The Impact of Bioinspired Prototypes on Pollution Management in an Aquatic Environment

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Background Information

The pollution of natural waterways by man-made garbage is a global pandemic. This is especially true in rivers. Trash in rivers is a threat to all organisms in the immediate environment and environments beyond. The most common form of pollution found in waterways is plastic bottles. Most of litter ends up in a river, as it either gets washed down the watershed through rainfall or ends up in a sewer that filters to a river. From there the trash not only pollutes the river, but the river also carries that trash to beaches, oceans, lakes, bays, etc. which in turn ruins multiple different ecosystems.

Purpose

Rivers are the primary source of transportation of litter and waste; therefore, the best way to limit aquatic pollution damage is to stop it at the source. This project tests new, innovated, bioinspired prototypes that will be used to collect common manmade waste found in rivers and other water ways. The prototypes are bioinspired, meaning that their design is drawn from already existing biological organisms. The thought behind this is that after thousands of years of evolution, organisms have adapted to complete certain specific tasks (such as filtering) with precise efficiency. Therefore, if the prototypes are structurally inspired by organisms, or parts of organisms, that have been carefully crafted through centuries of natural selection then, they are more likely to succeed. Also, since these organisms already exist and benefit their environments, we know that these bioinspired prototypes will most likely be more useful and beneficial to the environment than a prototype that was completely designed and inspired by man. This experiment will aid and assist in the pollution pandemic as well as create a healthier environment for fish and other aquatic and semi-aquatic organisms to flourish in. These new structures may additionally benefit these ecosystems by providing shelter and structure that could be utilized by multiple organisms, and overall, providing a positive impact to the environment.

Materials and Methods

We used the following materials: Robo C2 Compact Smart 3D Printer, 3D Printed Prototypes, 4 10-gallon tanks, 36 minnows, 21 3D printed PLA water bottles, 24 3D printed PLA cans, pieces of 3D printed trash, 4 fish tank filters, gravel, fish food, 4 small current fans (CP1 Hagen Fluval Sea Circulation Pump), de-chlorinator, clove oil, clamps, metal rod, yarn, tape, 2 rulers, and clothes pins.

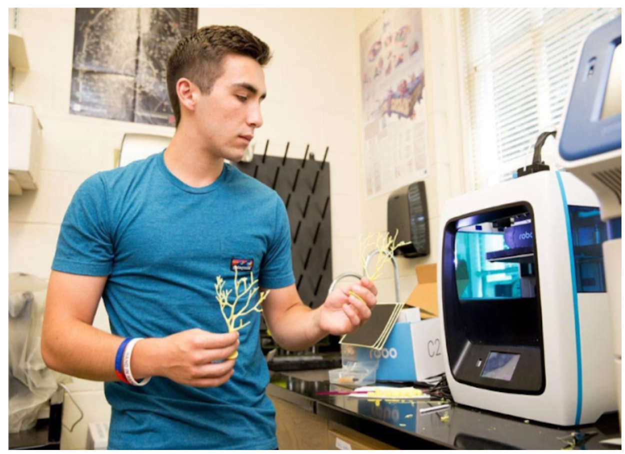

Figure 1: Testing the 3D Printer

We set up each individual 10-gallon fish tank with gravel and filter. We then filled each tank with water and appropriate amount of dechlorinator and set the temperature of the water between 64-75 degrees Fahrenheit. We mounted a current fan on the tank to simulate water flow in a natural river. Twelve minnows were added to each tank.

Minnows were used in this experiment for the following reasons:

i. Minnows are easily attainable freshwater fish.
ii. The average minnow size is 2.5 inches, and since everything in the experiment is on a 14.33% scale from actual size; this means the minnows would be the equivalent to a fish that’s roughly a 1.45 ft.
iii. They help our testing environment closer simulate a natural river environment.

We set up 3D prototypes in each tank, and made sure to place them down current. One tank was left with no prototypes to be the control. Three distinct prototypes were used:

Prototype 1: Mangrove Roots.
Prototype 2: Spider Webs
Prototype 3: Whale Baleen

Mangrove roots were chosen as a design because they have already been proven to collect trash in aquatic habitats, as well as, provide homes for multiple organisms (Mangroves keep sea trash out of villages). The spider web design was used because spider webs are notorious for snagging unwanted objects. With correct placement and large enough holes, this design could be effective in catching trash while leaving the fish completely unharmed. This prototype will differ from actual spider webs by being rigid so that the fish won't get caught in it as they would in a net. Finally, the bristles found in the mouth of some whales, baleen, filters water and other small organisms while keeping larger objects out. This design differs than the other two as this wouldn't allow fish to swim through, however, the fish and other animals could swim under while the trash was collected on top and water flowed through. (cite: Personal Communication, Dr. David Schmale III and Dr. Kristin Fischer 5/6/2017)

Each prototype had a unique set-up technique. To set up mangrove roots, we had to lay two rulers parallel to each other across the middle of the tank and sandwich them together so that most of the branches of the mangrove roots were submerged in the water, but the base was still above the water level. To set-up spider webs, we taped the piece of yarn across the tank and used the clothes pin to clip the webs to the yarn while leaving them mostly submerged.

To install baleen, we placed a metal rod across the tank and ensure that it is stabilized (in the experiment we used Styrofoam holders) then used clamps to clamp baleen to the rod so that the baleen is submerged but the base is still above the water.

We added 15 pieces of 3D printed trash to each tank on the end closest to the current fan so that the trash would flow towards the prototypes (objects will be scaled to 14.33% of the size of industrial standardized product) The 3D products consisted of 7 bottles and 8 cans.

The tanks were allowed to sit for 3 days. The fish were feed the daily and observations were made every twelve hours. If a minnow had died, it was promptly removed. After each trial the prototypes were rearranged into different tanks to avoid a confounding variable.

Observations were taken every 12 hours for 60 hours which means 5 observations per trial. In this experiment, 3 trials were performed. For each observation we noted how many bottles slipped past the prototypes, how many cans slipped past the prototype, how many living minnows were in the tank, and how many dead minnows were in the tank. If unusual phenomena were observed, it was recorded. If a minnow was mortally wounded and obviously beyond recovery it was euthanized in a separate tank that contained water with one tablespoon of clove oil. Clove oil was chosen as it has been deemed a humane way to euthanize the fish.

Results and Conclusion

After examining the data, it became apparent that none of the 3D structures were dangerous to the fish. The number of dead minnows in the tanks with the prototypes is consistent with that of the control. The deaths are most likely due to the poor quality of the fish. These minnows were bred to be live bait and therefore are not very resilient, one aspect that would change in future trials would be the type of fish being used.

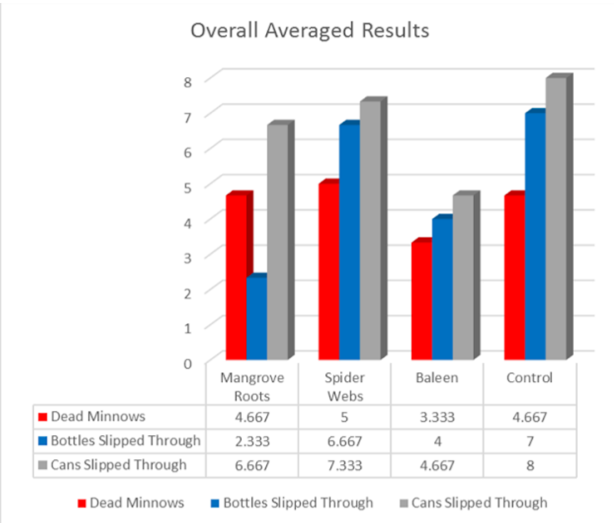

Figure 2. Representative Averaged Data

By observing the different prototypes over the course of this experiment, we were able to identify strengths and weaknesses in each structure. The spider webs and the baleen had very similar problems. They served merely as barriers. The trash would be pushed against the structures as if it had run into a wall then simply floated to the outside. The baleen was more effective than the spider webs because the baleen had a straight edge that could be pushed directly against the tank allowing for no gaps that the trash could pass through. This would be incredibly inefficient in real world application as rivers don't necessarily have walls like that the baleen pressed against. In reality, the trash would simply float around the baleen wall or wash up on the shore, but the trash would never be ensnared in the baleen, which was the result we were hoping for. Despite the negatives, however, there is a lot of potential in the baleen design.

In future works we could experiment with different materials that the baleen could be made from so instead of a rigid plastic it could be made from a slightly softer material that may be able to engulf the trash instead of simply serving as a barrier.

Unlike the baleen, the spider web structure was round and could not be fastened against the edge of the tank which left a gap. Because of this gap trash was easily able to deflect from the web and flow by. The spider web was by far the most inefficient design as it had the highest failure rate of all the structures. After running this experiment, we determined it'd be best that the spider web idea be abandoned. Unlike the baleen, the spider web shouldn't be made of a softer material because at that point it'd just be a net, which we know can be detrimental to an ecosystem as it would ensnare and kill fish.

The mangrove root design is the structure with the most potential. Unlike the other structures, the mangrove roots didn't serve just as a simple barrier, but instead ensnared the pollution. The roots were especially effective against the larger water bottles, however the structure had a harder time collecting the smaller cans. In future work, we would experiment with the structural design and placement of the prototype. Originally, the roots were designed with wider gaps so that there would be a slimmer chance that a fish would become entrapped; however, the fish never became ensnared. Next time, we will design a structure that will have less space between the branches of the roof. Another way to improve the results of the mangrove root structure may be to alter its placement in the water. Instead of making a single line of mangrove roots, they could be separated in rows. This would make it much more difficult for trash to slip through.

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