Celia Jacobs, Alyssa Milton, Ketan Prunet, Jasleen Narula, Elizabeth Beling
Dr. Eri Saikawa
ENVS 326
10 December 2020

Striped Bass: An Overview on Population Health and Anthropogenic Threats to the Species

Research Question:

Why are Atlantic striped bass migrating northward and what conditions affect their populations and migration patterns?

Introduction:

This paper evaluates the Atlantic striped bass, with a particular focus on contemporary research about fluctuations in striped bass populations. Firstly, we examine the basic taxonomy of striped bass and provide an overview of their distribution. Additionally, the first section of this paper aims to evaluate the history of striped bass, primarily how striped bass populations declined dramatically as a result of overfishing until legislative efforts to conserve striped bass populations resulted in a resurgence of the species.

Secondly, this paper evaluates more contemporary research on striped bass with a focus on research by Dr. Wilson Laney, an adjunct assistant professor at North Carolina State University and striped bass expert. Dr. Laney's research has demonstrated that striped bass have begun to move further offshore. While there is still much research necessary to provide evidence for a strong conclusion, some scientists speculate that this shift may be because climate change has raised temperatures in surface waters where striped bass would normally inhabit. This phenomenon could occur because of two possible reasons. Firstly, raised temperatures may directly affect the striped bass population or secondly, indirectly, by causing a shift in predator and prey distribution which, in turn, could cause the striped bass to change location as well.

To conclude this essay, we evaluate potential threats to the striped bass population such as habitat loss, disease risk, and prey abundance. Climate change may also present an increasing risk to striped bass populations, while there is still more research necessary to demonstrate this link as well as to understand the gravity of this relationship. Additionally, the resurgence of overfishing of striped bass may mean that more stringent management policies are necessary to protect the species. There are several policies that may be useful in protecting striped bass in addition to the existing management policies such as regulating the maximum size of fish to be harvested, as well as punitive measures to ensure that these policies are effective in disincentivizing over-harvesting. Legislation limiting pollution and coast development could also be beneficial to protect striped bass habitats.

Taxonomy of Striped Bass:

Striped bass (*Morone saxatilis*) is also called rockfish, striper, bass, or linesider. Striped bass is an anadromous fish, meaning that it migrates into rivers from the ocean to spawn (Coutant 98). Striped bass is the largest true sea bass; they can grow to be five feet long and weigh up to 77 pounds (NOAA). Striped bass coloration ranges: some have olive, blue, black, or brown bodies. They are recognizable by their silver sides that have seven or eight longitudinal dusk colored stripes that run from their gills to their tails (Lander 34). Striped bass mature at two years for males and four to five years for females, but they can live to be up to 30 years old. However, the typical lifespan of striped bass is generally around 10 years (Coutant 99). The striped bass' diet is based on their life stage. Immediately after birth, striped bass larvae feed on zooplankton. Juvenile striped bass eat fish larvae, insects, and crustaceans. Mature striped bass eat most kinds of smaller fish as well as crabs and squid (NOAA).

History of Striped Bass: From Decline to Resurgence

Striped bass are native to the coastal waters of North America. Their natural range is along the Atlantic coast, ranging as far north as New Brunswick and as far south as Florida. However, they have also been introduced into the Central and West Coast of the United States as well (Texas Parks & Wildlife). The striped bass' West Coast range runs from Mexico to British Columbia. They have historically been abundant. In his early writings, Captain John Smith wrote that striped bass were so common that it looked as if one could walk across the water on their backs (Jordan and Evermann 374). Since then, striped bass has maintained popularity given their economic, ecological, recreational, and cultural significance. They are a popular fish for recreational fishing and sport fishing. In 2017, 9% of all 202 million marine angler fishing trips taken in the United States caught striped bass (Carr-Harris and Steinback 2).

However, after years of overfishing, striped bass populations plunged to dangerously low levels. In 1973, 14.7 million pounds of striped bass were caught, but by 1979 the amount had reduced to 3.7 million pounds (Baker 520). In 1983, striped bass harvest fell to an all-time low of just 1.7 million pounds (Chesapeake Bay Program). This decrease had adverse economic effects as well. The U.S. Fish and Wildlife Service and the National Marine Fisheries Service conducted an Emergency Striped Bass Research Study which estimated that the decline in striped bass population during the period between 1973 and 1980 had cost an estimated 7,000 jobs and a loss of 220 million dollars per year (Coutant 103). While most of this decline was blamed on overfishing, there are several other theories that may have contributed to the decline of striped bass populations including contamination from commercial pollution which increased water acidity, runoff pollution from sewage treatment plants, and water temperature shifts around striped bass spawning grounds (Chesapeake Bay Program).

In response to the decline of the striped bass population, several management strategies were enacted to restore the species. In 1984, Congress passed the Striped Bass Conservation Act which granted the federal government power to examine states' conservation practices and to revise their legislation (Baker 520). This act, along with the Atlantic Coast Fisheries Cooperative Act, remains in effect today and requires states to cooperate with the Atlantic States Marine Fisheries Commission's striped bass management plan (NOAA). More aggressive state-level regulations were also put in place. In 1985, Maryland and Delaware enacted five-year moratoriums on striped bass fishing (Baker 520). Additionally, Virginia enacted a 1-year moratorium on striped bass fishing in 1989. By 1995, the striped bass population was considered restored (Chesapeake Bay Program).

Striped Bass Management and Current Threats to the Population

Currently, striped bass populations are regulated through a series of adaptive management plans, meaning that there is consistent surveying of striped bass population health, and regulations are subsequently adjusted. Since striped bass are so widely distributed, there are commercial fisheries in eight Atlantic coastal jurisdictions and recreational fisheries in sixteen jurisdictions; this requires a complex set of regulations (Atlantic States Marine Fisheries Commission). The Interstate Fishery Management Plan for Atlantic Striped Bass under the Atlantic States Marine Fisheries Commission sets many of these regulations which include enacting a state-by-state quota system, gear-type regulations, minimum size limits on catching striped bass, and seasonal fishery closures (NOAA).

While previous policy efforts successfully recovered the striped bass population from severe decline, there is some concern for the sustainability of striped bass. In particular, anthropogenic impacts threaten the viability of striped bass populations. In 2018, the striped bass was considered overfished (NOAA). Additionally, Maryland's annual survey of juvenile striped bass found that populations were the lowest that they had been in four years (Maryland Department of Natural Resources). This is particularly concerning because 90% of the Atlantic striped bass spawning occurs within the Chesapeake Bay. There are several other threats to the health of striped bass populations, including the availability of prey species such as menhaden and bay anchovies and the previously mentioned environmental stressors which may have resulted in the initial vulnerability of striped bass populations (Chesapeake Bay Program). Another potential threat to striped bass is diseases such as mycobacteriosis which causes skin ulcers and spleen, kidney, and liver damage within fish. This disease has been isolated in striped bass populations as well as in many other Chesapeake Bay species (Kane et. al, Rhodes et. al). Recent studies indicate that the prevalence of mycobacteriosis infections may increase with the concentration of suspended solids that result from water pollution (Chesapeake Bay Program). Striped bass habitats are also under threat. Seagrass habitats, which are used by juvenile striped bass as nursery habitats and serve as an important guard from predators, are threatened by a variety of anthropogenic activities (Orth et. al). The variety of threats to the wellbeing of striped bass populations reflects the need for a more ecosystem-based approach to striped bass management with a conservation lens (Chesapeake Bay Program). Threats to striped bass populations, as well as potential policy solutions, will be explored in more depth in the final section of this paper.

Changes in Predator-Prey Dynamics in Striped Bass Ecosystem

Climate change, resulting in rising ocean temperatures and changing weather patterns, has been shown to alter the dynamics and characteristics of predator-prey relationships and the overall structure of the striped bass ecosystem. It is necessary to look at how the changes in populations of zooplankton, which are particularly vulnerable to climate change (Richardson), are affected in order to study how rising ocean temperatures are impacting larger, predator fish such as the striped bass which have a "high" biological sensitivity to climate change (Hare).

Striped bass depend on prey availability and feeding success in order to survive. Researchers found that the primary prey of the striped bass is the estuarine copepod, a type of zooplankton, *Eurytemora affinis* and the secondary prey is the freshwater cladoceran *Bosmina* spp. (Shideler and Houde 561). These results indicate that the striped bass largely rely on/prefer the same prey, so disruptions to these prey species would alter the patterns of striped bass as well. In the same study, researchers also found that it is not merely the abundance of prey that the striped bass rely on, but also the location variability of the prey species.

The data reported in the study confirmed that the Estuarine Turbidity Maximum (ETM), which is a feature of the coastal plain estuaries usually in a position near the salt front, are where the fish larvae usually feed on prey along with the salt fronts. In the two years that the study was conducted (2007 and 2008), the Eurytemora prey species still comprised a large percentage of what was found in the guts of the striped bass larvae (50% both years) at the ETM and salt front locations. However, the Bosmina did not remain a large portion of the diet of the striped bass larvae as they comprised 32% of the prey found in the gut in 2007 and only 3% in 2008 at the ETM and salt front locations (Shideler and Houde 567).

Overall, it seems that the major prey species was the Eurytemora, and this is likely due to the abundance and higher concentrations of it that are available during the spawning season of the striped bass. When the striped bass are larvae, they would mainly eat what is most available around them. However, Bosmina serves as a great support for the growth of striped bass larvae that hatch late into the spawning season. The Bosmina thrive during May/early June due to zooplankton bloom cycles while the Eurytemora begins to die off in April (Shideler and Houde 571). Therefore, the larvae would eat more of the Eurytemora during and before April while the Bosmina is left for the late spawned larvae.

Considering the information that the striped bass larvae success is largely a result of the zooplankton blooms, the impact climate change has on the bloom cycles would result in adjustments to the striped bass ecosystem as a whole. According to data, global warming impacts on the zooplankton range shifts are some of the greatest of any marine group (Richardson). Overall, species are expected to move northwards towards colder waters as ocean water temperatures increase, and the zooplankton follow the same pattern (Richardson). This movement could affect the abundance of and availability of zooplankton (in this case specifically the Bosmina) during their critical reproduction period. Thus, an adjustment in location of the zooplankton could eventually impact the success of the striped bass larvae that hatch later in the spawning season and rely heavily on the Bosmina.

Not only are the zooplankton affected by the changes in the ocean temperature itself, but they are also affected by the changes in regional-scale climate (Kimmel). Studies have found that changes in weather patterns, specifically wet and dry periods, can cause variations to the salinity levels in the Chesapeake Bay, and another study revealed that climate change induced by humans could have caused a 27% salinity drop in the upper Bay area (Kimmel 375). A study done by Kimmel revealed that the zooplankton abundance was also variable depending on certain weather patterns. (Kimmel 380). Winter weather patterns were shown to correlate with spring freshwater discharge from the Susquehanna River. The freshwater discharge seemed to impact the changes in salinity levels in the Bay (Kimmel 382). Researchers found that in the years determined to be dry years (1985 and 1995), there was a low abundance of *Eurytemora affinis* in the southern area of the Bay and, in 1985, a high abundance of *Eurytemora affinis* in the upper areas of the Bay. In 1995, the abundance of *E. affinis* were moderate. In the wet years of 1994 and 1998, there were different abundance levels of the zooplankton than the dry years. The winters that were characterized by warm, wet conditions resulted in a greater abundance of *E. affinis* potentially because of an increase in freshwater input and higher detritus input which is a potential food source for the zooplankton (Kimmel 383).

Because of the increased discharge during the wet period, the ETM location is altered which affects many anadromous fish species, including the striped bass (Kimmel 383). Overall, the study makes it clear that researchers will be able to predict how the abundance of *E. affinis* will vary as a result of climate change. According to the journal, winters with high temperatures and low precipitation levels will result in a decrease of range of *E. affinis* while winters with weather patterns that result in high precipitation and high discharge will have the opposite effect (Kimmel 385).

Changes in climate and weather patterns would therefore impact the spawning and success of the striped bass species. Since the *E. affinis* is the major prey of the striped bass larvae in the spring period, it is essential to have an abundance of zooplankton for the success of the fish. In years that there is increased freshwater discharge and displaced ETM's, there could be detrimental impacts on how the larvae can obtain their food and other concerns that may come with an altered habitat such as predation, oxygen levels, etc.

Dr. Wilson Laney and Bass Species Migration

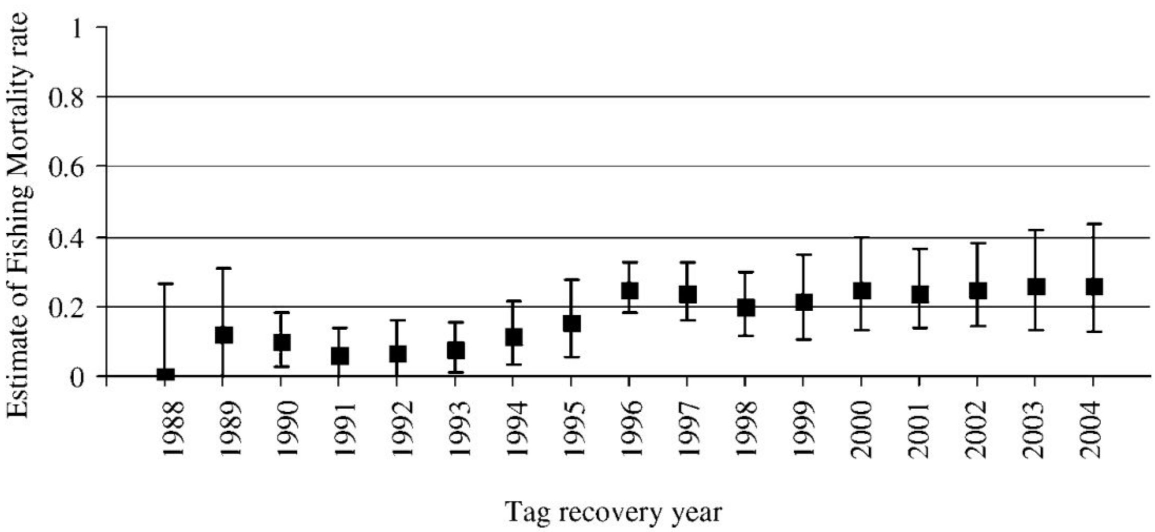
Dr. Wilson Laney is a fishery biologist and a current member of the North Carolina State University faculty within the department of Applied Ecology. He also serves on the board of directors of the North Carolina Wildlife Federation and was awarded Conservationist of the Year by the Governor's Conservation Achievement Awards in 2019. In recent years, Dr. Laney has been conducting research that includes tagging and tracking fish species along the East Coast in order to determine mortality rates as well as migration patterns among different species. This research covers striped bass populations, as well as Atlantic sturgeon, spiny dogfish, summer flounder, and clupeidae fishes (which include herrings, shads, sardines, menhadens, etc.). In this paper, however, we will focus specifically on the results found within migration and depletion of striped bass populations.

There are eight different programs deployed through the United States Fisheries and Wildlife Service that capture and tag striped bass; Laney's research program is located specifically along the coast of North Carolina and Virginia. Laney and his team's efforts are unique in that they are the only location that tagged a mixed stock of striped bass; they tag bass from the Chesapeake Bay area, the Hudson River, Delaware, and North Carolina that all mix off the coast of North Carolina in the wintertime after migrating (Laney et al). Participants capture and tag the bass in federal research vessels and trawls, and more recently hook and line capture methods have been employed. Researchers then release them back into the water and rely on commercial fishermen (as well as recreational fishers) to pick them up at more northern locations and report back to Laney and his team. Fishers report the tag number of the fish they have caught, the date and location of their capture, and if the fish was killed or released back into the water. There is a reward system in place for fishers who catch and contribute to the tagging system. The United States Fisheries and Wildlife Service then manages the tag-recovery database throughout the East Coast. The program has a relatively high return rate, somewhere around 17-20% of tagged fish are recaptured and recorded (Laney et al). Acoustic transmitters have also been used effectively to track striped bass populations as well as other species, these instruments allow researchers to observe exactly where striped bass are at a given time, and how long they stay in certain locations. The mortality that occurs when observing the stock in commercialized and recreational fishing and through transmitters is recorded by researchers in order to make assumptions about change in striped bass populations and migration patterns.

This specific research regarding the survival and mortality of striped bass took place over a period of many years, with original research of tag-based estimates beginning in 1988 and continuing to the present day. As researchers collected this information and began to make assumptions, they accounted for different variables that may have skewed results. One example of this is when striped bass exhibit schooling behavior and many tagged individuals make it to one location around the same time. This results in overdispersion appearing on the distribution models, but this can be corrected by adjustments to inflation factors within the chi-squared dispersion statistics (Welsh et al). It is important to include and understand confounding variables like this, in order for research to be considered notable. It is also important to account for all sorts of irregularities within observations, and specifically within this research, which is ongoing and changing as fishing management and species habitat continue to change.

Results found that there was a decrease in striped bass populations from 1986-1989 when research began (Welsh et al). From 1990-1994, results showed that populations began to increase again when stricter regulations were placed on fisheries throughout the East Coast (Welsh et al). Two other regulatory periods were observed (1995-1999 and 2000-2004) and also showed similar results when comparing species mortality with fishing regulation and management. While we cannot conclude that sustainable management allows for striped bass populations to experience greater recovery, we can predict to see striped bass mortality rates decrease when there are more regulations and policies in place protecting this species and their habitats. The graph below shows the results of data collected by the American Fisheries Society in regards to mortality rates of striped bass through the years 1988-2004.

Annual Estimates of Fishing Mortality Rates of Striped Bass (Welsh et al.)



While the above research lasted only between the years of 1988 and 2004, Dr. Laney and others continue to conduct research regarding striped bass and other fish populations. Research from years later than 2004 has exposed even more trouble facing striped bass populations. Distribution maps show that striped bass populations have been moving further and further offshore throughout the East Coast (Laney et al). There has also been strong evidence that populations are migrating northward, there has not been a single striped bass caught in a commercial fishery off the coast of North Carolina since the year 2011 (Laney et al). Researchers cannot say exactly why this trend is occurring. We do know that larger striped bass, in particular, prefer cooler water temperatures, and in recent years, water temperatures in the Chesapeake Bay and other areas that are home to striped bass have not been reaching as low temperatures that they have in previous years due to climate change (Laney et al). It could be possible that these populations are moving further north in order to seek cooler temperatures that are more optimal to survival, as well as moving further offshore to deeper water, which have cooler temperatures overall. Laney and his team record surface temperatures where striped bass are found, but to conduct a more thorough assessment of changing temperatures it may be beneficial to collect and observe temperatures at the bottom of the ocean as well. Often, however, striped bass species tend to reside closer to the surface of the water in order to remain closer to prey species (Laney et al).

Typical preferred prey species that striped bass consume include Atlantic menhaden and Atlantic herring, as well as other small fish such as anchovies and sometimes different squid species. This brings up another possible explanation for the change in distribution, which is that striped bass may be following their prey species further offshore and to cooler waters. The preferred water temperature for Atlantic menhaden is between 15-20 degrees Celsius (Reintjes 5), which correlates with more northern locations along the East Coast, as water in North Carolina, Georgia, and Florida tends to reach higher temperatures than this, especially in the summer (NCEI). Geographical distribution of Atlantic herring species shows that populations are found even further north than menhaden populations, with prime fishing grounds off the coast of Maine and in Canada (Stroud). These trends definitely support theories that striped bass may be following their prey more northward, yet we still cannot assume that this is exactly what is causing shifts in distribution. Further, Atlantic striped bass are not the only populations observed that are shifting northward, research has shown that black sea bass, as well as other species, have also begun to move in this direction.

Dr. Laney and others have begun to implement “Climate Vulnerability Assessments” for striped bass and other species that project how climate change may affect certain fish species in the future if carbon levels continue to rise. These assessments analyze how temperature change may evoke responses in fish species (such as changes in distribution). Researchers making these assessments focus specifically on habitat, species response to temperature, reproduction cycles, spawning behavior, and more. They can then estimate the possibility of these species being affected by climate change. Striped bass specifically have been ranked as highly vulnerable to climate change under the RCP 8.5 scenario (business as usual) due to the following factors: increasing ocean surface temperature, ocean acidification, increased air temperature, complex spawning cycle, and early life history requirements (Massachusetts Wildlife Climate Action Tool). We cannot assume that distribution change in striped bass populations is due to a changing climate, but we can determine that this species is specifically vulnerable to climate change, and observe and record patterns as these populations begin to change in different aspects at drastic rates.

Effect of Changing Climate on Fisheries and Striped Bass Reproduction

Climate change will affect striped bass in more ways than altering predator-prey dynamics. It could also cause complete shifts in the striped bass populations, resulting in changes in entire ecosystems. Changes in dissolved oxygen, salinity, water level, and especially, water temperature, alter striped bass behavior (Woodland 65). These environmental changes will cause life cycle events like migration or spawning to occur earlier in the season. The alteration of these events could create serious consequences for the future of striped bass populations (Peer 94). Climate change will also affect fishery management, which relies on the predictable nature of life cycle events to inform management decisions and policies (Paukert 377).

Climate change creates phenological changes in striped bass behavior-most notably, changes in spawn and migration behavior. Natural selection dictates that life cycle events are triggered by environmental conditions, such as optimal water temperature or water level (Peer 95). This way, young are born in an environment with favorable conditions. In the case of striped bass, spring water temperatures are the main influence on spawning and migration behavior, and more eggs are laid during seasons with warmer temperatures (Peer 94). Temperature also has the highest influence on spawn mortality rates (Peer 95). One of the objectives of fisheries management is to protect the migration of spawning females while also allowing fishers to catch a certain amount of them every season. This is achieved by aiming to start the fishing season when females migrate back from spawning instead of before. However, changes in striped bass behavior without changes in management lead to overfishing (Paukert 378). In many cases, the start and end of fishing seasons are the same each year, as in the case of striped bass management in the Chesapeake Bay (Paukert 379). The issue of having a fixed date in the wake of climate change means that fishers will often catch spawning females before their eggs are laid, especially in colder years (Paukert 379).

Fishing management faces the challenging task of keeping fish species viable and resilient in the face of climate change (Hansen 57). Fortunately, models have been developed to help guide fishery management towards a more sustainable path. The first step fishery management should take is to alter the opening and closing of the fishing season to respond to changes in the environment (Hansen 59).

This will require flexible management, interdisciplinary partnerships, and vigilant monitoring of ecological systems (Hansen 62). Specifically, fisheries will need to make informed decisions based on data collected on age class, birth rate, and death rate of fish species (Hansen 62). The main goal of fishery management should be to maintain the primary structure and function of an ecosystem. This will require collaboration with ecologists, policymakers, and consumers (Peer 94). In the case of Chesapeake Bay, by monitoring birth rates, they can assure that the fishing season can open after females have laid their eggs and not before.

Modern fishery management does have experience with responding to social and political changes (Hansen 62), but now fisheries will also need to learn how to respond to the effects of climate change as well. Strategies should be implemented using experimental design and through trial and error. This method of management is known as active management. Active management strategies should also be evaluated to measure the effectiveness of maintaining fish resilience and revised when necessary. Successful implementation of this practice, such as in Ceded Lake territory of Wisconsin in 2011 observed a significant increase in the resilience of bass and Walleye species (Hansen 63). Active management in Ceded Lake was successful in growing the bass population from 2011 to 2013 (Hansen 59) and policies like the elimination of the minimum catch length attributed to the success of bass management. Today, it is crucial that more fishery management adopt active management practices to ensure the stability of fish species for years to come (Woodland 69).

Sustainability and Policy:

The action taken (or lack thereof) in the following decade will be crucial in determining the health of many important ecosystems for the preservation of striped bass populations. To start off, the statistics regarding recreational fishing in the country are worrisome. There has been a general increase in recreational release mortality rates since the 90s, to the point where 9% of striped bass caught by anglers do not survive. This means that in 2017, 38.2 million striped bass were released by recreational fishermen, and of those 3.4 million did not survive. It is unsustainable that one out of every ten striped bass that is caught does not survive (Striped Bass Stock Overview).

One potential policy that could be set in place to limit reductions in populations is regulating the maximum size of fish to be harvested. Female striped bass around 34 inches are usually the breeding ones that populations so heavily rely on. If they are overfished, reproduction rates will be too low for striped bass numbers to remain constant. Obviously for harvesting purposes, the larger the catch the better, but policy must be implemented to de-incentivize this at a certain size. Fines could be levied, and for repeat offenses, a ban from the fishing area could potentially work.

From an ecological point of view, another threat that striped bass populations face is habitat loss. Various unsustainable urban development initiatives heavily contribute to poor water quality and loss of structured habitat such as seagrass, in which large numbers of juvenile sea bass are nursed. Additionally, striped bass often reside near the shore due to its convenient location to avoid predators and because it's where a lot of prey live. Thus, they are especially sensitive to the effects of coastal urban projects with negative environmental externalities (Fabrizio, M. C., Tuckey, T. D., & Musick, S.) Industry-heavy states on the East Coast such as Massachusetts and New Jersey must especially monitor the health of their coastal ecosystems.

There is a large variety of policies that could be implemented to mitigate damage to coastal areas and striped bass habitats. On a basic level, limiting development on the coastline and opening these areas to the public would be very conducive to this. This kind of policy would avoid infringing upon striped bass habitats and would limit the pollution and runoff compared to developments with less distance from the habitats. California has acted on these incentives with the California Coastal Act of 1976, in which the use of land and water and development activities in coastal zones is heavily regulated. Because California makes up such a large portion of the West Coast, this policy has been incredibly beneficial to the health of coastal ecosystems there. An initiative with similar effects would be harder to implement on the East Coast because of the number of states spanning the striped bass habitat there. Thus, there are a number of bureaucratic issues preventing an equally effective policy from being created.

Another major issue affecting the health of striped bass populations is the abundance of their prey. They mainly feed on forage fish such as menhaden and bay anchovies, which rely on algae and other aquatic plants for their diet. So the prevalence of striped bass really depends on the health of the whole food chain, from bottom to top. The biggest threat to the critical autotrophs is pollution, which degrades water quality and thus their habitat. This in turn degrades the health of the entire food chain. Less autotrophs results in less prey for striped bass, which could lead to a decrease in striped bass populations. (Davis, Justin & Schultz, Eric & Vokoun, Jason.) Therefore, it is critical that policy be created, enacted, and maintained to prevent and limit pollution in waterways in which striped bass reside.

There are a variety of different policies and policy types that have and could be enacted to mitigate pollution in striped bass habitats. One form of pollution control is legal limitations on certain types of pollution, officially called a pollution diet. One such implementation took place in Chesapeake Bay watershed states and was enacted by the EPA. The Chesapeake Bay Total Maximum Daily Load Program places caps on phosphorus, nitrogen, and sediments. Each state developed an individual plan to outline strategies to meet their pollution caps, and to this day these plans are regularly revisited and revised. This is one of the most effective ways to promote the health of aquatic habitats because it involves assessing the current conditions of ecosystems and developing strategies that fit them. Updating the plan as time goes on is also very effective because new goals might have to be established due to changing environmental conditions, economic conditions, or both.

Another major issue related to water quality is the occurrence of deadly diseases. The most prevalent one for striped bass populations in the Chesapeake Bay is called mycobacteriosis, in which they develop external lesions usually in the stomach area. It is very difficult to diagnose, which makes measuring the scale of the issue quite the challenge. A recent study found there was a significant correlation between higher nutrient content and sediment loads in water and striped bass testing positive for the disease (ScienceDaily). This is yet another example of the damage that low water quality can do to ecosystems.

A similar policy to the one involving pollution caps for water quality maintenance would also help the prevention of this disease from spreading. Regular assessment and updates should also be in order, perhaps with additional methods of evaluation since the risk being assessed is different.

An issue that needs immediate attention from state authorities is the practice of illegal poaching and fishing of striped bass. Bass abundance already faces threats from various issues such as pollution, overfishing and habitat loss. However, though they shouldn't, at least most of these infractions have the excuse of operating under the law. Poaching and illegal fishing can take several forms. In Massachusetts, there is a large number of commercial permits that report no landing or sales of bass every year. This is often an indication of either engaging in black market sales, which obviously are not officially recorded or a method of fishing and catching more bass than allowed by their quota. Another form of unlawful activity is illegal fishing in federal waters off the coast of Virginia and North Carolina using gillnets (a wall of netting that hangs down a water column). However, in the last decade, there has been stricter law enforcement in these areas in the last decade with billions of dollars worth of fines being implemented.

The issue of illegal and unreported commercial fishing is a tough one to deal with and bring to light. Black markets will need to be cracked down on, and catch rates more closely monitored. These solutions will be greatly aided by more innovative technology that can monitor the fishing patterns in certain areas. Beyond the law, fishing communities need to unite to ensure that striped bass are being sustainably fished everywhere. A study conducted in Massachusetts and Connecticut found that 71% of recreational fishermen surveyed were supportive of some form of slot limits, and 74% for circle hooks that reduce fish mortality rates. However, while most fishermen were supportive of additional management strategies promoting the sustainability of striped bass fishing, they were less so of harvest reductions. This makes sense, because it's what most directly affects them economically. (Murphy RD Jr, Scyphers SB, Grabowski JH) Overall, community-driven action is often the most effective way to address challenges that are specific to a certain area, due to the intimate knowledge that the people living there have. This will also establish long-term healthy relationships among fishermen and women that will foster collaboration and mutual aid and support.

Conclusion

Striped bass are an ecologically and culturally important species. Despite the near-collapse of the striped bass population in the 1970s and 1980s, the species was rehabilitated with comprehensive management policies. However, striped bass continue to face many threats at the hands of anthropogenic activity. Striped bass are currently considered overfished. Striped bass habitats, namely seagrass, are impacted by development. Additionally, they and some of their prey species are vulnerable to bacterial infections that may be exacerbated by pollution. While more research needs to be done to understand the gravity and scale of these impacts, there is mounting evidence that striped bass are at risk.

Climate change has not only impacted the striped bass itself, but the Chesapeake Bay ecosystem as a whole. The larval striped bass success relies heavily on the components of the habitat around it such as salinity levels, water temperature, and zooplankton (prey) abundance. In order to maintain healthy predator-prey dynamics, the factors influencing the abundance and survival of the zooplankton species must be stable and conducive to success. Unfortunately, climate change makes it difficult to predict how the weather cycles will change for future years, but luckily researchers have been able to understand how zooplankton abundance will adjust according to certain weather patterns.

Predator and prey dynamics will not only be altered due to climate change but also create shifts in striped bass populations. This is due to the fact that bass populations are temperature sensitive and base life cycle events (like migration and spawning) off of optimal temperature environments. As climate change progresses, it will become more difficult to predict when optimal temperatures for striped bass will occur. This is why active management will become important for maintaining the resilience of fish species in the future. Active management strategies involving flexible planning based on evidence, data, and partnerships with ecologists and consumers. Fisheries have been successful in implementing active management strategies, like the Ceded Lake fishery site in Wisconsin, which saw a significant rise in their striped bass population. It is crucial that fisheries adopt active management practices to ensure the stability of fish species for the future.

Dr. Wilson Laney and his team have put great amounts of work into tagging and tracking striped bass species, and their research has revealed that striped bass population distribution has changed in recent years. This research is also effective in finding data about mortality rates of striped bass, which tend to correlate to strict or less strict management policy in locations where striped bass are present. Research has also exposed that climate change may have some detrimental effects on striped bass populations, and it will be important to continue to observe these trends in coming years.

Trends in policy regarding the preservation of striped bass populations and their habitat will be indicative of what kind of action we take in the global fight against climate change. Addressing the pollution from coastal infrastructure and promoting sustainable solutions that also benefit economies does not only help striped bass survive but also ensures the long-term health of ecosystems and ocean-related livelihoods around the world. Implementing and assessing ecosystem-specific pollution measures will be essential to the health of all oceanic food chains, and help prevent the occurrence of animal diseases that hurt both them and us as consumers. But the most important initiative that must be pursued everywhere is promoting community-driven action. This will help ensure the most reliable knowledge is applied to different issues in addition to empowering people to take action to preserve their own natural resources. We've seen all these types of challenges faced and addressed with striped bass with varying degrees of success, but it's clear that there's a real push for progress. The same must take place for all climate-related issues around the globe.

Works Cited

Atlantic States Marine Fisheries Commission. *Striped Bass*. http://www.asmfc.org/species/atlantic-striped-bass. Accessed 6 Dec. 2020.

Baker, Beth. "Striped Bass Success Spawns New Legislation." *BioScience*, vol. 44, no. 8, [American Institute of Biological Sciences, Oxford University Press], 1994, pp. 520–22. *JSTOR*, doi:10.2307/1312277.

Blinkoff, Kevin, et al. "Striped Bass Stock Overview." On The Water, 15 Feb. 2019, www.onthewater.com/striped-bass-stock-overview.

Carr-Harris, Andrew, and Scott Steinback. "Expected Economic and Biological Impacts of Recreational Atlantic Striped Bass Fishing Policy." Frontiers in Marine Science, vol. 6, 2020. www.readcube.com, doi:10.3389/fmars.2019.00814.

Chesapeake Bay Program. *Striped Bass*. https://www.chesapeakebay.net/S=0/fieldguide/critter/striped_bass, https://www.chesapeakebay.net/issues/striped_bass. Accessed 6 Dec. 2020.

Coutant, Charles C. "Thermal Niches of Striped Bass." Scientific American, vol. 255, no. 2, 1986, pp. 98–105., www.jstor.org/stable/24976022. Accessed 30 Nov. 2020.

Davis, Justin & Schultz, Eric & Vokoun, Jason. (2009). "Assessment of River Herring and Striped Bass in the Connecticut River: Abundance, Population Structure, and Predator/Prey Interactions."

Essington TE et al. "Fishing Amplifies Forage Fish Population Collapses." Proc Natl Acad Sci U S A. 2015 May 26;112(21):6648-52. doi: 10.1073/pnas.1422020112. Epub 2015 Apr 6. PMID: 25848018; PMCID: PMC4450419.

Fabrizio, M. C., Tuckey, T. D., & Musick, S. (2017) "A Brief Guide to Striped Bass Ecology & Management in Chesapeake Bay." Virginia Institute of Marine Science, College of William and Mary. https://doi.org/10.21220/V5NQ9X

Fisheries, NOAA. "Atlantic Striped Bass | NOAA Fisheries." *NOAA*, 18 Aug. 2020, https://www.fisheries.noaa.gov/species/atlantic-striped-bass. New England/Mid-Atlantic, Southeast.

Hare, Jonathan A et al. "A Vulnerability Assessment of Fish and Invertebrates to Climate Change on the Northeast U.S. Continental Shelf." *PloS one* vol. 11,2 e0146756. 3 Feb. 2016, doi:10.1371/journal.pone.0146756

Hansen, Gretchen J. A., et al. "Learning to Manage and Managing to Learn: Sustaining Freshwater Recreational Fisheries in a Changing Environment." Fisheries, vol. 40, no. 2, 2015, pp. 56–64., doi:10.1080/03632415.2014.996804.

Jordan, David Starr, and Evermann, Barton Warren. "American Food and Game Fishes: A Popular Account of All the Species Found in America North of the Equator." Doubleday, 1923.

Kane, Andrew S., et al. "Mycobacteria as Environmental Portent in Chesapeake Bay Fish Species." Emerging Infectious Diseases, vol. 13, no. 2, Feb. 2007, pp. 329–31. PubMed Central, doi:10.3201/eid1302.060558.

Kimmel, D.G., Miller, W.D. & Roman, M.R. "Regional Scale Climate Forcing of Mesozooplankton Dynamics in Chesapeake Bay." *Estuaries and Coasts: J ERF* 29, 375–387 (2006). https://doi-org.proxy.library.emory.edu/10.1007/BF02784987

Lander, Arthur B. "Striped Bass." A Fishing Guide to Kentucky's Major Lakes, University Press of Kentucky, 1998, pp. 34–35. JSTOR, http://www.jstor.org/stable/j.ctt2tv693.16

Maryland Department of Natural Resources. Juvenile Striped Bass Survey. https://dnr.maryland.gov/fisheries/pages/striped-bass/juvenile-index.aspx. Accessed 6 Dec. 2020.

"Massachusetts Wildlife Climate Action Tool." *Ecology and Vulnerability Coastal Fish | Massachusetts Wildlife Climate Action Tool*, 2016, climateactiontool.org/species/coastal-fish.

Murphy RD Jr, Scyphers SB, Grabowski JH (2015) Assessing Fishers' Support of Striped Bass Management Strategies. PLoS ONE 10(8): e0136412. https://doi.org/10.1371/journal.pone.0136412

Laney, Wilson, Narula, Jasleen et al. *Dr. Wilson Laney and Striped Bass Migration*, 11 Dec. 2020, soundcloud.com/celia-jacobs-151478706/dr-wilson-laney-and-bass.

National Centers for Environmental Information (NCEI), 2020, www.ncei.noaa.gov/access/data/coastal-water-temperature-guide/satl.html.

Norwegian School of Veterinary Science. "Mycobacteriosis in fish." ScienceDaily. ScienceDaily, 15 January 2013. <www.sciencedaily.com/releases/2013/01/130115085531.htm>.

Orth, Robert J., et al. "Boat Propeller Scarring of Seagrass Beds in Lower Chesapeake Bay, USA: Patterns, Causes, Recovery, and Management." Estuaries and Coasts, vol. 40, no. 6, Nov. 2017, pp. 1666–76. Springer Link, doi:10.1007/s12237-017-0239-9.

Orth, Robert J., et al. "A Global Crisis for Seagrass Ecosystems." BioScience, vol. 56, no. 12, Oxford Academic, Dec. 2006, pp. 987–96. academic.oup.com, doi:10.1641/0006-3568(2006)56[987:AGCFSE]2.0.CO;2.

Paukert, Craig P, et al. "Adapting Inland Fisheries Management to a Changing Climate." *Fisheries*, vol. 41, no. 7, July 2016, pp. 374-384.

Peer, A. C., and T. J. Miller. "Climate Change, Migration Phenology, and Fisheries Management Interact with Unanticipated Consequences." *North American Journal of Fisheries Management*, vol. 34, no. 1, 2014, pp. 94–110.

Rhodes, M. W., et al. "A Unique Mycobacterium Species Isolated from an Epizootic of Striped Bass (Morone Saxatilis)." Emerging Infectious Diseases, vol. 7, no. 5, 2001, pp. 896–99.

Richardson, Anthony J. "In Hot Water: Zooplankton and Climate Change." *ICES Journal of Marine Science*, Volume 65, Issue 3, April 2008, Pages 279–295, https://doi.org/10.1093/icesjms/fsn028

Reintjes, John W. vol. 42, United States Department of the Interior, 1969, pp. 1–30, *Synopsis of Biological Data on the Atlantic Menhaden, Brevoortia Tyrannus*.

Shideler, Allison C., and Edward D. Houde. "Spatio-Temporal Variability in Larval-Stage Feeding and Nutritional Sources as Factors Influencing Striped Bass (Morone Saxaülis) Recruitment Success." *Estuaries and Coasts*, vol. 37, no. 3, 2014, pp. 561–575. *JSTOR*, www.jstor.org/stable/44851188. Accessed 7 Dec. 2020.

Stroud, G.D. *The Herring*, Ministry of Agriculture, Fisheries, and Food, 2001, www.fao.org/3/x5933e/x5933e01.htm.

Texas Parks & Wildlife. Striped Bass (Morone Saxatilis). https://tpwd.texas.gov/huntwild/wild/species/str/. Accessed 30 Nov. 2020.

Welsh, Stuart A, et al. "Tag-Based Estimates of Annual Fishing Mortality of a Mixed Atlantic Coastal Stock of Striped Bass." *American Fisheries Society*, vol. 136, 2007, pp. 34–42.

Woodland, Ryan J, et al. "Environmental Drivers of Forage Fishes and Benthic Invertebrates at Multiple Spatial Scales in a Large Temperate Estuary." *Springer* , Sept. 2020, pp. 61-73.