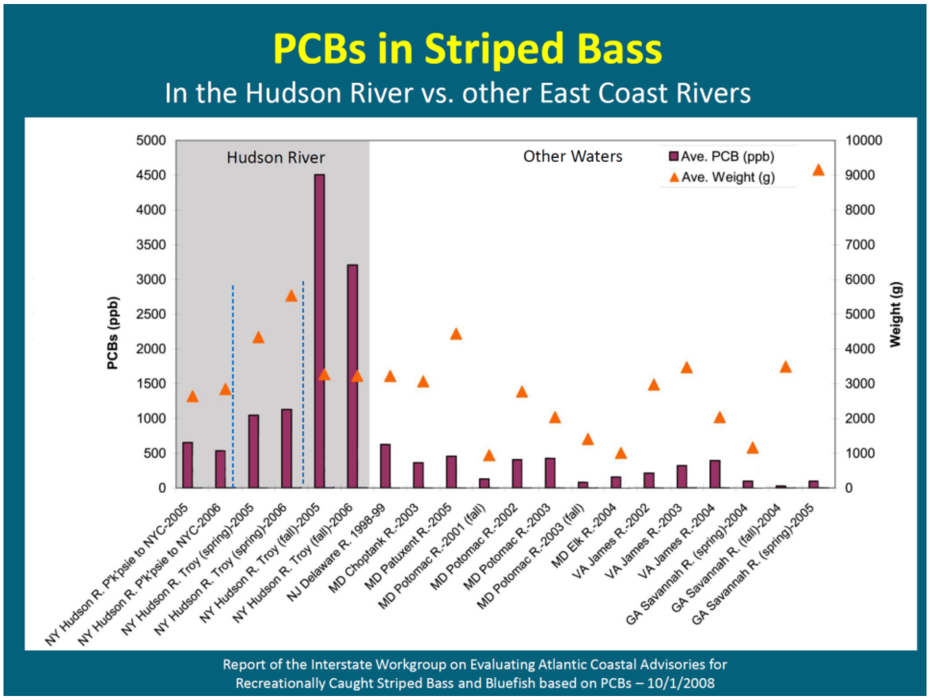
- Can PCB levels in fish change from year to year?

The amount of food available to a fish from year to year can vary a lot. How much food a fish eats affects the amount of fatty tissue it has, so the PCB levels also can change in a fish from year to year.

This curriculum uses striped bass as a focal organism since it is a favorite target of fishermen, and many students are familiar with the fish. Striped bass enter rivers to spawn each spring. Striped bass are born in the river in May each year, and the young are assumed to remain in the mid estuary. The two to five year old striped bass are thought to migrate from the mid-estuary into the New York Harbor in June and spend the summer months in Long Island Sound and the New York Bight. Six through seventeen-year-old striped bass are assumed to spend most of their year in the open ocean, but migrate into Long Island Sound and the New York Bight around March 15.

Some newer research by scientist David Secor (2013) helps explain the high levels in the fall collection near Troy and suggests that the behavior of striped bass is more complex than we originally thought. He has radio-tagged some Hudson fish and it appears that there may be a lot of variation in how long a fish stays in the river. Some appear to come in only for a short time, but some stay in the more freshwater area near Troy for long periods of time. And a fish may change its pattern of how long it stays in the river from year to year. This is some exciting research that may give us new insight into the data on PCBs in striped bass.

The graph below will give you some context for how PCB levels are different in the Hudson River versus other rivers of the East Coast.



The graph shows two years of data on PCB levels in striped bass in some East Coast rivers and illustrates that the levels in Hudson fish are significantly higher in striped bass from other parts of the East Coast. The Hudson striped bass are the first six bars on the left. The graph is in parts per billion (ppb). 1000 ppb = 1 ppm. 2000 ppb = 2 ppm, the supermarket standard for PCBs in fish that can be sold in stores for human consumption. Fish enter the river from the south in spring, and the first two bars are levels in striped bass collected near Poughkeepsie (river mile 50) in spring 2005 and 2006. The third and fourth bars from the left are the levels in striped bass collected in spring near Troy (river mile 100) in those years. The levels are almost double the levels of fish collected near Poughkeepsie. The fifth and sixth bars are the levels in striped bass collected in the fall of 2005 and 2006 at Troy. These are fish that stay for extended periods in a portion of the river about 50 miles south of the source of the contamination. The DEC collects some of these fish each year.

Data Analysis Concepts:

This lesson, and the two following it, use data to explore differences in PCB levels. Below are some data analysis concepts that are used in the curriculum (important ones are in bold). If you don't often use these concepts in your classroom, it might be helpful to go over them with your class as they come up in the lessons.

1. **Average/Mean**: it is a measure of central value for a dataset; it is the sum of all the numbers in a dataset divided by the number of samples in the dataset (the sample size).
2. **Probability**: the likelihood of a particular result. It is the number of occurrences in a dataset of that result (the **frequency**) divided by the sample size of the dataset.
3. **Variability:** How different the numbers in a dataset are from each other. There are four ways to measure variability: the range of all numbers in the dataset, the range of the middle section of the dataset (the inter-quartile range), the variance, and the standard deviation (discussed below).

4. Variance: how far numbers in a dataset are from the mean of the dataset. It is calculated by summing the squares of the differences of each number from the mean.
5. **Standard Deviation**: a measure of how spread out numbers in a dataset are from each other. The formula is the square root of the variance, and the best way to think about it is how far the samples in the dataset are on average from the mean of the dataset.
6. **Statistical Significance**: when two datasets differ enough in their means or other measures to say that they are not the same dataset.

Engage Day 1:

1. Do a quick count of hands: Does anyone go fishing or know anyone who goes fishing on the Hudson River? Do they eat Hudson River fish?? If they don't eat the fish - why not? Students may know that the Hudson River has had problems with PCBs and may have heard about the recent dredging project, but they may not know why PCBs are a problem, where they come from, and how they persist in the ecosystem.

2. Pass out the formative assessment prompt which asks students to develop a model of how PCBs move in the environment. Give students time to complete the cartoon and explanations. Then ask student to share their ideas, either by using volunteers, in peer groups, or in a gallery walk. Here are some of the "big ideas" to look for when reviewing student responses to the formative assessment, sorted by "upper level" and "lower level" students. Upper level students will include the idea of bioaccumulation, will consider the fate of PCBs upon leaving an organism's body (through excretion or death), and will ask questions about the ways in which PCBs move in the environment including evaporation and ingestion.

Student "levels"	**What students may include in their diagrams/explanations**	**Scientific mechanism**
Upper level student	1. PCBs attach to sediment particles and can be suspended in the water column. 2. Primary consumers accumulate PCBs through eating contaminated sediment. 3. PCBs attach to fatty tissue in organisms and accumulate. Some PCBs will return to the environment through waste (poop). 4. Larger fish will eat smaller fish and invertebrates, and thus accumulate PCBs. 5. People will eat the fish and accumulate PCBs. 6. PCBs can also evaporate into the air, and be taken up by plants.	• PCBs are incredibly stable molecules, but behave differently depending on the number of chlorine atoms - "lighter" PCB molecules are more likely to enter the atmosphere through evaporation, for example. • Primary consumers, such as benthic invertebrates, are after the organic components of sediment - therefore, as they eat, some of the PCBs will be discharged with the waste sediment, while some will enter into the body in the gut as the organic material is broken down. • PCBs accumulate in the fatty tissue of organisms, although

		some is lost through waste.
Lower level student	1. PCBs move from the factory into the water. 2. Small fish eat the PCBs. 3. Larger fish eat the smaller fish containing the PCBs. 4. People eat the larger fish and accumulate the PCBs.	• Most students intuitively understand the concept of bioaccumulation. However, they probably do not think about other pathways of the PCBs, such as whether PCBs are excreted. • Lower level students likely think of PCBs as something that gets "eaten" outright, instead of being attached to a sediment particle. • Students might not be aware of the importance of plankton acting at the 'base' of the food chain. • Students likely are not thinking about the persistence of a compound like PCBs.

Then, explain that: "Today, we will be looking at data about PCB contamination in striped bass from the Hudson River."

3. Either read the background reading in class, or assign it as homework.

Explore - Day 2:

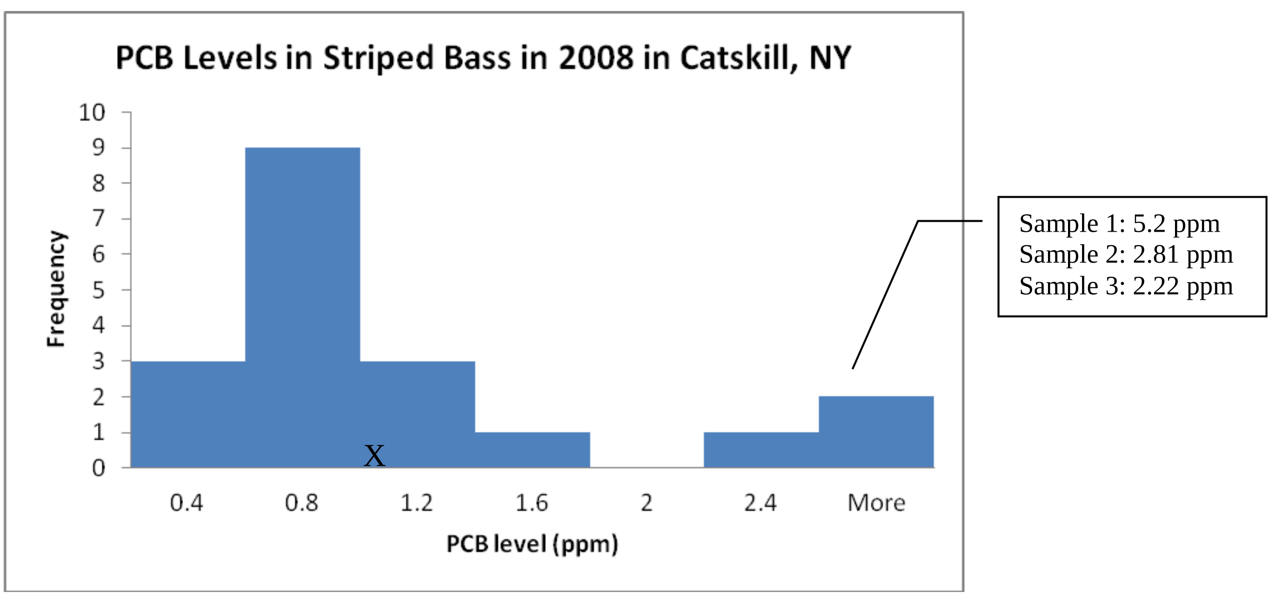
1. Ask students to complete Part 1 (reading questions) to gain background knowledge about the Hudson River and PCBs. An answer key is provided with this lesson.
2. There are a number of online videos that can be used to highlight different aspects of the PCB story; here is an example:
    a. Dredging video: https://www.youtube.com/watch?v=O639E5ppQlg
    b. EPA PCB site: https://www3.epa.gov/hudson/cleanup.html
3. For the last question about the Hudson fish advisory, students can answer it on their own with an internet-ready computer, visit the site as a class, or use the handout. The goal is to familiarize students with two concepts - that there is an acceptable level of PCBs, or a supermarket standard set by the FDA for fish sold in stores. They will also be introduced to how the fish advisory is set up: there is different advice depending upon who is going to eat the fish, where they catch it and what type of fish they catch. In this exercise, the students are going to explore some of the data from the Hudson fish that is the basis for the advice:
    a. FDA: 2ppm PCB supermarket standard – fish with PCBs above this level cannot be sold in stores
    b. Hudson River advisory: No one should eat fish from the Hudson River from the contamination site to the Troy dam. Women under the age of 50 and children under the age of 15 should NOT eat fish from the Hudson River.
    c. For men over the age of 15 and women over the age of 50, it depends on the type of fish and the location. From Troy to Catskill, (Albany, Rensselaer, men over 15 and women over 50 are advised to only eat four species of fish up to once a month. South of the Rip Van Winkle Bridge at Catskill many fish can be eaten up to once a month

and blue crabs can be eaten up to four times a month. . People should not eat any catfish, walleye, gizzard shad, or crab/lobster tomalley (the green stuff! which is like a liver in a crab).

Explain – Day 2:
Use the PCB reading to gain background knowledge about PCBs in the Hudson River.

Explore - Day 3:

1. Explain to students that they will be taking "samples" – in the form of cards – from the Hudson River in order to understand more about the PCB levels in different striped bass.
2. Hand out an envelope to each small group.
3. Students should take a sample of three fish (cards) from the envelope (the Hudson), record the PCB level for each and calculate an average.
4. Then, students will share their averages with the class, and record each sub-group's average on the chart (question #4).
5. Students should calculate the class mean (mean of the means), and answer the questions (#5-7) to reflect on whether having more samples changes their initial answer about whether fish are healthy to eat.
6. Pause here and ask students to discuss how their individual averages compare with those from the other groups - what might make one group's average higher than another?
7. Next, students should graph ALL of the data that are in the envelope, using the frequency histogram provided. Students should label the values that are above 2.0 ppm in order to recognize how high the PCB levels are in some fish. They also should calculate the mean for the entire sample and either write it on their graph, or mark it's location (e.g,. with an X or vertical line) at the appropriate point along the x axis. The mean for 2008 is 1.09 ppm. The graph should look like this:



8. Students calculate the probability that, from this sub-set of fish, they would catch a fish that has a PCB level above 2.0 ppm.

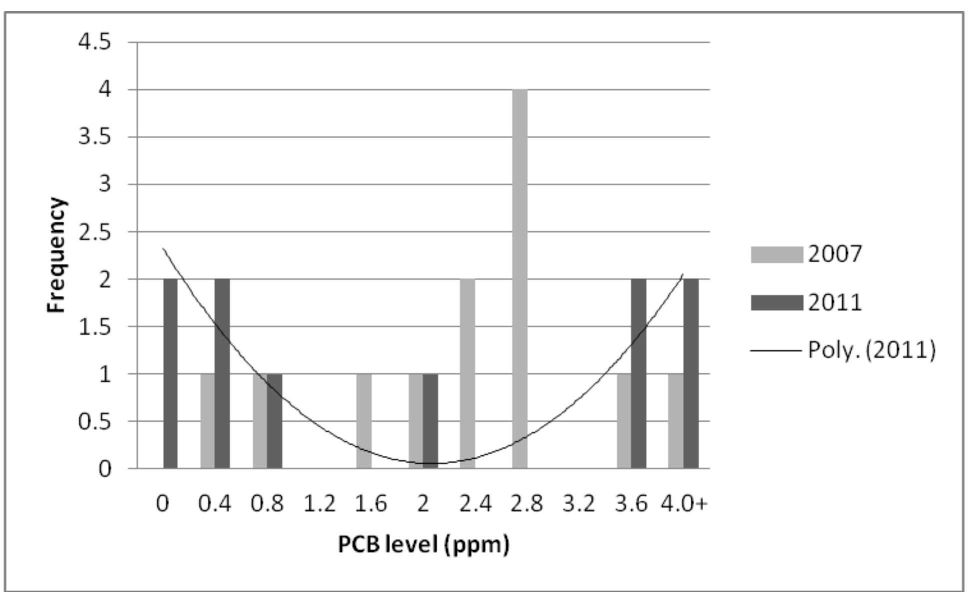
9. Students should reflect on whether these additional data change how they feel about eating striped bass from the Hudson. Ask: Are you concerned that once in a while, you might get a fish that has a really high PCB level? What if you eat five fish in one year, and each fish happens to have a really high level? See if students can connect the idea of bioaccumulation with their own consumption.
10. Next, students will look at data for striped bass sampled in 2002 at the same location. They are asked to compare this data set with data from 2008.
11. Then, students try to explain which year has more, or less, variability.
12. Students look at the summary statistics (mean, probability) and think about what this tells them about the data
13. Finally, students look at data from two years at Troy. There is more variability in the 2011 data, while the overall means are essentially the same.
14. Students should reflect on what they've learned about PCBs and eating fish from the Hudson River. Ask students whether they would be willing to eat striped bass from the Hudson River, based on what they've learned. The students may start to draw conclusions about varying contamination at different locations as the Troy means are a lot higher than the Catskill means. The NYSDOH fish advisory allows men to eat striped bass up to once a month from Catskill south, but not from Catskill north to Troy.
15. Highlight the need for additional data - more years, more locations, more fish - if students do not discuss this in response to the last question on the worksheet: "What else would you need to know in order to make a decision [to eat striped bass from the Hudson River]?"

Explain –Day 3:

1. ***Science:***
    a. Small organisms in the river take up PCBs through direct absorption from the water or sediments, or in the course of taking in particles as food. Some or most of the PCBs they take up remain in their cells.
    b. Fish accumulate PCBs in their bodies by eating smaller organisms that contain PCBs. Fish like striped bass also migrate throughout the estuary, with adults spending the majority of their lives in the New York Harbor or open ocean. Consequently, PCB levels will vary based on the size and age of the fish, the location where it lives and has lived, what it eats, and the lipid (fat) levels. Explain the striped bass graph in Figure 3 as described in Preparation for this lesson.
2. ***Data literacy:***
    a. This lesson helps students see how they can use data to evaluate a claim, in this example, “How likely is it that striped bass caught near where I live on the Hudson River will be above the FDA supermarket standard of 2 ppm?” They are given data from a sample of striped bass at a specific location and year, and the established benchmark of 2 ppm above which fish cannot be sold in a store. Taking just a small sub-sample from the larger data set, they calculate the average and compare it to the benchmark. It is important for students to appreciate that they are using a sample and its mean to estimate the actual population mean of all the fish in that location at that time. <u>It is the population mean that is the best predictor of what anglers catching and consuming fish at that location will encounter.</u>

b. Then, students compare their result with others, and they will see that some groups may have selected fish that averaged below the federally acceptable level of 2 ppm but other groups may have had fish that had a high level of PCB contamination. This should lead them to be wary of their ability to evaluate the claim based on such a small sample size, and to see the benefit of more and/or larger samples in order to estimate a mean.
c. Students create a frequency histogram of the data points, and also calculate the overall mean for the entire sample. When they compare their individual subsample means, and the mean of the subsample means to the actual mean, they should see that small samples can be quite far from the actual mean, and that the mean of the means is much closer. This should help them understand the relationship between a sample estimate of the mean and the actual population mean. The graph should help them visualize why their means varied from the overall mean – to see the spread of the actual data. Ideally, students will begin to get comfortable with looking at a frequency diagram or "distribution" like this, since it contains a lot of information about the underlying thing being measured – in this case, PCB levels in striped bass.
d. This exercise should help students think about the importance of extremes in influencing the mean, since those subsamples that did not include one of the highly contaminated fish would have much lower means than the ones that did include these fish.
e. When looking at the Troy data, students consider what variability tells them about a data set by comparing datasets with different variability.

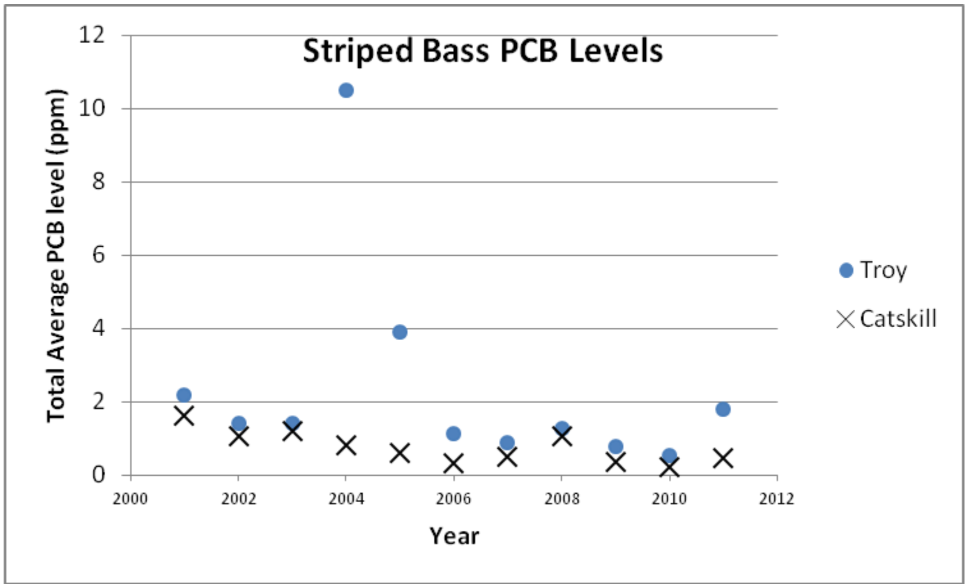
- In the first example, the mean in 2002 is slightly less than the mean in 2008, but 2008 had a slightly higher variability than 2002. There is a little more variability in the 2008 data, but these years are fairly similar. In the second example, 2011 had more variability than 2007. If you look at the frequency histogram for 2011, it has a more bimodal distribution (more high and low data points and fewer near the mean), while the 2007 data are more normally distributed.



f. New York State uses a more cautious approach to its advisories than the federal limit.

Extend:

1. Ask students about the sample size of fish that they have been looking at - point out that for all four years, less than 20 fish were part of the sample. Discuss with students the potential tradeoffs - a larger sample would mean spending more time and effort (and money!) to catch fish, but would provide a better understanding of whether striped bass from a given year are safe to eat.
2. Consider showing your students a trend over time. Here are yearly averages for striped bass data at the two locations explored in this lesson:



Students should notice that in 2004, the total average PCB level was very high in Troy (10.5 ppm). This is due to a few fish that had very high levels of contamination - one fish had PCB levels of 36.6ppm, while a second had a PCB level of 115.96ppm. Ask students to consider how they would feel about eating fish from the Hudson River at Troy if they only had 2004 data.

Evaluate: Using exit slips, ask students to answer the following: Is it safe for you to eat striped bass from the Hudson River? Explain your answer.

<u>New York State Science Learning Standards</u>

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. *[Clarification Statement: Emphasis is on recognizing patterns in data and making warranted inferences about shifts in populations due to changes in the ecosystem.]*

Science and Engineering Practices	Disciplinary Core Ideas	Cross-Cutting Concepts
1. Asking questions and defining problems	LS2A: Interdependent Relationships in Ecosystems	1. Patterns
3. Planning and carrying out investigations	LS2C: Ecosystem Dynamics, Functioning and Resilience	3. Scale, proportion, quantity
4. Analyzing and interpreting data	LS4D: Biodiversity and Humans	4. Systems and system models
5. Using mathematics and computational thinking		7. Stability and change
7. Engaging in argument from evidence		

References:

Farley, K. et al. 2006. Transport, Fate, and Bioaccumulation of PCBs in the Lower Hudson River. In Levinton & Waldman, editors, *The Hudson River Estuary*, Cambridge University Press.

Secor, D. 2013. Striped Bass Habitat Use and Migrations in the Lower Hudson River Estuary. Final report to the Hudson River Foundation.