Water quality of the South Stann Creek River near a banana plantation at mile 21 ½ on the Southern Highway

A Thesis Submitted to the University of Belize in Fulfillment of

BIOL 4992 - Independent Research

As Part of Bachelors of Science in Biology

Submitted by

Cheryl Jones

Under the Supervision of

Dr. Abel Carrias

Education Empowers a Nation

Department of Science

Faculty of Science and Technology

University of Belize

Water quality of the South Stann Creek River near a banana plantation at mile 21 ½ on the Southern Highway

Except where reference is made to the work of others, the work described in this thesis is my own or was done in collaboration with my advisor. This thesis does not include proprietary or classified information.

____

Cheryl Jones

Certificate of Approval:

________________ ________________

Abel A. Carrias
Assistant Professor
Marine Biology

ABSTRACT

Banana plantations require a range of fertilizers and pesticides to keep crops disease free and produce high yields of fruits. They also require a significant amount of irrigation; therefore, they are cultivated near natural water sources. Heavy usage of fertilizers and other chemicals on crops and the proximity of the farm to the water bodies can affect water quality and hence rendering the water unfit for human use and organisms that live in it. This research aims to evaluate the water quality of the South Stann Creek River near a banana plantation along the Southern Highway at mile 21 1/2. Two water quality sampling sites were selected for this study. Parameters that were measured using an YSI 556 Multiprobe System (MPS) and a portable colorimeter meter DR 850, HACH were temperature, conductivity, salinity, dissolved oxygen, pH, nitrates, nitrites, reactive phosphates and turbidity. Readings were taken on two separate occasions, two weeks apart. All parameters for site 1carried out on April 1st were within normal range except for low pH values ranging from 4.9 to 5.43. This was after a period of extensive rain. Other results which stood out were the low dissolved oxygen (DO) values at both Site 1 and Site 2 for both sampling times. With the exception of the low DO and pH levels observed, there were no values outside acceptable ranges. Additional testing is required to obtain a better understanding of the water quality status of the area studied.

ACKNOWLEDGEMENTS

A sincere thank you is extended to Dr. Abel Carrias for helping to facilitate data collection for this research as well as providing general guidance with conducting the research. Gratitude is also extended to the Natural Resource Management Program at the University of Belize and the Laboratory staff for providing the equipment necessary for the research. Gratitude is also extended to Francisco Lopez Jr. and Kingsley Requeña for helping as technical support.

Table of Contents

LITERATURE REVIEW

Fresh water is one of the Earth's most vital resources. Only 3% of the water on earth is fresh water. About 2% of that is contained within glaciers and ice at the poles. This means potable water which can be used domestically, commercially and industrially all comes from 1% of earth's water. It needs to be preserved as it is greatly important to the health of the environment as well as human health. Ensuring that water quality is monitored can help to keep clean, viable water sources readily available. Water consumption of all nations, which can also be referred to as earth's "water footprint", has been quantified to equal 9,087 billion cubic meters (24 x 10^{14} gallons) according to researchers from the University of Twente in Netherlands (Hoekstra & Mekonnen, 2011). This water is used to provide running water for domestic use in homes, fuel irrigation of crops, quench the thirst of livestock and wild animals etc. Every living thing on earth depends on water for survival. Humans depend on water not only for survival but for domestic, industrial and commercial usage.

Currently, freshwater sources are placed under tremendous pressure due to the heavy and taxing demand which the growing human population places on it. Currently the US, China, India and Japan are the largest consumers of freshwater in households (Fischetti, 2012). The US consumes the most freshwater in industry and India leads in consumption for agriculture (Fischetti, 2012). The recognition that freshwater resources are subject to global changes and globalization has led a number of researchers to argue for the importance of putting freshwater issues in a global context (Hoekstra & Mekonnen, 2011). This led to the establishment of acceptable ranges of water parameter indicators. For example, the acceptable levels of nitrates, nitrites and reactive phosphates in milligrams per liter squared are 10, 1 and 1 respectively as set by the United States Environmental Protection Agency (EPA). Standards for different chemical parameters help to ensure the safety and health of the earth's population that utilizes the earth's water. The most common sources for nitrites, nitrates, and phosphates are from the excessive use of fertilizers and pesticides in agriculture. Improper waste disposal from human or animal sources can also affect sources of nitrogen in water. The acceptable level of pH for drinking water in accordance with EPA standards is 6.5-8.5 on the logarithmic scale. Various organic and inorganic contaminants can change the alkalinity or acidity and thus affect the power of hydrogen (pH).

The farming of bananas requires the use of a range of chemicals, including fertilizers, and pesticides. These chemicals are abundantly applied to the plantation to ward off the many diseases that affects bananas. In 2006, a third of the volume of imported pesticides in Costa Rica was used solely on banana plantations (Castillo, 2006). Some compounds used include dithiocarbamate, chlorophenyl, conazole and benzimid-azole fungicides; organophosphate and carbamate nematicides and insecticides; and triazine and bipyridyl herbicides (Castillo, 2006). Conventional production of bananas requires great quantities of agrochemicals, particularly fungicides, to control the disease *Black Sigatoka.* Spraying of bisdithiocarbamates to control *Black Sigatoka* takes place in nearly all conventional managed banana farms at high frequencies and doses (Geissen, 2010). Bisdithiocarbamates have a medium life span. They are thought to have low toxicity since they only last one to seven days in soil. While this may be true, the byproducts of its decomposition can still be harmful to the environment. There are certain metals which are sub-compounds of the chemical such as manganese and zinc which may leach into the soil. The main metabolite of bisdithiocarbamates is ethylenethiourea (ETU). This compound is highly soluble in water and pollutes groundwater or rivers/streams which are near effluent sites of the plantation. Ethylenethiourea (ETU) has a high potential to cause cancer, and genetic defects in laboratory animals (Shukla Y, 2001).

INTRODUCTION

Citrus orchards and banana plantations are located along the Southern Highway in Belize at mile twenty one and a half. These farms use the South Stann Creek River as their main source of water for its irrigation needs. One of these farms is located near the study site. The farm has been in existence for over thirty years now. Since its establishment, fertilizers and pesticides have been used to aid in crop yields. The most prevalent chemical application is fungicides. These chemicals are sprayed aerially by planes. This is done every 10 days in the dry season and every eight days in the wet season. The excess use of fertilizers and pesticides in banana farms have the potential of causing negative impacts to the surrounding aquatic ecosystems and even pose health threats to humans and animals that use these water bodies.

Farming of bananas also requires the utilization a lowland areas. These areas are commonly cleared of all foliage and vegetation before cultivation of the land. Banana plantations also require a lot of water and so are generally located near a natural water body. Water is used for irrigation to keep the plants hydrated and healthy. While the location of farms near water bodies benefits the farmer, it can harm the surrounding terrestrial and aquatic environment and obstruct the natural flow of water bodies used for water extraction. Having banana plantations so close to natural water bodies also poses a threat from the potential of fertilizers and pesticides used in the farm leaching out into these water bodies. This is because intensively managed banana plantations are characterized by an extensive system of drainage canals where surplus water may flow into local streams and rivers (Castillo, 2006). Clearing of forests for planting banana trees is also another factor to consider. The decrease in foliage makes it that much easier for leachate from soil to seep into surrounding water. In the plantations, there are large canals which are dug out to collect water which flows out after irrigation and, it also acts as a catchment system if there is heavy rain and consequent flooding. While banana farms try not to let the water flow directly into surrounding water bodies, all drainage sites in banana plantations typically leads to a central canal which eventually drains the site into a catchment area; typically a nearby river or stream.

The interest in this study stemmed from the fact that Belize has an abundant supply of water for its size. There are 18 major rivers in the country with many other small streams or watersheds. They are the source of our potable water in homes, agriculture and industry. Because there is an abundance of water in the country, people can easily take it for granted. As a developing country, it is important that resources are properly managed and best practices in agriculture are utilized to ensure sustainable development. The Environmental Protection Act of Belize was enacted in 1992 and was the first legislation which concerned protection and conservation of Belize's resources. It is enforced by the Department of the Environment and under the legislation is water pollution and subsequent monitoring. It is important that water quality is continuously monitored and that a high standard is always kept and met.

The potential for water pollution form banana farming activities raises alarms and encourages the study of water quality. Therefore, the objective of the study was to evaluate the physical and chemical water quality status of a section of the South Stann Creek River near a banana farm.

MATERIALS AND METHODS

Site Description

The sites selected for this study is a section of the South Stann Creek river near a banana farm located at 21 ½ miles Southern Highway in the Stann Creek District, Belize C.A. The farm has been around for more than 30 years, with 4 banana plantations, some being older than others. Together the farm has 1,345 acres of land under banana production. Each of the 4 four plantations possesses a packaging plant whereby the bananas are cut from the stalk, sprayed, sorted, washed, and packaged for shipping. In addition, the farm has a housing area in which farm workers live. The farm is one amongst many in the world that produces and packages bananas under the Fyffes brand of foods. Fyffes plc is a leading importer and distributor of tropical produce, headquartered in Dublin, Ireland.

The South Stann Creek River runs along a banana plantation. From the plantation, the river is approximately 9 – 10 miles from the Caribbean Sea. The river does not only pass through the banana plantation but also other citrus farms along the way. Along the river, two sites with the coordinates N 16^{o}42.918' W 088^{o}24.874' and N 16^{o}43.074' W 088^{o}25.215' were selected for the study. Site #1 (N 16^{o}42.918' W 088^{o}24.874') was located near a housing area adjacent to the river and the banana plantation. Site #2 (N 16^{o}43.074' W 088^{o}25.215') was located near the water pump of the plantation where water is extracted from the river for irrigation purposes for the plantation.

Water Quality Testing

In situ physical and chemical water quality parameters were measured using an YSI 556 MPS (multi probe system). Parameters measured include temperature, dissolved oxygen (DO), salinity, pH, and conductivity. Additionally, a DR 850 model colorimeter was used to test for chemical parameters including nitrates, nitrites and phosphates, as well as the physical parameter, turbidity. Measurements were taken in triplicates: at the top, middle, and bottom layer of the water. At each site sampled, measurements were taken across a transect of the river; at both edges of the river and at the middle.

RESULTS

Results of physical water quality parameters are presented in Tables 1-4. The results of the physical parameters tested at Site 1 on April 1st are presented in Table 1. At site 1, the dissolved oxygen levels are low and the pH values are acidic unlike any of the other site tested.

Table 1. Results of water quality parameters measured at study site #1 of the South Stann Creek River at mile 21 ½ Southern Highway during April 1, 2015.

Site 1 YSI 556 MPS Reading April 1, 2015						
South Bank						
Probe Depth	**Temperature (°C)**	**Conductivity (mS/cm)**	**Salinity (ppt)**	**DO (%)**	**DO (mg/L)**	**pH**
Top	23.83	0.045	0.02	16.50	1.35	5.02
Middle	23.81	0.045	0.02	22.10	1.91	5.12
Bottom	23.81	0.045	0.02	24.10	2.03	5.17
Average	23.82	0.045	0.02	20.90	1.76	5.10
Mid-River						
Probe Depth	**Temperature (°C)**	**Conductivity (mS/cm)**	**Salinity (ppt)**	**DO (%)**	**DO (mg/L)**	**pH**
Top	23.75	0.045	0.02	14.00	1.18	4.90
Middle	23.80	0.045	0.02	17.60	1.48	5.14
Bottom	23.80	0.045	0.02	17.30	1.46	5.25
Average	23.78	0.045	0.02	16.30	1.37	5.10
North Bank						
Probe Depth	**Temperature (°C)**	**Conductivity (mS/cm)**	**Salinity (ppt)**	**DO (%)**	**DO (mg/L)**	**pH**
Top	23.80	0.045	0.02	14.20	1.20	5.08
Middle	23.79	0.045	0.02	20.40	1.72	5.32
Bottom	23.79	0.045	0.02	19.90	1.68	5.43
Average	23.80	0.045	0.02	18.17	1.53	5.28

The results of the physical parameters tested at Site 2 on April 1st are presented in Table 2. At site # 2, the dissolved oxygen levels are low and the pH values are close to neutral.

Table 2. Results of water quality parameters measured at study site #2 of the South Stann Creek River at mile 21 ½ Southern Highway during April 1, 2015.

Site 2 YSI 556 MPS Reading April 1, 2015						
Point A						
Probe Depth	**Temperature (°C)**	**Conductivity (mS/cm)**	**Salinity (ppt)**	**DO (%)**	**DO (mg/L)**	**pH**
Top	23.85	0.044	0.02	10.10	0.84	8.09
Middle	23.85	0.044	0.02	12.70	1.06	8.07
Bottom	23.84	0.044	0.02	11.70	1.07	7.91
Average	23.85	0.044	0.02	11.50	0.99	8.02
Point B						
Probe Depth	**Temperature (°C)**	**Conductivity (mS/cm)**	**Salinity (ppt)**	**DO (%)**	**DO (mg/L)**	**pH**
Top	23.86	0.044	0.02	8.30	0.71	7.84
Middle	23.84	0.044	0.02	8.9	0.75	7.84
Bottom	23.84	0.044	0.02	8.9	0.75	7.84
Average	23.85	0.044	0.02	8.70	0.73	7.84

Results of the physical parameters tested at Site 1 on April 15th are presented in Table 3. The values obtained are similar to those obtained at site # 2 during the April 15 sampling, with the exception of temperature reading which is roughly 4 to 5 degrees higher in this location.

Table 3. Results of water quality parameters measured at study site #1 of the South Stann Creek River at mile 21 ½ Southern Highway during April 15, 2015.

Site 1 YSI 556 MPS Reading April 15, 2015						
South Bank						
Probe	**Temperature**	**Conductivity**	**Salinity (ppt)**	**DO (%)**	**DO**	**pH**

Depth	(°C)	(mS/cm)			(mg/L)	
Top	29.17	0.075	0.03	3.30	0.25	7.84
Middle	29.19	0.075	0.03	3.80	0.30	7.80
Bottom	29.21	0.075	0.03	4.80	0.33	7.80
Average	29.19	0.075	0.03	3.97	0.29	7.81
Mid-River						
Probe Depth	**Temperature (°C)**	**Conductivity (mS/cm)**	**Salinity (ppt)**	**DO (%)**	**DO (mg/L)**	**pH**
Top	29.17	0.075	0.03	4.40	0.34	7.74
North Bank						
Probe Depth	**Temperature (°C)**	**Conductivity (mS/cm)**	**Salinity (ppt)**	**DO (%)**	**DO (mg/L)**	**pH**
Top	29.16	0.075	0.03	4.50	0.34	7.77
Middle	29.21	0.075	0.03	4.80	0.37	7.71
Bottom	29.20	0.075	0.03	4.90	0.38	7.71
Average	29.19	0.075	0.03	4.73	0.36	7.73

Results of the physical parameters tested at Site 2 on April 15thare presented in Table 4. The values do not vary greatly from those obtained in site 1 during the April 15 sampling time. However, the pH is also slightly lower in this site.

Table 4. Results of water quality parameters measured at study site #2 of the South Stann Creek River at mile 21 ½ Southern Highway during April 15, 2015.

Site 2 YSI 556 MPS Reading April 15, 2015						
South Bank						
Probe Depth	**Temperature (°C)**	**Conductivity (mS/cm)**	**Salinity (ppt)**	**DO (%)**	**DO (mg/L)**	**pH**
Top	29.08	0.063	0.03	6.10	0.47	7.16
Middle	29.09	0.063	0.03	9.20	0.70	7.09
Bottom	29.12	0.063	0.03	9.70	0.74	7.08

Average	29.10	0.063	0.03	8.33	0.64	7.11
Mid-River						
Probe Depth	**Temperature (°C)**	**Conductivity (mS/cm)**	**Salinity (ppt)**	**DO (%)**	**DO (mg/L)**	**pH**
Top	29.09	0.063	0.03	6.70	0.51	7.07
Middle	29.11	0.063	0.03	9.20	0.70	7.07
Bottom	29.11	0.063	0.03	9.10	0.70	7.08
Average	29.10	0.063	0.03	8.33	0.64	7.07
North Bank						
Probe Depth	**Temperature (°C)**	**Conductivity (mS/cm)**	**Salinity (ppt)**	**DO (%)**	**DO (mg/L)**	**pH**
Top	29.09	0.063	0.03	5.20	0.41	7.09
Middle	29.10	0.063	0.03	6.40	0.49	7.05
Bottom	29.11	0.063	0.03	6.60	0.51	7.07
Average	29.10	0.063	0.03	6.07	0.47	7.07

Results of the chemical parameters (nitrites, nitrates and reactive phosphates) for both sampling sites are presented in Table 5 and Table 6. All the values were within acceptable range as defined by the Belize Effluent Regulations amendment of 2009.

Table 5. Results of chemical water quality parameters measured at study site #1 of the South Stann Creek River at mile 21 ½ Southern Highway during April 15, 2015.

Site 1 DR 850 Reading April 15, 2015			
Nitrate (mg/L $NO3^{-}N$)	**Nitrite (mg/L $NO2^{-}N$)**	**Reactive Phosphate (mg/L PO_4^{3-})**	**Turbidity (FAU)**
0.14	0.041	0.90	47

Table 6. Results of chemical water quality parameters measured at study site #2 of the South Stann Creek River at mile 21 ½ Southern Highway during April 15, 2015.

Site 2 DR 850 Reading April 15, 2015			
Nitrate (mg/L NO3¯N)	**Nitrite (mg/L NO2¯N)**	**Reactive Phosphate (mg/L PO_4^{3-})**	**Turbidity (FAU)**
0.05	0.028	0.16	17

DISCUSSION

Physical parameters measured included: temperature (C°), conductivity (mS/cm), salinity (ppt), DO (%), DO (mg/L) and pH. Temperature readings obtained were not abnormal in any of the sampling done It can be noted that the temperature at site 1 and 2 were about 5 C° lower for the readings on April 1st than they were on April 15th. This can be explained by the influence of rain which occurred during the April 1st sampling. The conductivity and salinity were very low across all sampling done. Conductivity and salinity are directly proportionate to one another. Conductivity is the degree to which a specified material conducts electricity, calculated as the ratio of the current density in the material to the electric field which causes the flow of current. According to Britannica Encyclopedia salinity refers to the amount of dissolved salts in the water. The conductivity of water is reliant on the dissolved ions in the water. When salts dissolve in water, they form the ions which can conduct an electrical current. It is characteristic of freshwater to have low salinity as reflected by the low levels of ions present in these environments.

The pH values at site 1 on April 1st were on the lower range of the scale making them acidic. These values ranged from 4.90 to 5.43. Most organisms living in an aquatic environment require generally neutral conditions to survive. Optimal pH for organism function and survival is between pH of 6 to 8 or so. If the water becomes too acidic or basic, the living conditions are outside of the optimal range, which can affect the metabolic function of fish, insects etc. and can ultimately cause them to die. Having acidic water can be detrimental to aquatic life which is why these values were so alarming. The specific cause of this is not easily determined. The fact that there was heavy rain could be a determining factor. Rain generally has an acidic pH ranging from 5.6 to 5.8 due to the presence of carbonic acid. The carbon dioxide in the atmosphere is dissolved in aqueous solution which forms the carbonic acid (H_2CO_3). Usually, calcareous deposits in the soil (usually in the form of calcium carbonate [$CaCO_3$]) act as a buffer which helps to keep the pH of the water neutral. It is possible that the soil for some reason has less calcareous deposits and did not buffer the water. It is also possible that the rain was more acidic than usual. Also, site 1 is located near a village which could largely impact the quality of the water there. On site, signs of pollution were clearly visible. Solid waste such as plastic, Styrofoam and even used diapers were seen near and in the river. It could also be hypothesized that the rain washed household chemical used by habitants of the nearby village which could contribute to the low ph. . . .

The one parameter which was consistently outside of the normal range across the two sampling sites and during the two sampling times was the dissolved oxygen. Dissolved oxygen describes oxygen molecules, which have actually dissolved in water (Mesner & Geiger, 2010). Dissolved oxygen fuels the oxygen demand of organisms which inhabit the water. All animals undergo the process of respiration to support their metabolic functions and to give them energy and, during the night plants do not photosynthesize but rather respire. The amount of dissolved oxygen in water is dependent upon the temperature. The temperature of a liquid and the solubility of gases are inversely proportionate. This means that the higher the temperature of the water, the less oxygen can be dissolved in it. According to the United States Environmental Protection Act, the maximum dissolved oxygen level for water that is 24 °C is roughly 8.40 mg/L and, the maximum dissolved oxygen level for water that is 29 °C is roughly 7.67 mg/L. All the dissolved oxygen levels were incredibly low. The highest value was 2.03 at Site 1 on the 1st of April. Even that value is 6.37 mg/L below the optimal level. It was noted that the riverbed had a lot of organic waste in the form of fallen leaves. Detritus encourages the growth of microorganisms as they decompose the organic substances. This could be a reason why the dissolved oxygen was low. There could be a high number of microorganisms which deplete the oxygen demand. The nearing village could be contaminating the river with sewage which would add the overpopulation of microorganisms. Runoff from fertilizers used at the banana plantation could also cause excess nutrient deposits in the water. This would cause photosynthetic organisms to flourish and deplete oxygen when they respire which could also be a factor contributing to the low dissolved oxygen levels. While both Site 1 and 2 had low readings on the 1st of April, Site 1 had a higher dissolved oxygen level. This can be attributed to the fact that it had higher turbidity which would mean more aeration thus, allowing more oxygen to transfer from the atmosphere into the water. The readings on April 1st were both higher than those observed during the April 15thsampling. This could also be a result of turbidity.

Low range testing was conducted for the chemical parameters nitrites, nitrates and reactive phosphates. The low range values for each respectively are 0-0.350 mg/L, 0.50 mg/L and 0.2.5 mg/L. This was done with a DR 850 which also measures turbidity. Normal turbidity levels can range from 0-1000 FAU. The results showed that in all chemical parameters tested all were well within low range values. The turbidity results were also low. It must be noted that due to time constraints and limited access to equipment, numerous samples were not taken. Also, these samples were taken after an extensive period of rain. The river was raised higher than normal. It is possible that the water was diluted enough to have made the results show low levels of the chemicals.

CONCLUSION

When evaluating all the parameters tested for the water in the South Stann Creek River from the two sites used, the values obtained indicate a medium impacted river area. However, some parameters of concern was also observed. What was in fact alarming was the pH values obtained at Site 1 on April 1, 2015. The acidic water ranged from 4.90-5.43. It was hard to determine a plausible cause since these odd values were isolated to Site 1 only on April first. The event, which caused the acidity of the pH values, is likely in the same nature of the values meaning it was isolated as well. Generally speaking, more testing would need to be done to see if this isolated event presents any sort of pattern, over the course of a few months or more. If this was done and there was a pattern, more conclusive data could be drawn from it to possibly identify a cause.

The other parameter which tested to be abnormal and can be considered of great concern to the health of the water was the dissolved oxygen. These values were consistently low in each sampling done at both sites. Further investigation would need to be done here. A study of the nearby village could also be done to see if there are any domestic wastes being directly drained into the river. Septic facilities can also be examined to ensure they are up to code and do not impact the river.

This research was limited by time constraints. The equipment to test the various parameters also presented an issue because free access to them was not an option. To be able to gather more conclusive evidence, the testing would have to be repeated over a longer period of time. With the collection of more data, statistical analysis of the results would be possible to increase understanding of the patterns of the varying parameters.

My recommendation would be to do more studies of the area. Conduct research and observe the waste from both the village and the banana plantation to see how they impact the water source. To draw more concrete information on how the farm affects the water, higher level testing may need to be conducted to test for highly specific chemical compounds found in the various pesticides, herbicides and fungicides used in the plantation or the byproducts of these same chemicals. If these chemicals can be isolated, the studies can possibly be furthered in an ecological aspect to see if there is bioaccumulation in the aquatic organisms in the river. As for the nearing village, the septic systems should be evaluated to ensure they are either treated properly and do not run directly into the river. Seminars can also be held to educate the villagers about how they can advocate for protection and conservation of the environment and how they can change their action to be more eco-friendly.

REFERENCES

(2005). Retrieved 2015, from Biology Online: http://www.biology-online.org/dictionary/Dissolved_oxygen

British and World English Conductivity. (2015). Retrieved 2015, from Oxford Doctionaries: http://www.oxforddictionaries.com/definition/english/conductivity

Castillo, L. E. (2006). Water quality and macroinvertebrate community response following pesticide applications in a banana plantation, Limon, Costa Rica. *Science of the Total Environment* , 418-432.

Drinking Water Contaminants. (2014, October 29). Retrieved 2015, from EPA: http://water.epa.gov/drink/contaminants/#List

Fischetti, M. (2012, May 21). *How Much Water Do We Consume? Earth Thirst: Solving the Freshwater Crisis*. Retrieved April 2015, from Scientific American: http://www.scientificamerican.com/article/graphic-science-how-much-water-nations-consume/

Geissen, V. (2010). Soil and Water Pollution in a Banana Production Region in Tropical Mexico. *Bulletin of Environmental Contamination and Toxicology* .

Hoekstra, A., & Mekonnen, M. M. (2011). The water footprint of humanity. *Gleick, Pacific Institute for Studies in Development, Environment, and Security* .

Mesner, N., & Geiger, J. (2010, December). *Understanding Your Watershed: Dissolved Oxygen.* Retrieved 2015, from Utah State University Water Quality Extension: https://extension.usu.edu/files/publications/publication/NR_WQ_2005-16.pdf

Oram, B. (2014). *Dissovled Oxygen in Water*. Retrieved 2015, from Water Research Center: http://www.water-research.net/index.php/dissovled-oxygen-in-water

Perlman, H. (2014, March 17). *The Effects of Urbanization*. Retrieved 2015, from USGS Science for a Changing World: https://water.usgs.gov/edu/urbanquality.html

Science Salinity. (2015). Retrieved 2015, from Encyclopedia Britannica: http://www.britannica.com/EBchecked/topic/519274/salinity

Shukla Y, A. A. (2001). Transplacental carcinogenic potential of the carbamate fungicide mancozeb. *Environmental Pathology, Toxicology and Oncology* , 127-131.

The Environmental Protection Act Chapter 328 of the Substantive Laws of Belize Revised Edition 2000. (2013). Retrieved 2015, from Department of the Environment: http://www.doe.gov.bz/index.php/legislation