

Chemical and Biological Aspects of the Indian River



Figure 1: Elizabeth River Map

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Executive Summary: Fallon Woolford

The System:

The Indian River is located in the Southeastern region of Virginia, it touches 3 of the cities that are in Hampton Roads. The Indian River is tributary of a larger river, Elizabeth River. The Indian

River is commonly referred to as the “lost branch” because of the neglect of the citizens surrounding it and the urbanization that has grown around it. The quality of this river has been in the decline since the 1980s while the other branches of the Elizabeth River are improving. The Indian River is remotely unusable to the residents surrounding it currently and many organizations are working to fix all the issues that are making the river this way. Chemical and Biological aspects are both affecting the rivers health.

Hazards:

Three threats in the chemical aspects of the river’s health are discussed further. They range from; fertilizers and pesticides, commonly used by farmers in the Hampton Roads area and industrial plants. Industrial plants are abundant in the Hampton Roads area surrounding the Indian River. Two threats encompass the biological aspects of the Indian River, dogs and abundant algae growth. Dogs’ feces contain bacteria that, because of runoffs, has lead to the contamination of the Indian River. Whereas algae growth can be detrimental to an ecosystem as well.

Impacts Based on the Hazards

The chemical impacts of these hazards can lead to groundwater pollution because of excess pesticides used by farmers. Secondly chemicals pollution from the industrial plants surrounding the Indian River can cause pollution to the water, and lastly eutrophication is also caused by the overabundance of nutrients found in pesticides and fertilizers. Furthermore the biological impacts of the hazards, shellfish and fish populations of the river can be strained. Secondly, people can be affected by the bacteria found in the water, especially if they consume fish living in the Indian River.

Foresight Based on Land Use Change and Behavior Changes

For the chemical aspects of the Indian River, land use change from the growing industrial city of Chesapeake, was assessed. The city of Chesapeake has several industrial plants and the projection of more and how it would continue to affect the Indian River was assessed. For the biological aspects, the involvement of behavior change was assessed. The behavior change of the citizens along the Indian River is an important factor in decreasing the levels of bacteria from dog waste.

Decision Makers involved with the Indian River

The decision makers involved with anything that happens with the Indian River is similar in the chemical and biological aspects. The Army Corps of Engineers is a major decision maker where the Indian River is involved. Alongside of farmers, fishermen, US Government, based on the military using the Elizabeth River, as well as the Indian River, the residents and civic league members of the surrounding areas of the Indian River. Other decision makers are local nonprofits and companies, for example the Elizabeth River Project.

Options for the Indian River

For the chemical and biological aspects of the Indian River, 2 options for each were comprised based on evidence and research. For the chemical aspects, the first option was to do further research on another chemical aspect that has not be researched enough on the Indian River: the impact of ships and boats in the Indian River. After further research is done a possibility of limiting the access to non-motorized ships and boats. A second option would for the public to promote the use of safe and non-harmful ways for farmers to deter pests and make their plants grow more instead of using fertilizer and pesticides that are harmful to the Indian River. The options for the biological aspect problems of the Indian River include, a continuing public outreach and education involving the residents of the surrounding areas of the Indian

River, similar to the “Scoop the Poop” campaign carried out by the Elizabeth River Project. A second option could include the civic leagues of the areas around the river imposing a tax or fee onto residents with dogs in promotion with lowering the bacteria levels.

Recommendations

A combination of these options was determined as the recommendations for the chemical aspects of the Indian River. There needs to be more research done in the Indian River to see the effects of the ships and boats that use the Indian River as transportation. Also making safe and affordable pesticide and fertilizers for farmers readily available would be beneficial to the health of the river. The recommendations for the biological aspects of the Indian River is also comprised of a combination of the options listed. It also includes implementing a public forum for the residents of the Indian River to have an open discussion involving the bacteria levels of the river and the causes of it, most of which are dog waste.

1. Introduction: Fallon Woolford

The Elizabeth River is an estuary located in Southeastern Virginia, informally known as the Tidewater area. In 1983, the EPA stated that the Elizabeth River was one of the most polluted waterways in the entire Chesapeake Bay Watershed. The Elizabeth River consists of different branches, Western, Southern and Eastern (Figure 1, Di Giulio, 2015). The Eastern branch, is referred to as the “Lost Branch” of the Elizabeth River because of the fact that its hidden by the development of the cities it touches. The Indian River stretches across 3 major cities of Southeastern Virginia, Norfolk, Chesapeake and Virginia Beach. Starting in Virginia Beach the Eastern Branch flows 9 miles into the other two cities, flowing in the directions of East to West. Along with the river itself there are about 40 square miles of Watershed that feed into the Eastern

branch. The Elizabeth River, in whole, is shown in Figure 1, with the Eastern Branch labeled. The Eastern Branch of the Elizabeth River is made up of two tributaries, Indian River and Broad Creek. In 2014, a State of the River study was done. It tests water quality. The Eastern Branch, and more specifically the Indian River received an “F” grade for water quality. The grading is on an A to F scale, “A” being the best it could be and “F” being the worst. The water quality tests were done by the Elizabeth River Project in conjunction with the Hampton Roads Sanitation District. Along with those tests, a “State of the River” assessment was completed on the Elizabeth River as a whole, including the Indian River. This scorecard (Figure 2) measured the past five years of levels of dissolved oxygen, bottom health, bacteria, contamination of river bottom, nitrogen, phosphorus, phytoplankton/chlorophyll, contaminants in fish, and shellfish bacteria. (Elizabeth River Project 2014).

Elizabeth River - Report Card 2014

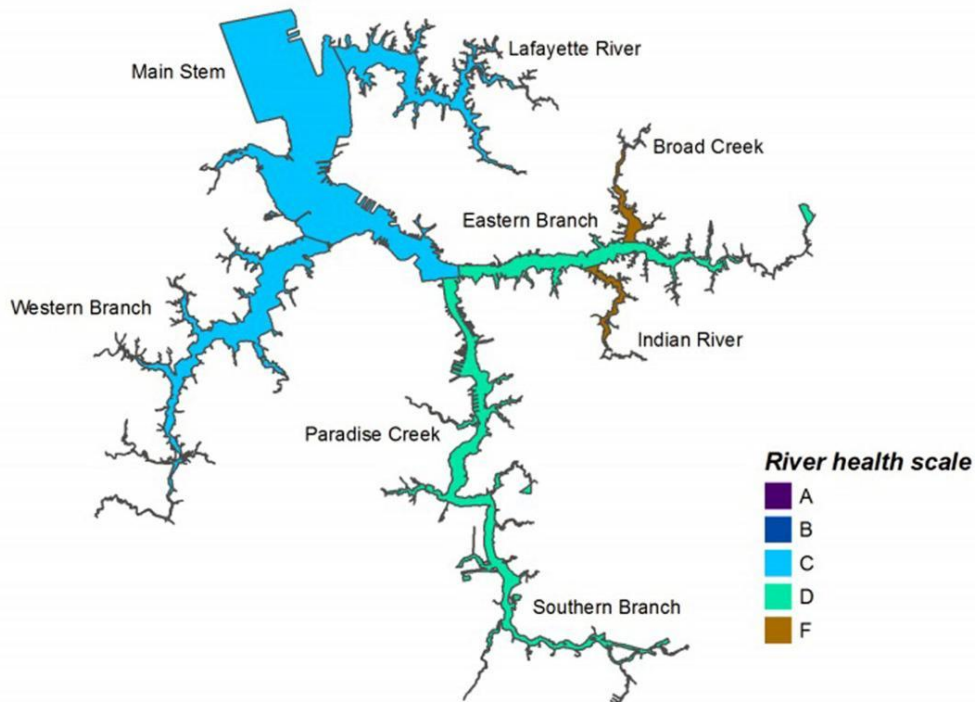


Figure 2: Map of Elizabeth River health scale.

2.0 Hazards for the Indian River

Chemical: Fallon Woolford:

2.1 Fertilizer and Pesticides:

Hampton Roads has at the very least, 10 fully functioning farms located in Norfolk, Virginia Beach and Chesapeake. One in particular is located in the Indian River watershed, on Indian River Road, and is specializing in vegetables, herbs and flowers (Richards, 2018). Fertilizers increase the rate at which the crops grow and increase their size. They provide the plants with nutrients required to grow more quickly for example, phosphorus, nitrogen and potassium (BBC 2014). Nitrogen is more easily drained from the soil, it constitutes the greatest threat of pollution.

Phosphorus binds quickly to plants, so draining away from the soil is less likely. The pollution in waterways caused by phosphorus mostly occurs in places where erosion is occurring. Potassium is also taken up very quickly into the roots of the plant, and used in a small quantity does not pose a great threat to waterway pollution but should not be used in large quantities (NSW, 1993). Many of the farms , through Hampton Roads and in the Indian River watershed, stated previously may also use harmful pesticides, substances that are used to deter or destroy insects or invasive plants in a garden and/or farm. All pesticides are formed with an “active” and an “inert” ingredient. The active ingredient is the one that actually “repels” the pest. And the “inert” is required by federal law to act as usability (EPA 2018). Along with plants pesticides are also found in many household items. The pesticides as well as the fertilizer, and industrial plants reach the Indian River by ways of stormwater runoff.

2.2 Industrial Plants

Throughout the 7 cities of Hampton Roads, there are 110 industrial plants. The industrial plants range from shipbuilding and repair, food and sonar systems and equipment and several varying plants (HREDA, 2015). The Indian River flows through three of these cities with industrial plants. Many of these industrial plants lack a reprimanding to illegal dumping. Several plants in the United States engage in illegal dumping and are hopeful that they can just pay a fine and keep continuing these practices. Industrial plants also don't always have updated equipment and continue to work with them even though they may be faulty and leading to excess pollution. A lot of companies want to move towards an environmental way of operating but it tends to cost more than a business as usual approach that they are accustomed to .

Biological: Alissa Ralston:

2.3 Dogs

In 1991, the EPA recognized dog waste as a pollutant and was placed in the same category as toxic waste and oil. While there is no specific number for the Indian River Watershed, approximately 40% of households in Virginia own dogs (Kiersz, 2014). A big reason why this branch is failing has to do with the amount of bacteria in the water. The Elizabeth River Project partnered with the Hampton Roads Sanitation District, taking various samples in the water, they found that 80% of the samples in the water came from dog waste. Just one ounce of dog waste contains 23 million fecal bacteria, and about 10.6 million pounds of dog waste is produced yearly in the United States (Cross, 2016). Due to excessive dog waste being deposited into the river, this can give life to a lot of different kinds of bacteria in the water. Dogs have so much bacteria in their waste, that if 100 dog owners in the Indian River area did not clean up after their dogs for three days, it would be enough to close roughly 20 miles of the watershed (Alvarez, 2012). This would prevent all aquatic activities like swimming and crabbing.

Enterococci is an example of a common bacteria found in dog waste. Enterococci is a bacteria that is common in intestinal tracts but when found in other parts of the body can cause blood infections (Byappanahalli, 2012). When enterococci is deposited into a body of water, sunlight can kill off most of the bacteria, but when the sun goes down or if it is a cloudy day then it's harder to kill (Byappanahalli, 2012). This bacteria was recommended, by the EPA in the 1980's, to be the indicator for fecal pollution. This is because it is one of the bacteria to survive the longest in an aquatic environment, and it is also very easy to detect (Byappanahalli, 2012). Other common bacteria found in dog waste would be E. coli, salmonella, and hepatitis. These bacteria commonly spawn in warmer weather. When the temperature rises this means the bacteria will be

present when they are normally not present and will have a longer period of time to grow (EPA, 2017).

2.4 Algae

Too much algae poses a threat to any ecosystem. Light and limited nitrogen and phosphorus are limiting factors for algae. A main cause of algal blooms (cyanobacteria) is excessive amounts of phosphorus and nitrogen in the water from agricultural and urban runoff (Indiana University, 2018). Low concentrations of dissolved oxygen also promote cyanobacteria growth, this occurs when sediment releases phosphorus into the water (Indiana University, 2018). The temperature in the water has to be at least 25 degrees C, this is the minimum temperature for algae to grow. Because Southeastern Virginia stays below this temperature for almost half the year this cyanobacteria has a growing season (Indiana University, 2018). Cyanobacteria also cannot grow in direct sunlight, it flourishes when it is at a low water depth, night time, or cloudy (Indiana University, 2018). Because Virginia can be cloudy for a few days to even weeks at a time, this means that the bloom can grow exponentially. This makes it harder on other organisms in the water to receive oxygen, eat, or get sunlight (Indiana University, 2018). Low turbidity and calm waters are other exceptional circumstances for growth. These conditions are similar to the Indian River. Algal blooms haven't posed a problem yet this year, but with the amount of pollution in the water, as discussed in section 2.1, it's only a matter of time before it becomes an issue (Indiana University, 2018).

3 Vulnerabilities to the Indian River:

Chemical: Fallon Woolford

3.1 Groundwater Pollution:

Groundwater is one of the most heavily affected sites for pesticide pollution. The movement of pesticides does not take a long amount of time to be carried by runoffs into nearby rivers. The groundwater can carry the pesticides for long distances (All About Water Filters 2012). Nitrates filtering through the soil present a serious problem regarding river health hazards. Nitrates are also a leading contributor to soil acidification. If this groundwater is going to be used for a domestic use, it can propose a serious threat with a low PH (BBC, 2014).

3.2 Chemical Pollution from Industrial Plants

Virginia is rated 22nd worst state in toxic gas admissions according to, Virginia Chapter Sierra Club 2014. Chesapeake, which is the main city the Indian River touches, ranks 5 on a list of cities with the highest levels of gas pollution. According to the same study done by the Virginia Sierra Club in 2014, Chesapeake Energy Center located just streets away from the Indian River is the top contributor to gas emission in Chesapeake. In other parts of the United States gas emissions, for example, naturally occurring radioactive materials and methane, has leaked into the water. In conjunction with Section 3.1, gas emission can also affect the groundwater and lead to it becoming polluted by natural or man-made fractures that allow the gas into the subsurface. (UCSUSA, 2014).

3.3 Eutrophication:

Eutrophication is caused by the excess of nutrients in the water. These extra nutrients, like nitrogen, cause for increasingly large numbers of algal blooms. Fertilizer can cause an increase of eutrophication in the Indian River. According to the “State of the River” assessment done in 2014, the Indian River had an F rating for excess Nitrogen and Phosphorus in the water. The Elizabeth River Project stated that this will lead to, “algal blooms and fish kills” (ERP, 2014).

Biological: Alissa Ralston:

3.4 Animals

Shellfish are susceptible to filtering and absorbing the pollution and cyanobacteria in the water. While humans have excellent screening processes to protect against consumption, the same cannot be said for the other organisms in the food chain. Because shellfish are pretty low on the food chain, and these toxins can be stored in the fatty parts of animals, the bacteria will get passed around to different organisms and could be disastrous to a food chain (CDC, 2018). When dog waste decomposes in a body of water, it takes up the dissolved oxygen in the water while depositing ammonia (Holt, 2018). The reduction of dissolved oxygen in the water will result in fish and plants dying (Holt, 2018).

3.5 People

Humans are at risk of getting sick from being in or near the water, and also from eating fish or drinking from the river. Hookworms are commonly found in dog feces, and when one is even stepped on it can burrow itself in the foot, making its way through an individual's body to the lungs (Delgado, 2018). Hookworms are typically found anywhere with excessive amounts of feces, especially dogs and cats, and so can be indirectly passed to humans (Delgado, 2018). Children and the elderly are the most susceptible to waterborne illnesses (Holt, 2018). Bacteria can find its way into an individual's system by being swallowed or even absorbed through the skin (Holt, 2018). Shellfish, highlighted in the previous section, also pose a threat to people. Bacteria and pollution pose a threat to the shellfish and to any other organism that consumes them, including people (EPA, 2017). This not only poses a threat to the overall health to a community like Indian River, it could even affect the prices of the fish (EPA, 2017).

4.0 Foresight for the Indian River:

4.1 Chemical: Fallon Woolford

Land Use Change From Industrial Growth Leading to Pollution

Chesapeake is the main city that touches the Indian River. It is a vastly growing city in Hampton Roads, Virginia. Chesapeake has economic growth along the lines of 4,500 businesses in just that city, along with 50 international companies and industrial plants (City of Chesapeake, 2017). With that amount of growth comes more issues with runoffs of the toxic chemical emission that could come into the Indian River. If Chesapeake were to expand to more than 4,500 business, and industrial plants, more chemical emission would be evident. If the City of Chesapeake officials continue on a “business as usual” approach to not adding more urbanization, the river would have ample time to improve its quality.

4.2 Biological: Alissa Ralston

Behavior Change Assessment of the Residents around the Indian River

Behavior change is the best method for lessening the amount of bacteria in the water. If everyone always picks up after their dogs, then bacteria from dog feces will not be the most prominent component in any more samples. The business as usual approach means that not everyone will partake in picking up after their dogs, and there will still be some dog fecal bacteria. This does not mean that it will be as bad as it is now, but not as good as everyone picking up after their dogs. The worst thing for the Indian River is no one picking up after their dogs. This will result in the feces dissolving and taking up the dissolved oxygen. When there is no dissolved oxygen the fish in the water can't breathe, and this will lead to mass fish kills.

5.0 Decision Makers involved in the Indian River:

5.1 Chemical and Biological: Fallon Woolford & Alissa Ralston

The stakeholders involved in the chemical aspects of the Indian River are Some stakeholders are homeowners and fisherman who live in the watershed of Indian River. They have to look at the vast body of water and not use it. Some citizens of the surrounding neighborhoods refuse to go crabbing there recently even though they have for years before. Other stakeholders would include the US Army Corps of Engineers, who work in conjunction with another stakeholder, the non-profit organization, Elizabeth River Project. US Army Corps Of Engineers have an environmental sustainability platform that they uphold with all their work. They are responsible for making the codes and plans for waterway dredging (USACE 2014). The Elizabeth River Project's entire message is to bring the public of Hampton Roads a healthy, safe river to enjoy. The Elizabeth River Project has to work with the US Army Corps of Engineers to work on projects to help the health of the river often. Also working with the Elizabeth River Project is the Elizabeth River State of the River Steering Committee of 2014, it was the group of people who made the State of the River information available and accessible to the public so everyone in the watershed areas could see the ratings of the Indian River's failing grade. Farmers also hold a big stake in the surrounding areas of the Indian River, their use of pesticides, and fertilizers. They are a bombing industry bringing food to many plates of Hampton Roads (Richards 2017). The Sanitation District is also a stakeholder because they take samples of the river to measure the number of bacteria in the water, they determine if the water is safe to swim and fish.

6.0 Options For the Indian River:

6.1 Chemical: Fallon Woolford

6.1.1 The first options the stakeholders should consider is, limit the access to the Indian River to non-motorized aquatic vessels. Little research has been done in Hampton Roads and the Indian River about the boats, commercial and recreational and their impact on the river. By limiting the access the researchers of the river's quality would be able to better access if the boats' chemicals or "dumping" have a critical effect on the health of the river. Also they would be able to do more in depth research that what has been done previously on the impacts of boats. The stakeholders could limit the access to just kayaks, canoes and paddle boarding over the span of a year and see the effect that it has on the river's health and quality.

6.1.2. A second option to improve the health of this once flourishing river would be to monitor and carry a heavier penalty for those who do use fertilizers and pesticides to an excessive extent. Most farmers that use both to an extreme amount think there is nothing wrong with this practice because they are making money without any "consequences".

6.2 Biological: Alissa Ralston

6.2 1. Public education is a great way to get the public engaged in local issues. An interactive website describing the issues in the Indian River in a fun way can help residents see why it's important not to always pick up after their dogs. This is achieved in individuals being emotionally invested in the issue at hand. This can be done by highlighting the potential health risks associated with dissolved dog feces, or stating how other animals and plants are affected.

6.2 2. If the quality of the river doesn't improve, the Civic League should consider imposing a small fee on dog owners. This fee will be used to pay a service to come clean up after their dogs on a weekly basis. This is important because it can motivate the dog owning residents to clean up after their dogs. Hopefully the residents will learn how one small act can help the health of the surrounding ecosystems.

6.2 3. One way to lessen the chances of algal blooms in the water is Floating Treatment Wetlands (EPA, 2018). The plants will have to be periodically harvested so there is not a build up of nutrients (EPA, 2018). This also means that when the plants die off, those will also have to be harvested before they break down in the water (EPA, 2018). This option will mesh very well with the natural processes in the water, and will also require little attention (EPA, 2018).

7.0 Recommendations for the Indian River:

7.1 Chemical: Fallon Woolford

A recommendation in how to improve the chemical pollution of the Indian River would be a combination of the options stated in section 6. To do further research on boats' impact on the health and quality of the river. More research needs to be done, and from that the US Army Corps of Engineers and other officials could vote to limit the use of the river to only kayaks, paddle boards and other non-motorized vessels. Also implementing harsher laws to keep excess nutrients from pesticides and fertilizers out of the water needs to be established on farmers and surrounding homeowners of the watershed. Making natural pesticides and fertilizers more available, affordable, and easy to use would be a greater step in the direction of a healthier, cleaner, usable river for the residents of Indian River and the greater Chesapeake areas.

7.2 Biological: Alissa Ralston

A public online forum is a great way to get residents educated on the current Indian River environmental issues. This can be an interactive website that explains what is wrong and how the Indian River residents can improve the health of their river. If homeowners do not take this seriously I believe the city should impose some kind of fee to live in their neighborhood so they can afford to have a service come and pick up after the dogs. This could also increase public knowledge about a common issue or give an opportunity for a company to find more work. Residents think that leaving their dog's poop on the sidewalk is not a big deal, but more education and a consequence from doing nothing could be beneficial. A Floating Treatment Wetland is a great way to prevent an algal bloom. This method will take up any extra nutrients in the water that would otherwise be used by the cyanobacteria (EPA, 2018). The FTW will require constant maintenance, and if it is not monitored could lead to deoxygenation in the water (EPA, 2018).

References

- A.Alvarez, L. Botzong, K. Burke, E, Rosenberg. June, 2012. Dog Waste in Santa Barbara: Strategies and Solutions. City of Santa Barbara.
<https://www.santabarbaraca.gov/civicax/filebank/blobdload.aspx?BlobID=42936>. Accessed on July 28, 2018.
- A.Kiersz. July 11, 2014. Here's the Official Cat States v. Dog States. Business Insider.
<https://www.businessinsider.com/cat-and-dog-ownership-maps-2014-7>. Accessed on July 30, 2018.
- BBC. (2014). Science and Yield Crop.
http://www.bbc.co.uk/schools/gcsebitesize/science/add_gateway_pre_2011/chemical/fertilisersrev1.shtml Accessed on July 30th, 2018.
- Byappanahalli, M. Nevers, M. Korajkic, A. Staley, Z. Harwood V. (December 2012). Enterococci in the Environment. *American Society for Microbiology*. Vol. 76.
<http://mmbbr.asm.org/content/76/4/685.full>. Accessed on July 29, 2018.
- Center for Disease Control (CDC). (2017). Marine Environments. *Harmful Algal Bloom (HAB)-Associated Illness*. <https://www.cdc.gov/habs/illness-symptoms-marine.html>. Accessed July 31, 2018.
- C, Cross. August 10, 2016. Why Dog Business Should be Your Business. Swim Guide.
<https://www.theswimguide.org/2016/08/10/dog-business-business/>. Accessed on July 29, 2018.
- Delgado, A. (2018). Hookworm Infections. *Healthline*.
<https://www.healthline.com/health/hookworm>. Accessed July 31, 2018.
- Di Giulio, R. and Clark, B. W. (2015). The Elizabeth River Story: A Case Study in Evolutionary Toxicology. *Journal of Toxicology and Environmental Health. Part B, Critical Reviews*, 18(6), 259–298. <http://doi.org/10.1080/15320383.2015.1074841>
- Elizabeth River Project. (2014). State of the River: Scorecard 2014.
<https://www.elizabethriver.org/sites/default/files/State-Of-The-River-2014.pdf> Accessed on July 16th, 2018.

Environmental Protection Agency (EPA) 2018. Information about Pesticide Ingredients. <https://www.epa.gov/ingredients-used-pesticide-products/basic-information-about-pesticide-ingredients> Accessed on July 30th, 2018.

Environmental Protection Agency (EPA). 2017. Climate Impacts on Human Health. <https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-human-health.html>. Accessed on July 24, 2018.

Environmental Protection Agency (EPA). 2018. Control and Treatment. <https://www.epa.gov/nutrient-policy-data/control-and-treatment>. Accessed on July 24, 2018.

Evans, K. Athearn, K. Chen, X. Bell, K. Johnson, T. (2016). Measuring the impact of pollution closures on commercial shellfish harvest: The case of soft shell clams in Machias Bay, Maine. *Ocean and Coastal Management*. Vol. 130.

<https://www.sciencedirect.com/science/article/pii/S0964569116301144>. Accessed July 30, 2018.

Hampton Roads Economic Development Alliance (HREDA). 2015. Manufacturing Companies list. <https://technologyhamptonroads.com/wp-content/uploads/Manufacturing-Companies-in-HR.pdf> Accessed on July 20th, 2018.

J. Holt, L. Floyd. June 16, 2014. Storm Water Pollution: Pet Waste. Barrier Island Ecology UNCW. <https://sites.google.com/site/barrierislandecology2013/coastal-and-barrier-island-ecosystem-factors/stormwater-pollution-pet-waste>. Accessed on July 30, 2018.

Indiana University. (2018). What Causes Algal Blooms? Center for Earth and Environmental Science. <https://cees.iupui.edu/research/algal-toxicology/bloomfactors>. Accessed July 30, 2018.

NSW Government: Department of Primary Industries. (1993). Fertilizers and the Environment. <https://www.dpi.nsw.gov.au/agriculture/soils/improvement/environment> Accessed on July 29th, 2018.

Powledge, F. (1996). Changing Chesapeake. *Bioscience*, 46(6), 397

Richards, Lindsey. 2018. Field Life: A Guide to Local Farms In Hampton Roads. <https://altdaily.com/field-life-a-guide-to-local-farms-in-hampton-roads/> Accessed on July 29th, 2018.

Sierra Club (2014). Top 15 Air Polluting Localities in Virginia.
<https://www.sierraclub.org/sites/www.sierraclub.org/files/sce/virginia-chapter/documents/2014toxicreport.pdf> Accessed on August 1st, 2018.

Union of Concerned Scientists.(2014.) Environmental Impacts of Natural Gas.
<https://www.ucsusa.org/clean-energy/coal-and-other-fossil-fuels/environmental-impacts-of-natural-gas#.W3h3NuhKjIV> Accessed on August 2nd, 2018.