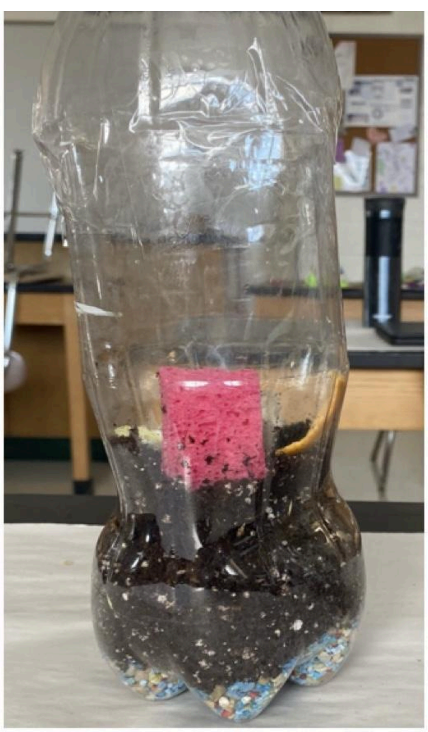
How does the cycling of essential elements affect biotic and abiotic components of an ecosystem?






ABSTRACT

In this experiment, an engineered aquatic and terrestrial ecosystem will be observed for four weeks. The ideal outcome of the experiment is the adequate cycle of nutrients for both plant and animal life to be sustained throughout the four weeks. By collecting qualitative data (including the height of plants, water height, level of condensation, and pH) as well as qualitative data, the success as to which this goal is achieved will be measured. The hypothesis was: if the correct amount of natural materials are added to the ecosystem, then the biotic components will be able to survive and thrive due to the cycling of oxygen, carbon dioxide, and nitrogen. The ecosystem was created by cutting two 2-liter soda bottles, one of which was for the aquatic ecosystem, and the other was for the terrestrial ecosystem. The bottles were connected with a plastic tube to allow for the exchange of oxygen, carbon dioxide, nitrogen, and other essential elements for the maintenance of life. At the conclusion of the lab, none of the animals survived, and the elodea and grass were beginning to wither and slowly die. It was evident that the cycling of nutrients has slowed almost to a complete stop. While these nutrients could be cycled for some time, more resources and materials would be required to sustain life in this artificial way for longer.

INTRODUCTION

An ecosystem is a system consisting of biotic and abiotic components that function together as one cohesive unit. Biotic components are the living or once-living organisms in the environment. Abiotic components are the non-living physical and chemical elements that are present in the ecosystem. Both of these components are exceedingly important in the success of both engineered and natural ecosystems. Creating an ecosystem in which living creatures can survive and thrive such as they do on Earth is an extremely difficult task. For life to be sustained, a delicate balance of essential nutrients must be maintained. The interaction between aquatic and terrestrial ecosystems is essential for this balance, as nutrients such as carbon, oxygen, and nitrogen are exchanged between these two ecosystems which aid in the survival of organisms and the regulation of abiotic components.

MATERIALS AND METHODS

- Two 2-liter bottles were used to contain the aquatic and terrestrial ecosystems. The top of the lids were cut off and taped back on with duct tape after the ecosystems were constructed.
- Plastic tubing placed in each of the bottles connected both bottles, allowing for the exchange of oxygen and carbon dioxide between the aquatic and terrestrial ecosystems.
- Duct tape was used to secure the plastic tubing on the tops of the bottles.
- Scissors were used to cut the tops off of the bottles.
- Clear packaging tape was utilized to tape the lid of the bottles back on after the ecosystems were constructed.

Aquatic Ecosystem:

- About 1 tablespoon of activated carbon was placed in the empty soda bottle.
- 1 cup of multicolored aquarium rocks were placed on top of the activated carbon.
- 1 strand of live elodea
- 1 live goldfish
- About 2 cups of pond water were placed in the bottle
- 2 snails

Terrestrial Ecosystem:

- About ⅓ cup of multicolored aquarium rocks were placed on the bottom of the empty bottle.
- 2 cups of soil
- 5 flowering plant seeds
- 20 grass seeds
- 2 live crickets
- 1 live worm
- A 1x1 inch sponge

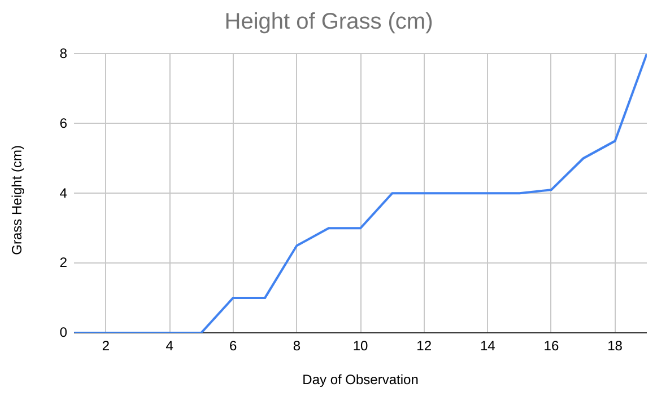
- A section of an orange peel
- 1 dead moth
- 1 cardboard egg carton section

PROCEDURES

1. Acquire two 2-liter soda bottles. Cut off the tops of the bottles about ⅓ of the way down from the top. Wash out any remaining liquid to prevent contamination.
2. Put one of the cut bottles aside. Fill the other empty bottle with the activated carbon. Once the carbon is inside of the bottle, add the multicolored aquarium rocks on top. Add the pond water to the bottle carefully, to prevent the water from splashing and unsettling the aquarium rocks.
3. Place the strand of elodea in the bottle filled with water. Next, add the goldfish into the newly constructed aquatic ecosystem. Using clear packaging tape, place the lid of the bottle back on and secure the lid. Set this bottle aside.
4. Obtain the second 2-liter bottle. Place the multicolored aquarium rocks at the bottom of the empty 2-liter bottle. Next place the soil on top of the rocks carefully. Add the flowing plant and grass seeds, covering them in the soil.
5. Add the worm into the environment, carefully placing it in the container. Next add the orange, egg carton, and dead moth. Soak a sponge and place it on the top of the soil.
6. Add the crickets to the bottle, and quickly tape the lid of the second bottle back on with clear packaging tape.
7. Place one end of the plastic tubing in the lids of each of the bottles. Secure it with duct tape.
8. The aquatic and terrestrial ecosystems have been successfully constructed.

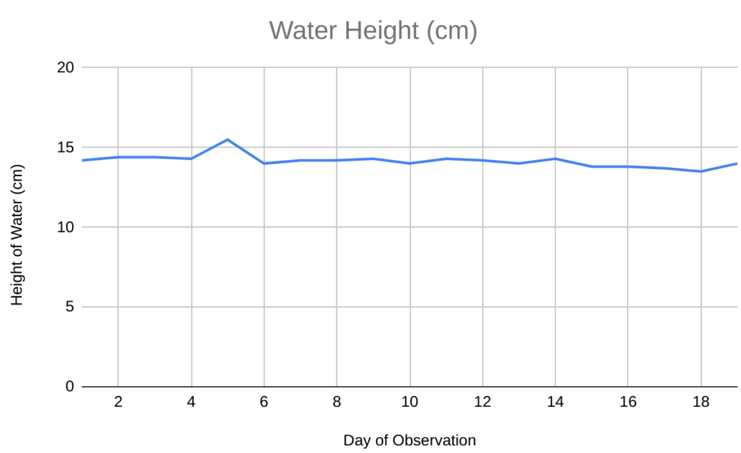
RESULTS (Quantitative Data)

Figure 1: height of grass grown over the four weeks of the experiment



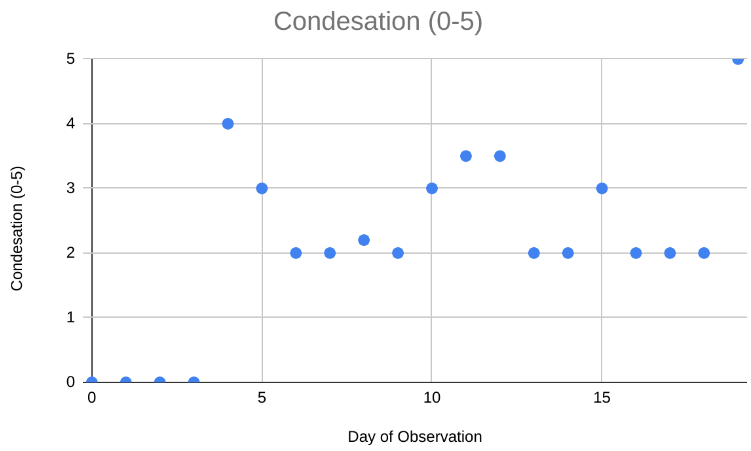
The grass was first observed in the terrestrial ecosystem on day 6 of observation. The grass continued to grow at varying speeds throughout the experiment. When left for a week without observation, the grass grew 2.5 cm.

Figure 2: height of water in the aquatic ecosystem over the four weeks of the experiment.



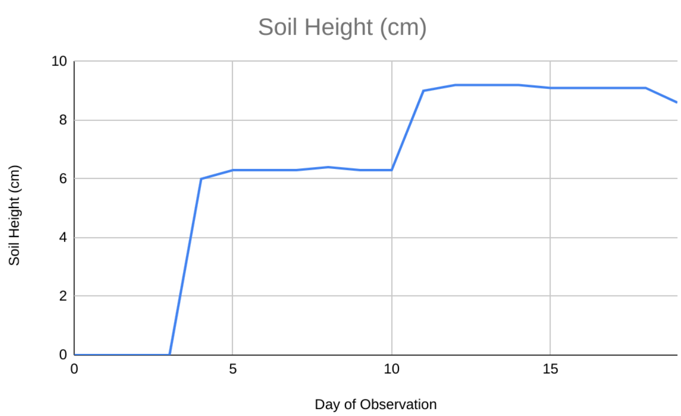
The height of the water remained fairly constant throughout the four weeks of observation. There was a slight increase in the height of the water on day 5, but this may have been due to a measuring error, as it decreased back to 14 centimeters on day 6.

FIgure 3: Condensation of the terrestrial ecosystem over the four weeks of the experiment.



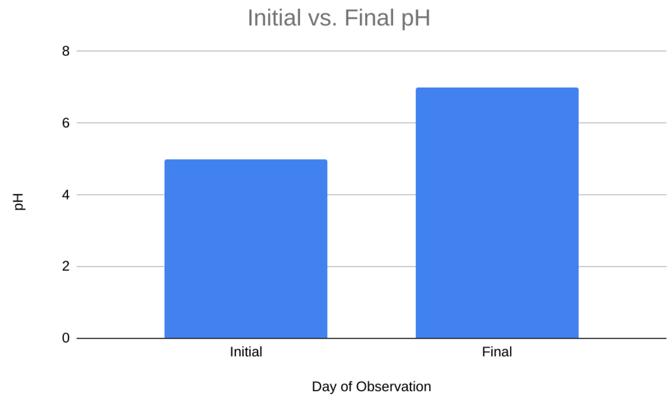
The condensation of the terrestrial ecosystem fluctuated throughout the experiment. On the first day it was measured (day 4) the condensation was very high, rated at a 4. Over the next few days, the condensation decreased, but increased again at around 12 days. After we returned after a week, there was a lot of condensation present (a 5), it was difficult to see inside the bottle.

Figure 4: Height of the soil in the terrestrial ecosystem over the four week period.



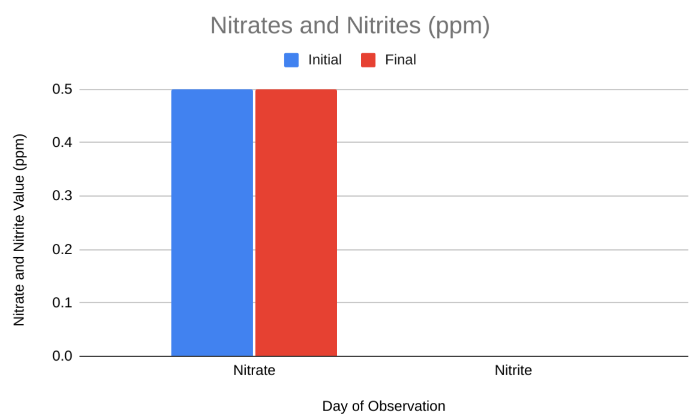
Throughout the duration of the experiment, the height of the soil increased, and then remained the same for about 5 days at a time. When the ecosystem was left for a week without observation, the height of the soil decreased by 0.5 cm.

Figure 5: Initial vs. Final pH of the aquatic ecosystem.



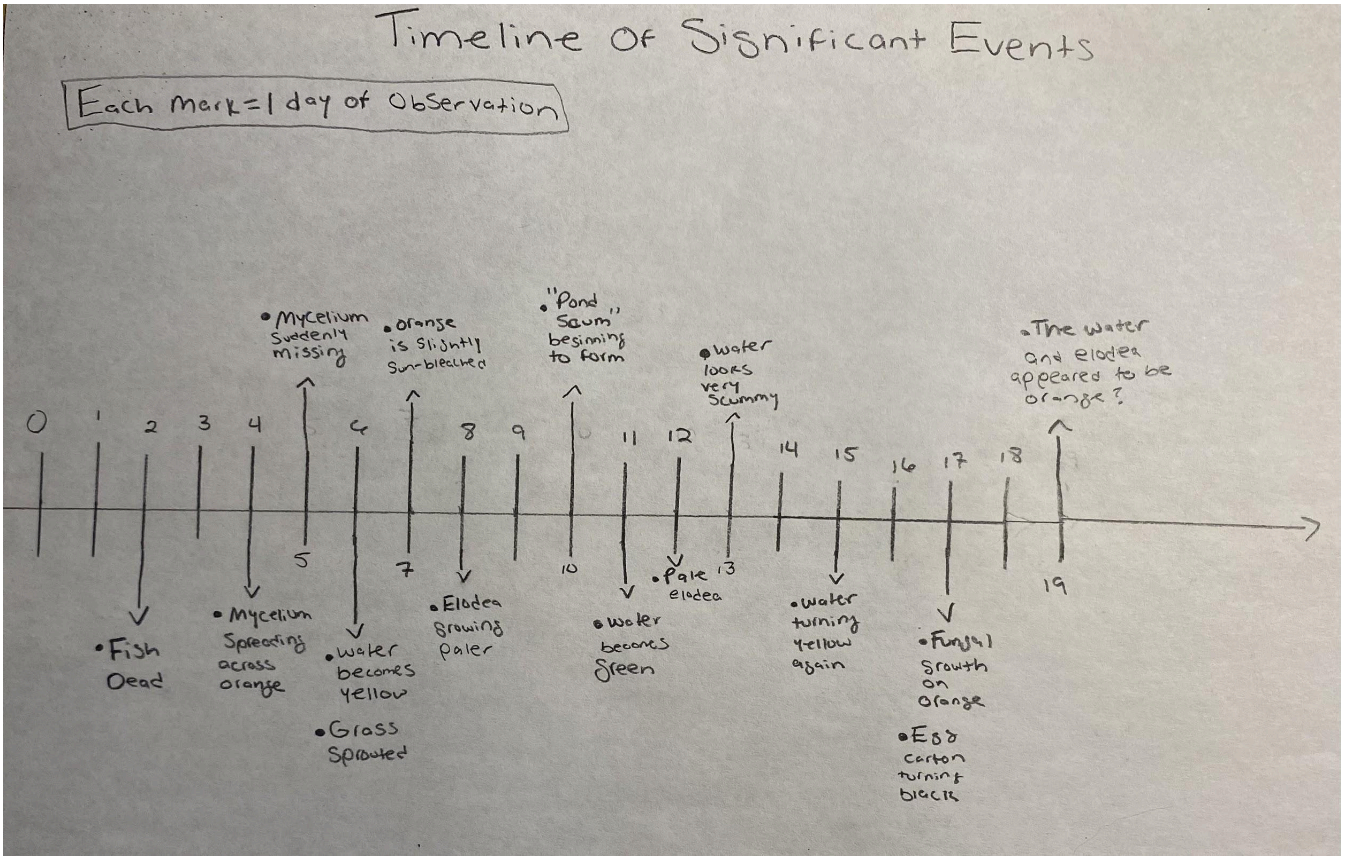
The initial pH of the aquatic ecosystem was 5, which is slightly acidic. At the end of the experiment, the pH had a value of 7, over time the pH of the system had grown more basic.

Figure 6: Nitrates and Nitrites of the aquatic ecosystem on the first and final day of the experiment.



The nitrates and nitrites both remained the same throughout the duration of the experiment. The nitrates remained constant at 0.5 ppm, and the nitrites were measured at 0.0 ppm.

Figure 7: Timeline of significant qualitative events observed during the 4 weeks of the experiment.



ANALYSIS

The goal of this experiment was to create a self-sufficient ecosystem that slightly resembled life here on Earth. The group attempted to keep two crickets, a worm, a goldfish, elodea, and grass or a flowing plant alive for 4 weeks. One 2-liter bottle was dedicated to being a "terrestrial" ecosystem, filled with soil and grass as well as two live crickets and a worm. The other 2-liter bottle was an "aquatic" ecosystem and contained activated carbon, a goldfish, and elodea.

In this experiment, the independent variable was what the group chose to add to the ecosystem. It was up to each of the groups to determine what materials were to be added to the bottle and how much of each of these materials was to be added. For example, one choice that was made was to add activated carbon to the aquatic ecosystem. The goal of adding the activated carbon to the ecosystem was for the carbon to filter the water, preventing the buildup of algae and the water from becoming discolored throughout the experiment. Another choice that the group made was to connect the two “ecosystems” with a thin plastic pipe through the top of the two bottles. The idea in doing this was that the water in the aquatic ecosystem would evaporate, due to the bottle sitting in the sun. Instead of this water evaporating into the atmosphere as it would on Earth, this evaporated water would condensate the terrestrial ecosystem, providing the plants with the moisture that they require to grow and thrive. Water is an essential reactant in the process of photosynthesis, so the condensation provided from the aquatic ecosystem aided in the survival of the grasses. Due to this process, it was observed that the grass began to grow after 5 days, and continued to grow throughout the experiment, reaching a height of 8 centimeters on the final day of observation.

The dependent variable was the biotic components of the ecosystem, as the goal of the experiment was to see how the aquatic and terrestrial environments that were created affected the ability of these living organisms to survive inside of the bottles. An ecosystem such as the ones on Earth is only considered successful if life can be sustained. In this experiment, the goal was the same. By keeping the animals and plants in the ecosystem alive, it demonstrated that there was an adequate amount of nutrients available that allowed the organisms to survive. One of the constants of the experiment was the amount of light that the ecosystems received. The bottles were not moved throughout the experiment, so the only light that the bottles received was from the natural sunlight during the day, resembling the earth. There was not a control group in the experiment, all of the biotic components were exposed to the same conditions in the engineered ecosystem. To add a control group, one could compare how much grass would grow outside on Earth, or how long the goldfish, worm, and crickets would survive in their natural ecosystems. The experimental group in the experiment was the biotic components that were contained in the ecosystem. The object of the experiment was to observe whether or not the organisms in the contained ecosystem were capable of surviving and thriving without access to the abundant elements of carbon, oxygen, and nitrogen that are available on Earth.

Many ecological interactions took place throughout the experiment, some of which were very interesting, unique, and even confusing! One of these interactions was The photosynthesis of the elodea in the aquatic environment. On day 6 of the experiment, the elodea began bubbling a lot, showing signs of photosynthesis, as the elodea was producing oxygen as a result of the process of photosynthesis. This continued until day 10, when the elodea began to wither and decay. This oxygen was released from the elodea into the “atmosphere” and could be used by the living organisms as well as the orange peel. The live organisms in the terrestrial ecosystem, such as the crickets would take in this oxygen and release carbon dioxide back into the bottle. The oxygen also contributed to the decay of the orange peel, as an abundance of oxygen allows microorganisms to survive, which helps to break down the orange peel as was observed later in the experiment.

A second ecological interaction that took place was between the orange peel and the mycelium that appeared (and later disappeared?) on days 4 and 5 of the experiment. Mycelium helps to create more nutrient-dense soil, as it aids in the breakdown of the orange peel. As the orange peel was broken down, nitrogen was released into the environment, which could be used by the grass and flowering plants in the terrestrial ecosystem as well.

A third ecological interaction that took place was the interaction between the elodea and grass and the fish, crickets, and worm. The plants performed photosynthesis, using energy from the sun and carbon dioxide to produce oxygen. This oxygen that was produced was used by the other organisms to complete cellular respiration, upon which carbon dioxide and water was produced that the plants would once again use. This cycle helped to keep all of the organisms alive. One could predict that once the plants began to wilt and die, the other organisms died as well, as there was nothing to produce the oxygen that they needed to undergo cellular respiration.

One unexpected thing that happened was the temperature of the water that we added to our initial ecosystem. The pond water that was added was extremely cold, and this had a negative impact on the life span of the goldfish. Because the temperature of the water was so cold, the fish likely went into a state of hypothermia, attempting to conserve energy as heat for its survival. This may have slowed down the rate of cellular respiration (which affected the survival of the plants), in addition to shortening the life of the fish itself. If the goldfish was not capable of carrying out its essential processes for life, it quickly died (after 2 days). The setup could also be modified to increase the survival of all organisms by layering the bottles rather than having two separate 2-liter bottles connected by the plastic tubing. It would be much easier for oxygen and carbon dioxide to be exchanged in one bottle rather than be forced to travel through a plastic tube to reach the other ecosystem. The more effective the exchange of materials was in cellular respiration and photosynthesis, the more likely the organisms would be to survive.

The group modified the design of the ecosystem to collect qualitative and quantitative data by not filling both of the bottles too full with the soil or the multicolored aquarium rocks. By doing so, it would be more difficult to observe what was happening inside of the bottles due to condensation. By having the surface of both ecosystems at eye level, it was easy to observe what was occurring within each of the ecosystems. Qualitative data is important to collect in addition to quantitative data because it makes it easier for the observer to hypothesize what may be going on inside of the ecosystem. If a pH change is noted (such as the change in pH from 5 to 7 in this experiment), many factors may have contributed to this change. But by observing what is occurring in the ecosystems day by day, it is much easier to get an idea of what may have caused that change. In this example, the change in pH may be due to the rate of photosynthesis and cellular respiration that was taking place in the aquatic and terrestrial ecosystems.

Despite some of the successes that were seen in the ecosystem, there were also some failures and sources of error. It would have been beneficial to measure the pH of the aquatic ecosystem as well as the nitrates and nitrites over time to see if these values fluctuated as time went on. However, the bottles were sealed so this was unable to occur. To prevent this, a small cut could have been made in the bottle to measure the nitrates, nitrites, and pH daily. The second source of error may have been in the measurement of the height of the water. The water height increased on day 5, but then decreased again on day 6, and then remained constant throughout the rest of the experiment. This was likely due to a measurement error. To prevent this, a mark could have been made on the bottle as to where the ruler should be lined up to measure the height of the water. The third source of error lies in the measurement of the level of condensation seen in the terrestrial ecosystem. In rating it 1-5, it is very relative and each individual may have a different idea as to what the level of condensation is. To create a more clear system, the level of condensation could have been ranked, as well as a short description of what the bottle looked like.

CONCLUSION

In observing the changes that occurred throughout this experiment, there were some interactions between organisms and the environment that had been predicted, and others that were quite strange. One prediction that was made was the idea that nutrients would cycle between the grass/elodea and the other living organisms through photosynthesis and cellular respiration. Because these two processes are inversely related, they are dependent on each other for the survival of the biotic components of the ecosystem. Once the health of the plants began to deteriorate, the other living organisms began to die as well, because there was less oxygen available, which they needed to survive. Another expected interaction was the condensation that occurred in the terrestrial ecosystem. This was due to the evaporation of water in the aquatic ecosystem into the “atmosphere,” moving its way into the terrestrial ecosystem bottle. A third expected cycle of nutrients was seen in the release of nitrogen as the orange peel was broken down over time. This nitrogen was absorbed into the soil, which aided in plant growth.

One unexpected result was the amount of water that traveled through the pipe into the terrestrial ecosystem. One would assume that more water would have dampened the soil rather than simply create condensation on the sides of the bottle. This may have also been a factor in the withering of the grass in the terrestrial ecosystem. A second unanticipated result was the active carbon. This product was added to prevent the water in the aquatic ecosystem from turning yellow. While the water did not turn yellow, the water instead turned orange. A third result was the reduced level of condensation in the aquatic ecosystem bottle. While some condensation was present, it had been expected for there to be more condensation in that bottle due to the rapid evaporation of water from the sun.

These findings partially supported the hypothesis. It was evident that there was cycling of nutrients taking place between the aquatic and terrestrial ecosystems, which was likely due to the quantities of natural materials that were added to the ecosystem. However, because this cycling of nutrients did not continually occur, the biotic components began to deteriorate and die by the end of the experiment.

The results of this experience can be used to see how practical it would be to create an enclosed ecosystem, even an enclosed ecosystem that contains humans and larger animals. There would be many more variables to deal with on a larger scale, but learning from the mistakes in this experiment, a larger scale experiment could be tested. The cycling of nutrients in a closed ecosystem will never be as efficient as it is on Earth naturally, but it is certainly worth an attempt. What can be taken away from this experience is that creating a fully independent ecosystem proved to be quite a difficult task, as there are always some unknown interactions that will occur. Life on Earth is extremely delicate and intricate, there is a lot that must go right for organisms to survive and thrive on this planet.