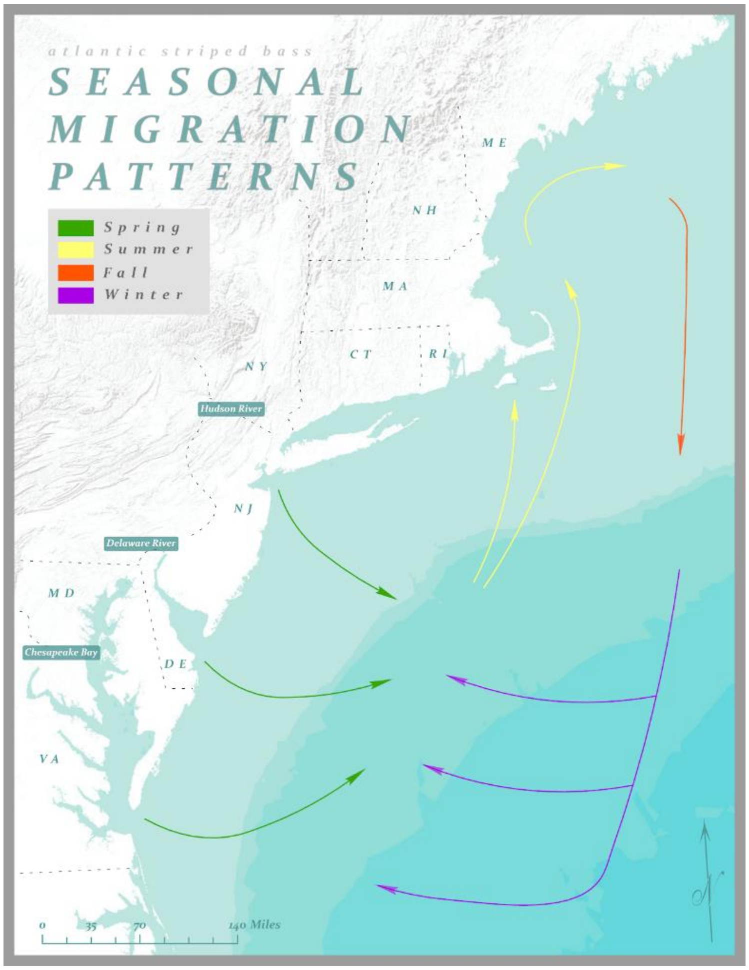
Striped Bass: A Regulatory Success Story

A Teaching Module by: Alex McCrickard, Amanda Thompson, and Angela Hanretty

Case Study - Striped Bass

The Atlantic Coast Striped Bass (*Morone saxitilis*), also commonly known as Striper or Rockfish, is native to the Atlantic coastline of North America ranging from the Gulf of St. Lawrence in Canada all the way south to the St. John's River near Jacksonville, Florida. Striped Bass are most prevalent from the coast of Maine to North Carolina, and most often spawn in freshwater rivers and streams of the Chesapeake Bay. Map 1 below displays Striped Bass seasonal migration patterns in the region.



Map 1: Map of seasonal migration patterns of striped bass

The Atlantic Coast Striped Bass is an anadromous fish, meaning that it spends most of its time in the saltwater but returns to freshwater rivers and streams to spawn. After hatching, juvenile Striped Bass spend approximately three years in estuaries or freshwater habitats before migrating to the ocean where they mature for anywhere from five to seven years (NOAA, 2018). When water temperatures start to rise in the spring, mature fish make the journey back into the freshwater estuaries to spawn (Map 1). Freshwater streams and rivers of the Chesapeake Bay are the preferred spawning grounds of Atlantic Coast Striped Bass. Fish that do not return to estuaries to spawn typically migrate North up the coast for the summer season, returning to the Southern coastline in the fall. Since the 1700s, Striped Bass have been a top recreational sportfish for East Coast fishermen because of their size, often weighing up to 50 pounds, and their fighting ability.

History of the Striped Bass Industry

Since the days of early colonization in America, fisherman valued Atlantic Coast Striped Bass as a very profitable resource. Steady Atlantic and West Indies trade and rapidly growing demand for food in accordance with rising population brought about the early commercial fishing efforts. In 1670, Plymouth County established one of the first public schools in America using income from thriving coastal striped bass fisheries. Striped bass were so abundant during this time that they were also used as agricultural fertilizer. As innovative fishermen continued to employ new technology to harvest considerable amounts of striped bass, commercial fishing rapidly expanded in the late 19th and early 20th centuries ("All About Striped Bass, 2008"). Briefly, when World War II began, military demands for personnel reduced the commercial fishing effort. Following the conclusion of the war, much of the equipment produced during the war effort was utilized in the commercial fishing industry and striped bass harvests increased substantially. Recreational fishermen began to organize Striped Bass fishing tournaments as well.

Landings of striped bass peaked in 1973 at a reported 14.7 million pounds ("All About Striped Bass, 2008"). In addition to the commercial overharvest occurring in the beginning of the 20th century, continuing construction of fish passage barriers such as dams prevented Atlantic Coast Striped Bass from reaching their spawning habitats. Catch rates continued to drop throughout the mid to late 1970s. The combination of overfishing and habitat destruction caused the Atlantic Coast Striped Bass population to spiral downward, and in 1983, the fishery catch reported was down to 1.7 million pounds ("All About Striped Bass, 2008").

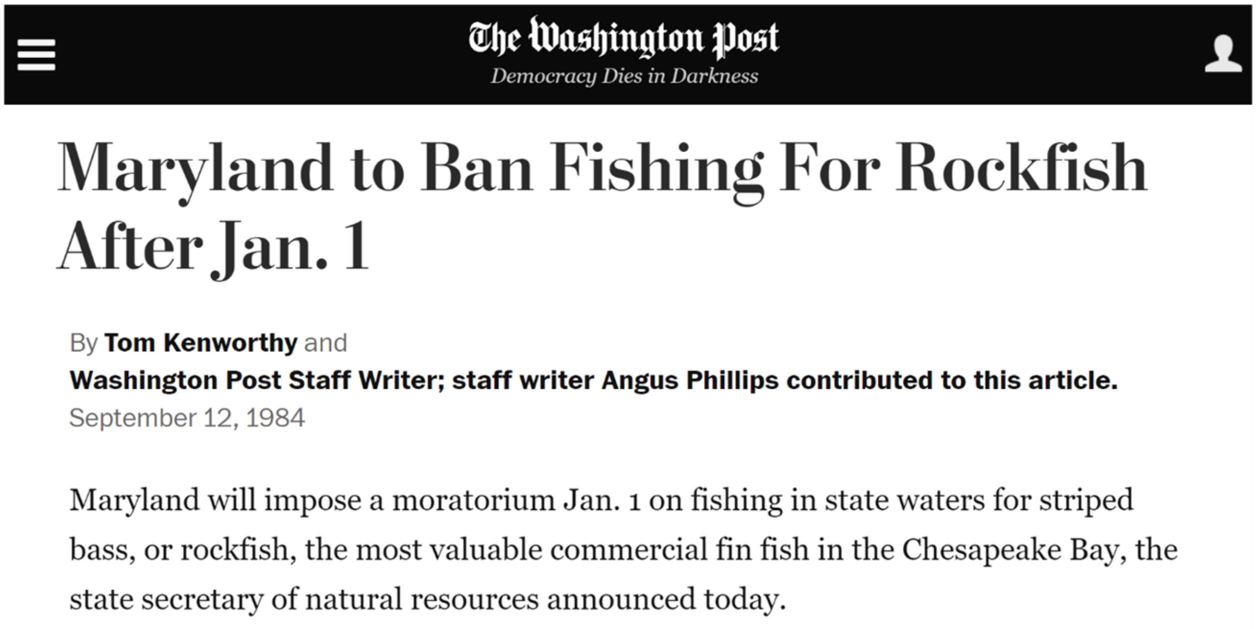
Pre-Moratorium

Figure 1: McCrickard, Alex. "Striper Catch and Release." Original Photograph, 2019.

Striped Bass stocks between Maine and North Carolina are managed by the Striped Bass Management Board of the Atlantic States Marine Fisheries Commission (ASMFC) (http://www.asmfc.org/). The ASMFC was formed in 1942 as a response to a dire need for a state, commercial and recreational cooperative commission that balanced both economic and environmental considerations for fisheries goals on the east coast. The commission includes three representatives from each state; one representative of the commercial industry, one recreational fisherman and one from the state's department of natural resources. The ASMFC adopted an Interstate Fishery Management Plan in 1981 which was aimed at controlling fishing mortality, developing regulations to allocate and control safe harvest levels, determining stock assessment and research needs, and examining the effects of environmental conditions, such as habitats and water quality, on striped bass stocks. Within the Interstate Fishery Management Plan, minimum retainment sizes of 14" in inland waters and 24" in coastal waters were established. However, these regulations were ignored by most states until 1984 when Congress passed the Atlantic Striped Bass Conservation Act (https://www.fws.gov/laws/lawsdigest/atlstri.html). This act required the states to comply with the Interstate

Fishery Management Plan or face federal **moratorium**. A moratorium is a legally authorized postponement of an ongoing activity. In response to the **Atlantic Striped Bass Conservation Act**, many states voluntarily imposed moratorium on striped bass fishing of various lengths, while the rest changed their regulations by imposing increases in minimum size limits.

Moratorium



The Washington Post
Democracy Dies in Darkness

Maryland to Ban Fishing For Rockfish After Jan. 1

By **Tom Kenworthy** and
Washington Post Staff Writer; staff writer Angus Phillips contributed to this article.
September 12, 1984

Maryland will impose a moratorium Jan. 1 on fishing in state waters for striped bass, or rockfish, the most valuable commercial fin fish in the Chesapeake Bay, the state secretary of natural resources announced today.

In 1985, the states of Maryland and Delaware imposed a complete moratorium on striped bass fishing. This moratorium applied to both commercial and recreational fishing of the species. These fishing bans resulted in loss of jobs and revenue, and thus were a topic of heated debate among fisherman, business owners, politicians, and conservationists. Many fishermen in Maryland reported losing almost 50 percent of their income when the moratorium was imposed without warning. Spokespeople for the Maryland Charter Boat Operators Association predicted at the time that the ban would put about 30 captains in the upper bay out of business, but generally members recognize the need for the ban. Despite being unpopular at the time of its development, the ban eventually won support from both commercial and sport fishermen, who were eager for the fish stock to return.

"It took tremendous courage on the part of DNR Sec Dr. Torrey Brown and Governor Harry Hughes to declare the moratorium. The watermen's lobby was dominant but science is what convinced Dr Brown and Governor Hughes that drastic action was necessary, especially the YOY, the spawning ground survey, and fishery data. Also, the growing concern of some in the 1970s built into the emergence of the recreational fishing lobby in the form of the MD Saltwater Sportfishermen's Association which is now defunct. The MSSA organized a march on the State House for a moratorium that gave Governor Hughes and Dr. Brown a bit of political cover. The moratorium occurred and in 1989 the YOY reached 24 and met the criteria of a 3-year average of 8, and the fishery reopened, albeit gradually, beginning the next year."

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Bill Goldsborough, Director of Fisheries for the Chesapeake Bay Foundation. Bill spent 33 years with the Chesapeake Bay Foundation, promoting sound science based management of Chesapeake Bay fisheries.

During the moratorium, marine scientists with the USFWS coordinated a restocking effort to help the Striped Bass population rebound. The scientists used electrofishing practices to net female striped bass and transported them to hatcheries, where eggs were removed and fertilized. Juvenile hatchlings were kept in ponds until they reached six to eight inches long to improve their chances for survival in open water, and then returned to the tributaries of the Chesapeake Bay. As early as 1988, watermen began to observe the population rising of Atlantic

Coast Striped Bass in the Chesapeake Bay. Commercial fishermen fought to have the moratorium lifted, but biologists and conservationists argued that the rise of population was extremely fragile and that the threats to its reproductive processes by pollution had to be controlled before the resumption of commercial fishing.

Maryland’s Department of Natural Resources required that the YOY index reach a three-year running average of 8.0 before the moratorium would be lifted. Young-of-the-Year(YOY) indices begun to improve dramatically. In the fall of 1989, the YOY index was measured at 25.2. In accordance with target YOY survey indices, the moratoriums were lifted and restricted striped bass fishing was restored in 1990.

Post-Moratorium

October 4, 1990 began a highly-anticipated 5 week recreational striped bass season in Maryland waters. When the moratorium was lifted, recreational fishermen were limited to only two rockfish a day, or five on a charter boat, and the fish were required to be at least 18 inches long to keep. Regulations came with strict enforcements by the state, utilizing aerial watchdogs, natural resources police staged as bank fishermen, fish census-takers stationed at boat ramps, and even “covert operations” to find poachers. Marine police warned that violators could expect to receive no warnings, only tickets. Violators were told to expect to face fines up to $1,500, seizure of their boat, and even jail time in extreme cases. The commercial season was set to resume in January of 1991, but the state would issue no additional commercial licenses.

> *“I was a biologist on the Striped Bass Stock Assessment Project. It was a team of eight biologists that conducted all the field work that collected the fishery independent data including spawning stock, juvenile finfish survey (YOY), and also fishery dependent sampling from pound nets and gill nets (etc.)...None of us at the time thought the fishery would reopen anytime soon. The spawning stock biomass and YOY data from 1989 was one of the biggest year classes in fifteen years. We were shocked and many conservationists thought it was an anomaly. We reopened the fishery with brief seasons for recreational and commercial anglers and the spawning stock and YOY were intensely monitored. It was eye opening to say the least.”*
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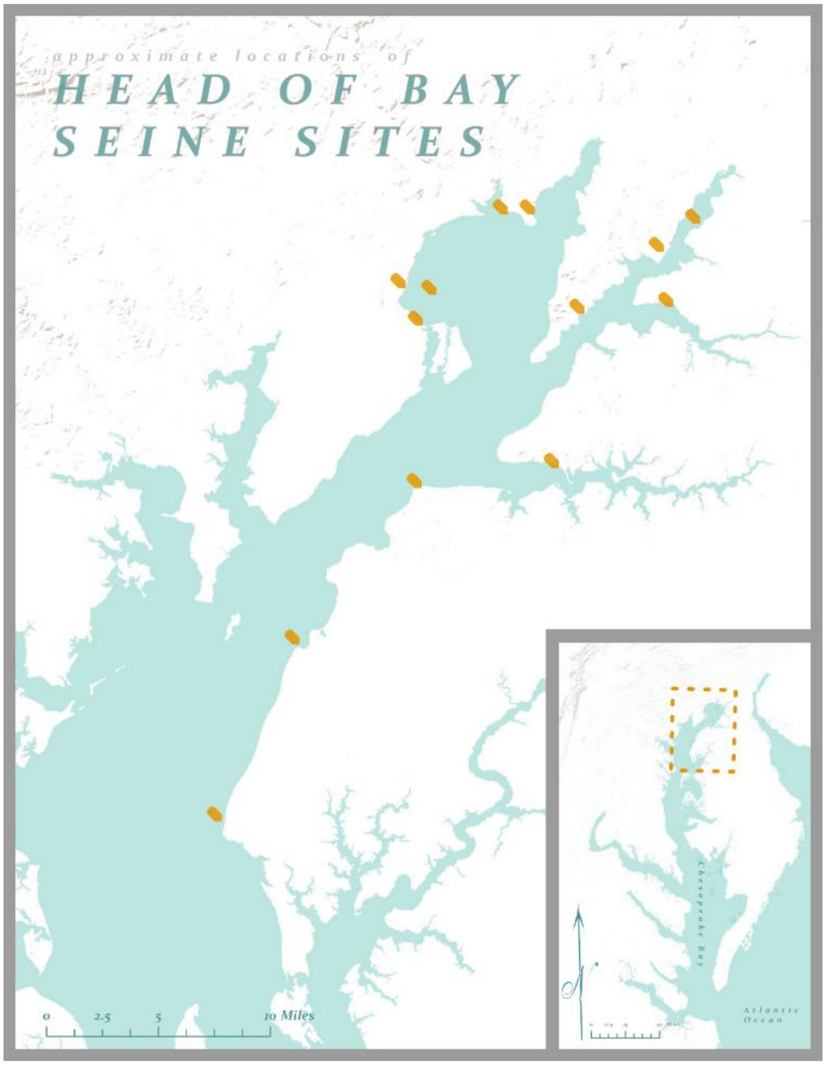
> *Martin Gary, a fisheries biologist for Maryland DNR at the time of the moratorium. Martin is now the executive secretary of the Potomac River Fisheries Commission.*

Stock of Atlantic Coast Striped Bass was formally declared to be recovered in 1995, and has since been maintained by monitoring, quotas, and seasonal closings. In continuing efforts to protect the Atlantic Coast Striped Bass stock, the minimum size of legal catch was increased, and tournaments were banned during spawning season as of 2006. Atlantic Coast Striped Bass stocks significantly rebounded since the 1970’s, and this species is considered a “poster child’ for successful interjurisdictional fishery management.

Data Introduction



Map 2: Map of Seine Sites in 'Head of Bay' survey area

Because the freshwater rivers and streams of the Chesapeake Bay are the most common spawning areas for the Atlantic Coast Striped Bass, most research on population of this species has been conducted within the bay. Since 1954, Maryland's Department of Natural Resources has been sampling striped bass at twenty-two sampling stations within the state's portion of the Chesapeake Bay. The stations are divided among four major spawning and nursery areas; the Potomac River, Head of Bay, Nanticoke River and Choptank River. During the months of June, July, and August, sampling rounds consist of replicating seine hauls at each site, totaling 132 samples contributing to calculation of bay-wide means. At each seine site, a 100-foot long net is deployed perpendicular from the shore and swept with the current. All fish are identified and counted on site, and body measurements and scale samples are taken for age verification, to ensure that only the age zero (or YOY) fish are counted. The juvenile striped bass index is then counted as the average number of YOY striped bass per sample. For the purpose of our lesson, we'll be evaluating data collected from the Head of Bay seine sites. The Head of the Bay area includes the southern reach of the Susquehanna River flats, which is a very popular spawning zone for the striped bass. Take a look at Map 2: Map of Seine Sites in 'Head of Bay' survey area that includes seven permanent sampling sites and six auxiliary sampling sites that make up the Head of Bay sampling area. Note that auxiliary sampling stations have not been sampled on a consistent basis and are not included in survey indices.

Geometric Mean Catch

The data that we will be working with for this lesson includes relative abundance of Atlantic Coast Striped Bass YOY presented as Geometric Mean Catch per haul. Geometric Mean Catch is a calculated average which indicates the central tendency of a set of numbers by using the product of their values. In other words, the geometric mean is calculated by finding the nth root of the product of n sample values. This differs from Arithmetic Mean Catch, which we know is simply the sum of all of the sample values divided by the number of samples. Geometric Mean Catch has been adopted by the ASMFC as the preferred index of relative species abundance because it is not as sensitive to a single large sample value. See the different means calculated below, using the same set of values, and notice the influence of the single large sample value.

Geometric Mean	Arithmetic Mean
$14 \cdot 2 \cdot 3 \cdot 3 \cdot 3 \cdot 2 = 1512$	$14 + 2 + 3 + 3 + 3 + 2 = 27$
$\sqrt[6]{1512} = 3.39$	$27 \div 6 = 4.5$

Our Hypothesis

If a moratorium is placed on a significantly decreasing Atlantic Coast Striped Bass population, the population will rebound.

Exercise

The exercise below can be used with or without the use of R Studio for statistical analysis. If you would like to utilize the R Studio then make sure to review the “working with data in R below.” If not you can continue on with this document.

Pre-Requisites

Students should have taken an undergraduate class in statistics and have an understanding and ability to interpret linear regression. If you are doing the R version, students should have working knowledge of the RStudio environment (if you need a refresher on R, check out this video https://www.youtube.com/watch?v=lVKMsaWju8w)

Optional - Working with data in R

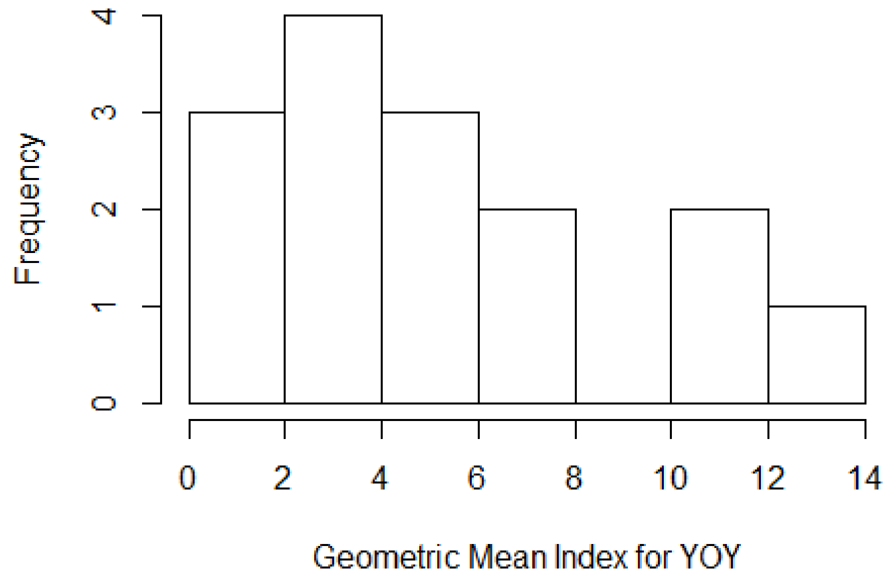
For this lesson, we’ll be using the programming language R inside the open source RStudio platform to evaluate trends in the Atlantic Coast Striped Bass data before, during, and after Maryland’s 5-year moratorium. We have prepared code in markdown format for you, but you’ll need to set up your working environment with the data and make sure you have the ‘readr’ package installed. Once you’ve set everything up in RStudio, follow the instructions in the ‘Striped_Bass_YOY_Exercise’ markdown file. Answer your questions inside the markdown and when you’re finished, knit the completed exercise with your interpretations and answers into a Word document for submission.

Exercise Introduction:

Lets investigate the Maryland Striped Bass Young of Year (YOY) survey data. For this exercise we will utilize the YOY survey data from the Upper Chesapeake Bay. The Upper Chesapeake Bay, including the Susquehanna Flats, are the largest spawning grounds in the entire bay. Using least squares linear regression, we will see if there is a linear relationship between YOY Index and year based on three time intervals. Imagine that you are a fisheries biologist, working for the Maryland Department of Natural Resources (MDNR), trying to infer overall striped bass population conditions based on YOY surveys which tend to shed light on spawning success. As a biologist, it's essential that you can utilize your data to make informed management decisions for the future of the fishery. Let's jump in and take a look at one major piece of data that influenced the Striped Bass moratorium in Maryland (1985-1989). Follow along parts one through three and provide short answers to the questions throughout this exercise.

Part 1: Pre-Moratorium (1970 – 1984)

Lets visualize the data. Its important to test for normality in the data before running a linear regression. We will conduct a shapiro-wilke normality test.



Shapiro Test Results

```
W = 0.90423, p-value = 0.1105
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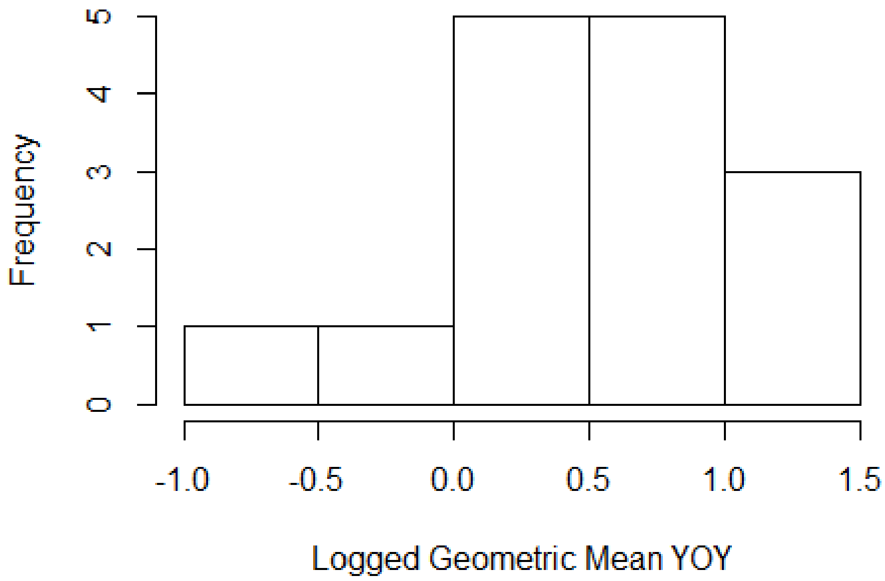
Hint: remember if the p value is less than 0.05 then the probability that the data is distributed normally is very low.

We can attempt to transform the data to see if normality is improved.

Lets log transform the data to see how it behaves.

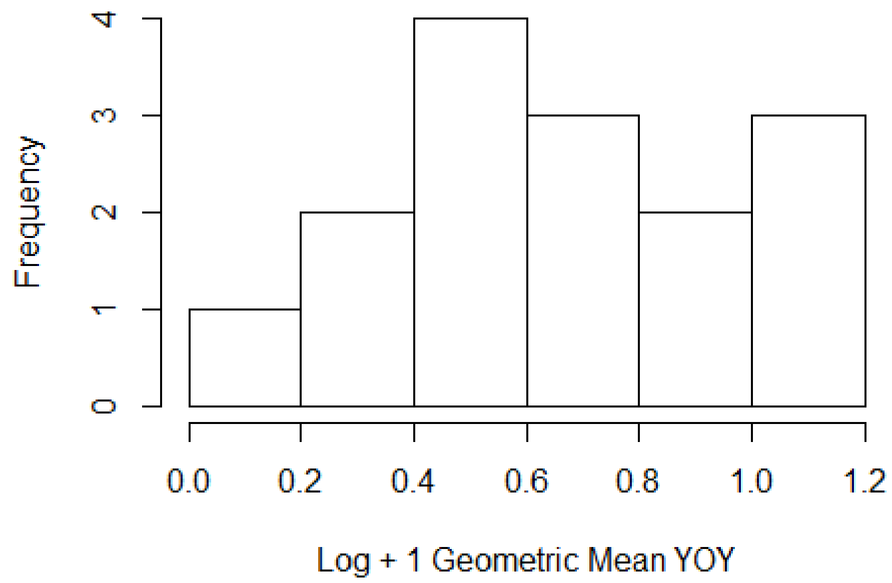
Sometimes, a log transformation can improve normality when performing parametric statistics and visualizing linear relationships.



Question 1. Do you think the data appears to be more normally distributed after the log transformation? What issues may have occurred with the YOY data after log transforming?

Answer: From a visual standpoint, the data appears to be more normally distributed (bell shaped curve) after being logged. However, notice we now have negative logged geometric mean values for YOY. This is an issue because we cannot catch negative striped bass YOY.

If negative values are present in your data after a log transformation, you can try to complete a log transformation + 1.



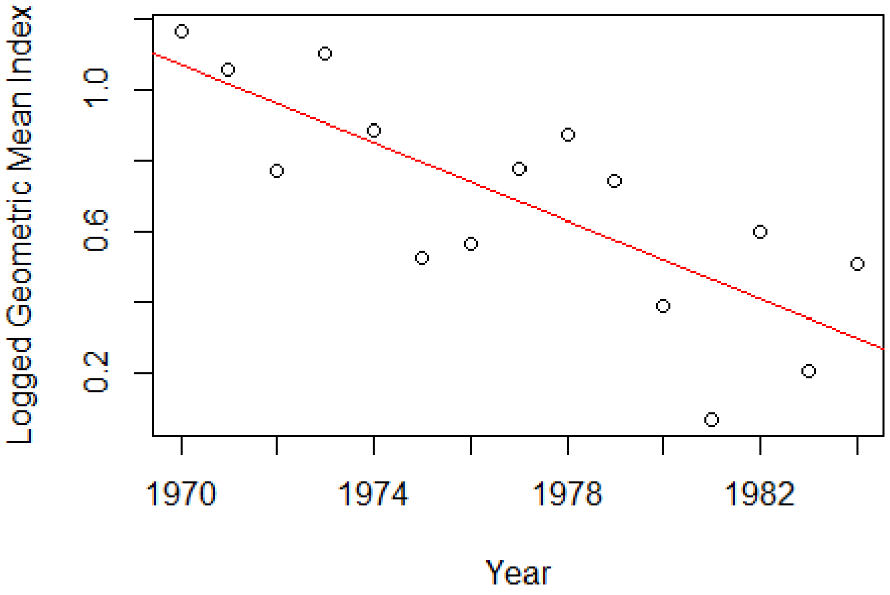
Shapiro Test Result

W = 0.97145, p-value = 0.8789

Question 2. Based upon the histogram and Shapiro-Wilkes normality test, did the log + 1 transformation improve the data? What can you infer about the data based on the p-value?

Answer: The log + 1 transformation has gotten rid of our negative YOY values. This transformation has also improved normality as our p-value has increased from 0.1105 to 0.8789.

Now that our data are conforming to assumptions of normality, we can continue with a parametric approach to analyze the striped bass population decline. Below you will see a linear regression on the log + 1 transformation of the geometric mean index for YOY striped bass (Dependent Variable) as a function of Year (Independent Variable).



```
## Residual standard error: 0.2086 on 13 degrees of freedom
## Multiple R-squared:  0.6023, Adjusted R-squared:  0.5717
## F-statistic: 19.69 on 1 and 13 DF,  p-value: 0.0006702
```

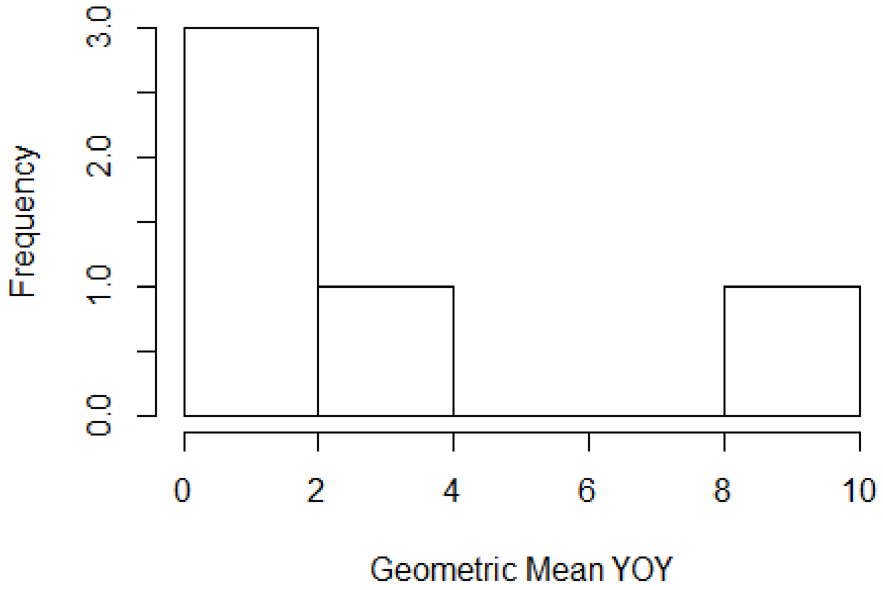
Question 3. Based upon the linear regression above, is the model statistically significant? Don't forget to utilize the p value and Adjusted R-Squared value in your explanation. Based on what you know about YOY as indicators of population stability, do you think the data raises concerns about the future of striped bass? As a fisheries biologist, what conclusions would you draw from this plot and how would these conclusions influence management decisions? (Hint: make sure to include trends with model summary)

Answer: The linear model above is statistically significant with a very small p-value of 0.0006702. Year alone is describing 57 percent of the variation in our geometric mean index for YOY based off our adjusted R-Squared value. This trend raises concern as numerous years of declining YOY shows a lack of reproductive success for Striped Bass. A lack of recruitment is a serious concern for the future of the fishery. Commercial and recreational overfishing of striped bass in the early 1970s is paralleling a steady decline in recruitment of the species. Extremely low YOY in the late 1970s and early 1980s raises red flags and calls for management action.

Part 2 – Moratorium (1985 – 1989)

Again, its important to make sure your data are normal before conducting a parametric model. However, keep in mind that our sample size is very small and deviations from normality may be hard to detect.

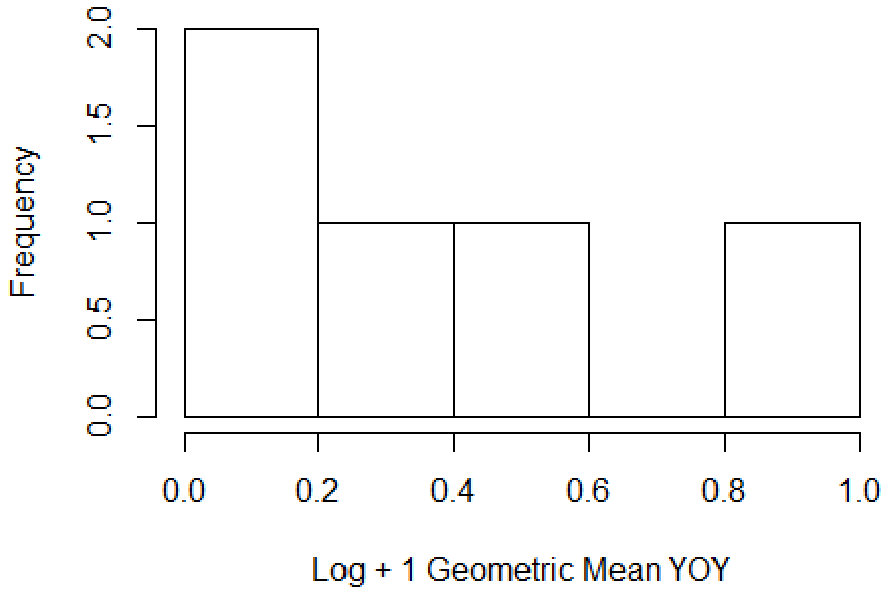
Lets visualize the YOY data unlogged first.



Shapiro Test Results

```
W = 0.73801, p-value = 0.02296
```

Now lets visualize the data logged.



Shapiro Test Results

W = 0.87878, p-value = 0.3038

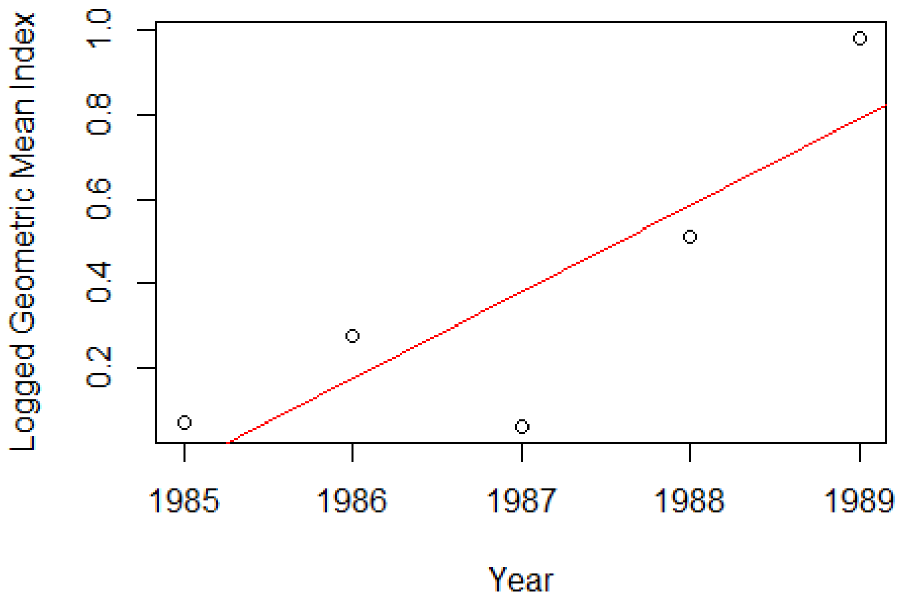
Question 4. Did the log transformation improve the data? Utilize the p-value in your answer.

Answer: The log + 1 transformation has improved the normalcy of the YOY data. The p-value increased from 0.02296 to 0.3038. We can now proceed with a parametric linear model.

Running a linear regression for the 5 moratorium years

Linear Regression Model

Now that our data are conforming to assumptions of normality, we can continue with a parametric approach to analyze the striped bass population over the moratorium years. Look at the least squares linear regression below showing the geometric mean index for YOY striped bass (Dependent Variable) as a function of Year (Independent Variable).



```
## Residual standard error: 0.2329 on 3 degrees of freedom
## Multiple R-squared:  0.7191, Adjusted R-squared:  0.6255
## F-statistic: 7.681 on 1 and 3 DF,  p-value: 0.06948
```

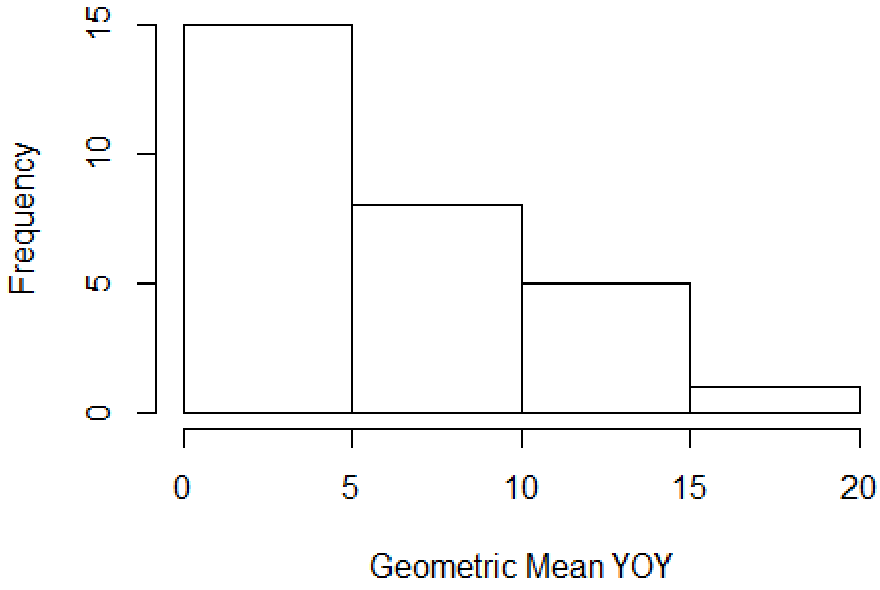
Question 5: Based upon the linear regression above, is the model statistically significant? Don't forget to utilize the p value and Adjusted R-Squared value in your explanation. Based on what you now know about striped bass and YOY as indicators of population stability, what is your interpretation of the data? Why was there an increase in striped bass YOY in 1989? As a fisheries biologist, what conclusions would you draw from this plot and how would these conclusions influence management decisions? (Keep in mind, fisheries decisions were based on the data from these 5 moratorium years)…

Answer: The model above is not statistically significant as the p value is 0.06948 which is greater than 0.05. However, year alone is describing 63 percent of the variation in our geometric mean index for YOY based off our adjusted R-Squared value. Although we only have 5 data points here, the trend clearly shows an increase in striped bass recruitment. It takes at least 4 years for a striped bass to become reproductively mature. The fish that were YOY in 1985 were protected through the moratorium. In 1989 those fish reached reproductive maturity and spawned for the first time. This is why we are seeing such a high number for geometric mean index for YOY in 1989. This result triggered the end of the moratorium as recruitment rebounded. Keep in mind that a linear regression on only 5 data points has low statistical credibility but is something that scientists may need to do from time to time.

Part 3 - Post Moratorium (1990 – Present)

Again, its important to make sure your data are normal before conducting a parametric model. However, keep in mind that our sample size is very small and deviations from normality may be hard to detect.

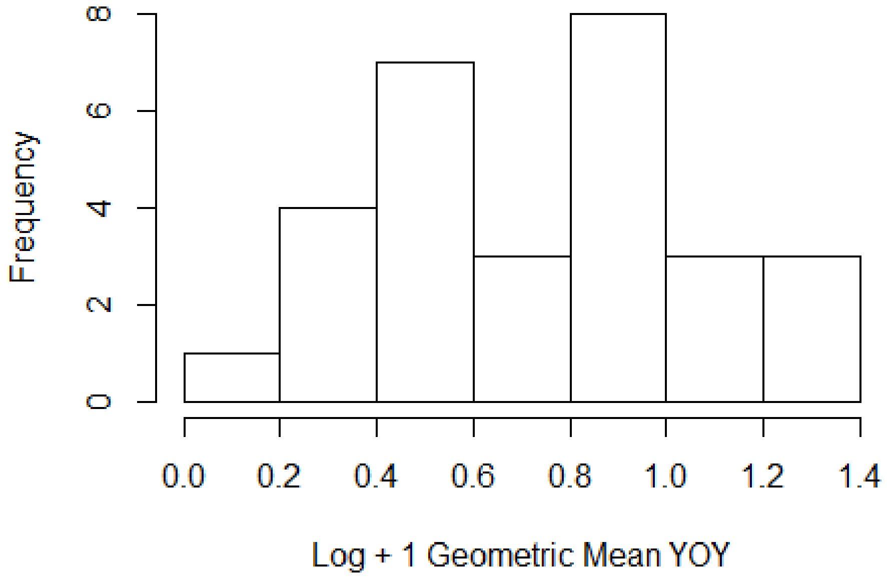
Lets visualize the data unlogged first.



Shapiro Test Results

data: GM_Post_Moratorium_YOY$GeomeanIndex
W = 0.889, p-value = 0.005396

Now lets visualize the data logged.



Shapiro Test Results
W = 0.96007, p-value = 0.33

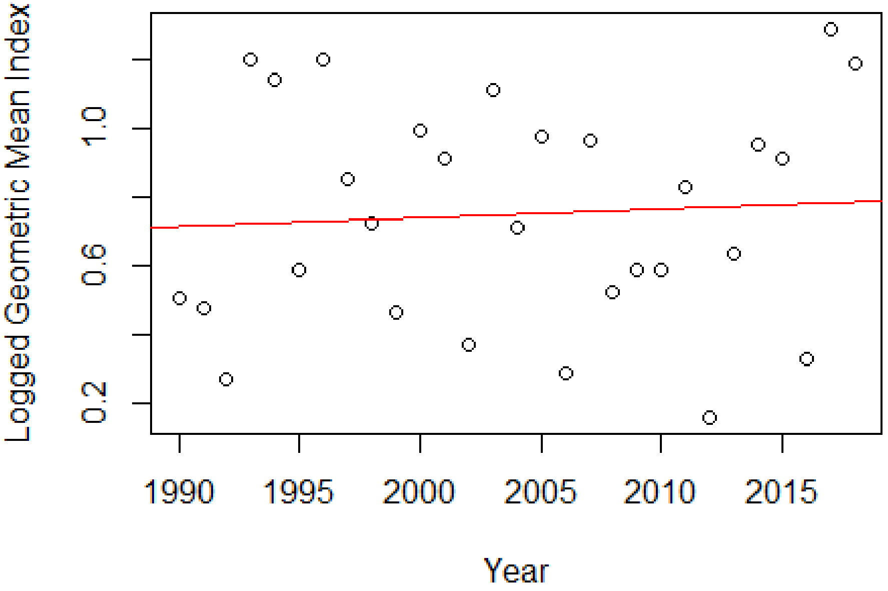
Question 6. Did the log transformation improve the data? Utilize the p-values in your answer.

Answer: The log + 1 transformation has improved normality as our p-value has increased from 0.005396 to 0.33. We can now proceed with a linear approach.

Now we will run a linear regression for Post-Moratorium years…

Linear Regression Model

Now that our data are conforming to assumptions of normality, we can continue with a parametric approach to analyze the striped bass population post moratorium to present day. Look at the linear regression on the log + 1 transformation of the geometric mean index for YOY striped bass (Dependent Variable) as a function of Year (Independent Variable).



```
## Residual standard error: 0.3283 on 27 degrees of freedom
## Multiple R-squared:  0.005086,   Adjusted R-squared:  -0.03176
## F-statistic: 0.138 on 1 and 27 DF,  p-value: 0.7131
```

Question 7. Based upon the linear regression above, is the model statistically significant? Don't forget to utilize the p value and Adjusted R-Squared value in your explanation. What is your interpretation of the data? As a fisheries biologist, what conclusions would you draw from this plot and how would these conclusions influence management decisions? Based off the YOY data, does the population appear to be decreasing, increasing, or stable? Strongly consider interannual variability and trends when assessing this. What factors could impact interannual variability in spawning success?

Answer: The linear regression above is not significant as our p-value is 0.7131. The slope is not different from zero and there is no evidence that the population is increasing or decreasing. Therefore we can infer that the YOY appears to be stable since 1990. Year is not describing the variability in YOY. The interannual variability highlights that some years the recruitment is better than other years. Its difficult to tell if the population is increasing or decreasing as the data is so variable. The important thing is we are not seeing numerous years in a row of declining YOY. Numerous factors could impact spawning success from annual precipitation and sediment to conditions in YOY nursery habitats. Also, keep in mind that YOY isn't the only indicator of population status.

Fisheries biologists use spawning stock as well as regular population estimations to assess conditions for different species.

Question 8. Based off our question, was our hypothesis supported or not? Looking at all of this information, do you think the moratorium was effective? As a fisheries biologist would you have done anything differently (shorter vs longer) in regards to the moratorium? (hint: think about policy, stakeholders, and the limitations of our data)

Answer: Our hypothesis was supported in this fisheries management success story. The moratorium was effective and essential to the health of the Atlantic coast striped bass fishery. As a fisheries biologist you have to consider science and differing stakeholder views. Finding a balance to promote productive policy is a challenge and this example is certainly no exception. When the moratorium was lifted the fishery was monitored intensely. In all, this is a prime example of a fisheries management success.

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Data

Maryland Department of Natural Resources
https://dnr.maryland.gov/fisheries/Pages/striped-bass/juvenile-index.aspx

Photos

News Headline from The Washington Post on September 12, 1984
https://www.washingtonpost.com/archive/politics/1984/09/12/maryland-to-ban-fishing-for-rockfish-after-jan-1/d29a6a06-acc6-46c5-afd7-ea79869fca52/?noredirect=on&utm_term=.1684cdcb31ba

Bill Goldsborough Photo

https://cbf.typepad.com/bay_daily/2013/02/maryland-governor-martin-omalley-this-week-heaped-praise-on-the-chesapeake-bay-foundations-fisheries-director-bill-gol.html

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Juvenile Striped Bass

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Maps

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