Is More Green Better?

Does Littoral Vegetation Enhance Habitat Suitability of Local Retention Ponds?

Photo taken by Finalist, 2024

Rationale

Flood control is an increasing challenge for coastal cities. Construction displaces natural marsh lands and forests that naturally accommodate temporary increases in local water due to heavy rain or extreme weather events. **League City[5] and Friendswood[1], Texas, have regulations that when new buildings and parking lots are constructed, a water control plan for the displaced surface area of land must be constructed as well.**

A retention pond is a great tool to manage water. They also help replace natural habitats that have been removed. **This project will determine if planting vegetation in the littoral (shoreline) around a retention pond in the League City and Friendswood surrounding area has a positive effect on the pond's trophic index (the biological productivity within a pond)[4].**

There are four trophic levels of ponds:

- ***Oligotrophic*** – Lowest biological productivity, clear water, limited plant growth.
- ***Mesotrophic*** – Moderate biological productivity, best for marine life.
- ***Eutrophic*** – Increased biological productivity, higher likelihood for algae blooms.
- ***Hypertrophic*** – Highest levels of biological productivity. May have mass algae blooms which deoxygenates the water and can kill fish, high turbidity.

Benefits of Vegetation: Vegetation can provide shade and absorb phosphorus from coming into the pond to prevent large algae blooms. They provide habitats for wildlife.

Disadvantages of Vegetation: Land vegetation also drops leaves and adds organic matter to the water which decompose and decrease the amount of dissolved oxygen. During times of year with increased temperature and low rainfall, vegetation can also drop the water level of a pond[3,2]. Large trees prevent wind from providing natural aeration.

The best type of littoral is specific to a geographic area. This project is important so local developers will know the best way to construct retention ponds for the benefit of local pond organisms.

Experimental Design

Problem: What is the effect of trees and shrubs in the littoral of retention ponds in League City and Friendswood area to the water quality and trophic index of the pond?

Hypothesis: If trees and shrubs in the littoral of retention ponds in the Friendswood and League City area provide more benefits than disadvantages, the water qualities and trophic indexes of ponds with more vegetation will be closer to the ideal for pond life.

Independent Variable: The percent of the pond's littoral with non-grass vegetation (trees and shrubs).

Dependent Variable: The trophic index and water qualities of the pond.

Constants: The ROV, DO meter, pH/TDS/EC meter, phosphate meter, turbidity sheet, and alkalinity meter. Ponds were also selected to be within the smallest possible geographic area within League City and Friendswood while providing littoral diversity.

Control: The ideal water qualities of a pond for marine life were determined by the nine variables in the table.[4,8]

Variable Type	Dependent Variable	Ideal Range (Control)
Trophic Index[4]	Phosphate	0.015-0.025 ppm
	Turbidity	2.43-4.00 m
Water Quality[8]	Dissolved Oxygen (DO)	≥ 6.0 mg/L
	Biochemical Oxygen Demand (BOD)	< 5 mg/L
	pH	7.5-8.5
	Alkalinity (KH)	95-150 ppm
	Electrical Conductivity (EC)	100-300 µS/cm
	Total Dissolved Solids (TDS)	< 400 ppm
	Temperature (summer)	20-23.3 °C

Table created by Finalist using PowerPoint, 2024

Materials

Water Sample Collection

- ROV (1)
- Jars, 225 mL each (12)
- Masking Tape (1 Roll)
- Pen (1)
- Notebook (1)
- Sharpie (2)
- Rubber Gloves (1 Pair)
- Sunscreen (1 Bottle)

Sample Analysis

- Pipette (3)
- Tin Foil (1 Roll)
- DO/Temperature Meter (1)
- pH/TDS/EC Meter (1)
- Phosphorus Meter (1)
- Alkalinity Meter (1)
- Turbidity Sheet (1)
- Microscope (1)
- Methyl cellulose (1 Bottle)
- Microscope Slides/Slips (5)

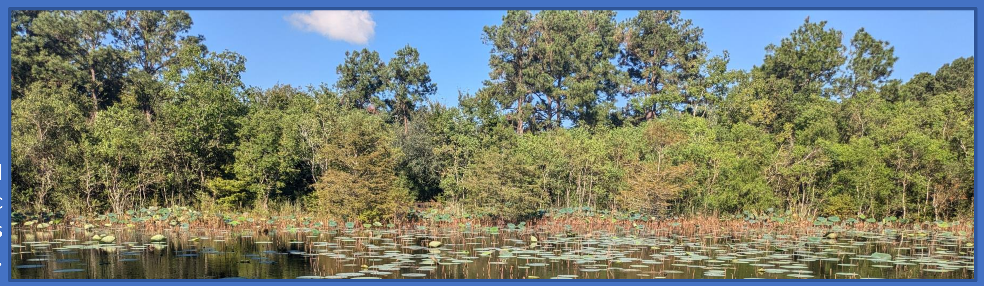
Project Materials. Photo taken by Finalist, 11/30/24.

Procedure

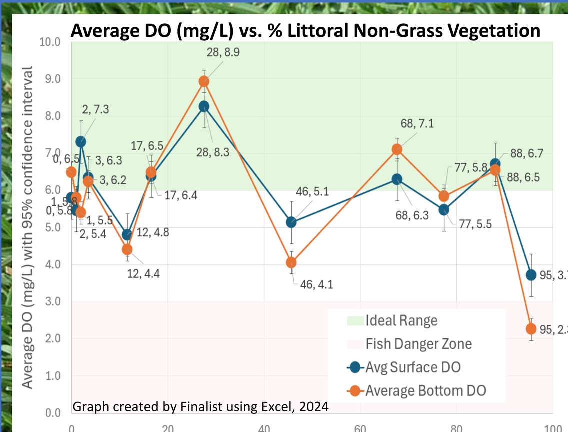
1. **ROV Development:** Build and test a ROV (Remotely Operated Vehicle) to collect water samples from the surface and bottom of retention ponds. Include a safety tether in case the ROV fails or gets caught in aquatic vegetation. The ROV needs a water collecting device, and a dive computer to record depth. The ROV must be slightly positively buoyant. Designs will be sketched and then built and tested in a pool. *Safety:* solder in a well-ventilated workspace and add a fuse to protect against short circuits.
2. **Site Selection:** Choose 12 retention ponds that have different amounts of non-grass vegetation around the littoral in the League City and Friendswood, TX area. Calculate the area, perimeter, and the percent of littoral with non-grass vegetation using Google Earth to ensure a diversity of littorals.
3. **Sample Collection:**
   a. Record Littoral Characteristics: Observe the characteristics of the littoral and wildlife surrounding the retention ponds, and record these in a notebook. *Safety:* Do not be around water without a buddy. Wear gloves if you have open cuts and sunscreen to prevent sunburn.
   b. Collect Water Samples: Use the ROV to collect two samples (~200mL) in the middle of each pond at the bottom and surface levels. Transfer water samples into jars and labeled with tape and sharpie. *Safety:* Be sure the ROV controller/electronics do not get wet.
4. **Sample Analysis:** Test nine characteristics of the water: alkalinity (KH), temperature (°C), dissolved oxygen (DO), biological oxygen demand (BOD), pH, phosphorous, electrical conductivity (EC), total dissolved solids (TDS), and turbidity using the meters, turbidity measuring sheet, and tin foil. Record the measurements in a notebook.
5. **Micro Life Observation:** From selected samples of each pond, use the pipette to add 1 drop of pond water to a microscope slide with 1 drop of Methyl cellulose if organisms are moving too quickly. Carefully put a slip on top of the sample. Use a microscope to observe micro life or algae.
6. **Repeated Collections:** Perform steps 3-5 multiple times at each pond over several months. Collected work resulted in over 120 hours in the field, 130 water samples, and 1,170 data points.
7. **Data Analysis:** Graph and analyze data for trends and patterns. Present conclusions.

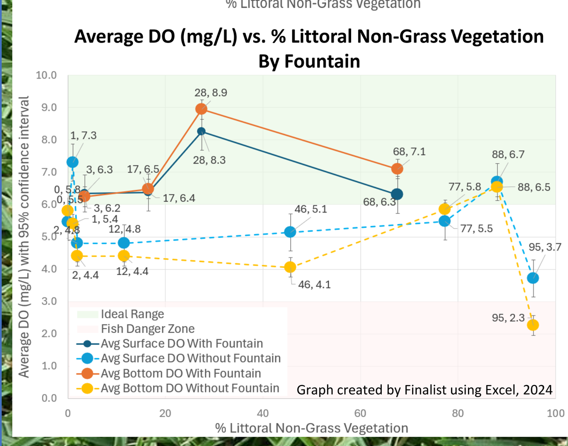
(Left) An example of a pond with 0% littoral non-grass vegetation. This pond was Eutrophic due to the storm drain which allows phosphorous to directly enter the retention pond. Photos taken by Finalist 8/10/24.

(Right) An example of a pond with 95% littoral non-grass vegetation. This pond was hypertrophic with DO at the bottom below sustainable levels for marine life. Photo taken by Finalist 8/10/24.



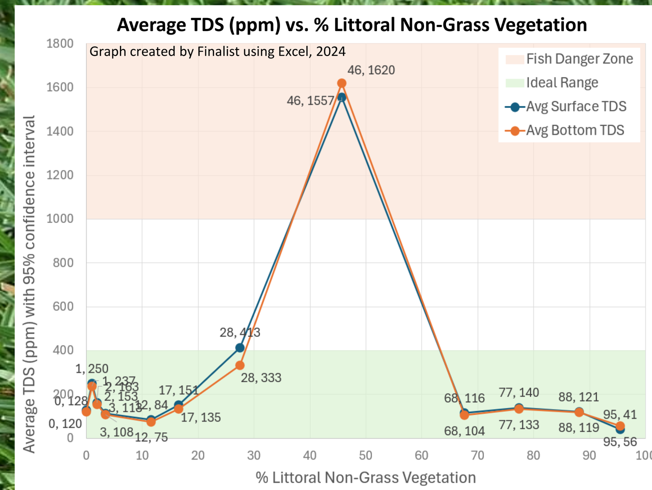
Graphs and Data Analysis

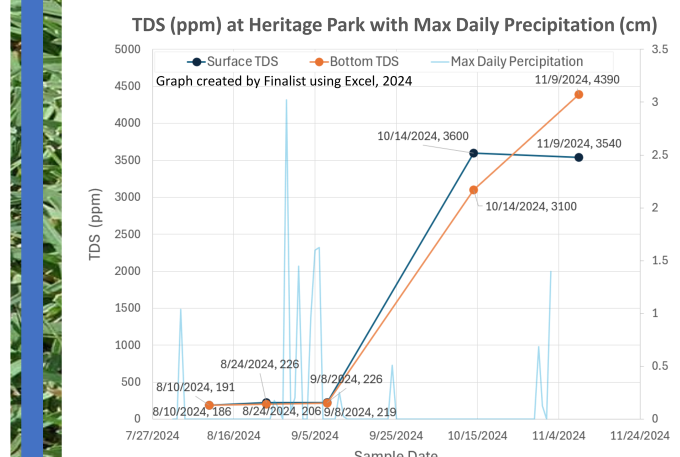




Dissolved Oxygen

- Fish thrive at a DO (dissolved oxygen) of 6 mg/L and higher (green region). They can die at levels of 3 mg/L or lower (red region) and experience stress in the middle range[8].
- **The top graph shows that the ideal percent of non-grass vegetation of the littoral is about 27%.**
- Ponds with high percentage of littoral vegetation have lower levels of DO because of the high amount of leaf litter results in decomposers using most of the oxygen in the water which leads to fish death[2].
- **Having a fountain makes the DO higher, especially at the bottom. Ponds with a fountain had a higher DO at the bottom (n=4, M=7.18, ST=1.22) compared to those without (n=8, M=4.84, ST = 1.35), t(6.66)= -3.06, p=0.02, as calculated with R v4.5.1.**



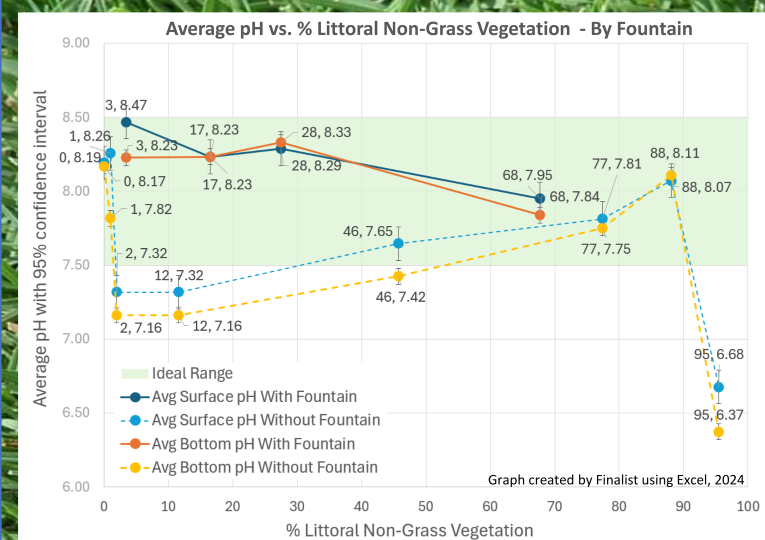


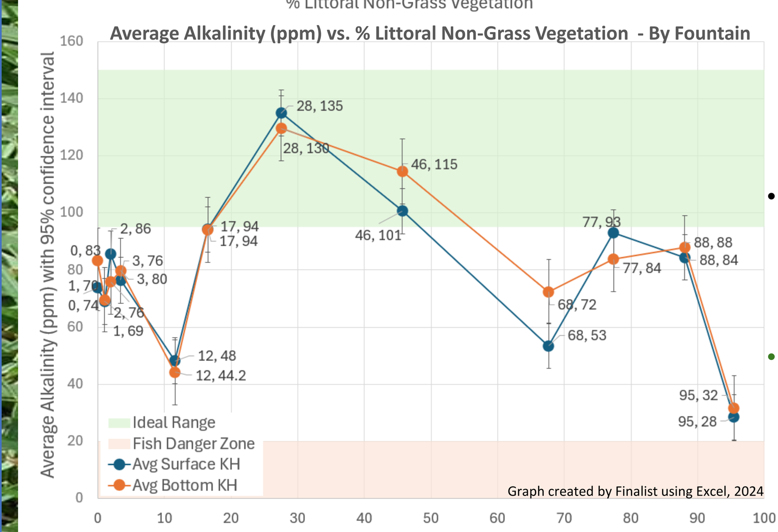
Total Dissolved Solids (TDS)

- TDS (Total Dissolved Solids) >1000 ppm (red region) can disrupt freshwater fish osmotic balance causing dehydration as the high amounts of dissolved minerals in the water will draw out water from the fish's cells, leading to stress and death. TDS levels of 400 ppm or lower are good for freshwater fish[8] (green region).
- **No relationship between TDS and the percent non-grass vegetation in the littoral was found.** No relationship was found with TDS and having a fountain.
- All of the ponds are about in the optimum TDS range for fish, besides Heritage Park Pond.
- TDS at Heritage Park spiked between the third and fourth sample collection. This spike did not correlate with precipitation. Heritage park is located by a bayou which maybe leaked salt water into the pond which raised the TDS. **A sudden TDS spike is an early indication something may be wrong with the pond. This finding was communicated to League City officials in a letter by the Finalist.**

Electrical Conductivity (EC)

- **EC follows the same patterns as TDS**, including the spike at Heritage Park. EC measures the ability of water to carry an electric current. EC does not directly affect marine life, but changes can indicate something is going on in the environment.





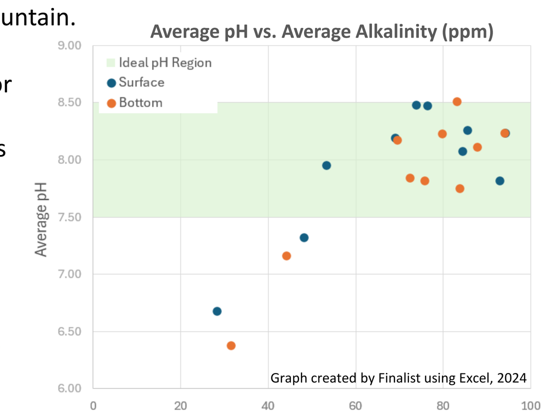
pH

- Ideal pH for marine life is 7.5 to 8.5 (green region). pH>9 can damage the fish cell membranes, cause them to change in color and cause death. When pH is too acidic (low), fish become stressed and damage can occur to their immune systems[8].
- **All ponds with fountains are all in the ideal pH zone. Only some of the ponds without a fountain have ideal pH for marine life. A fountain created a statistically significant difference at the surface t(9.85)= -2.62, p=0.03, and the bottom t(9.52)=-2.79, p=0.02, as calculated with R v4.5.1.**

Alkalinity (KH)

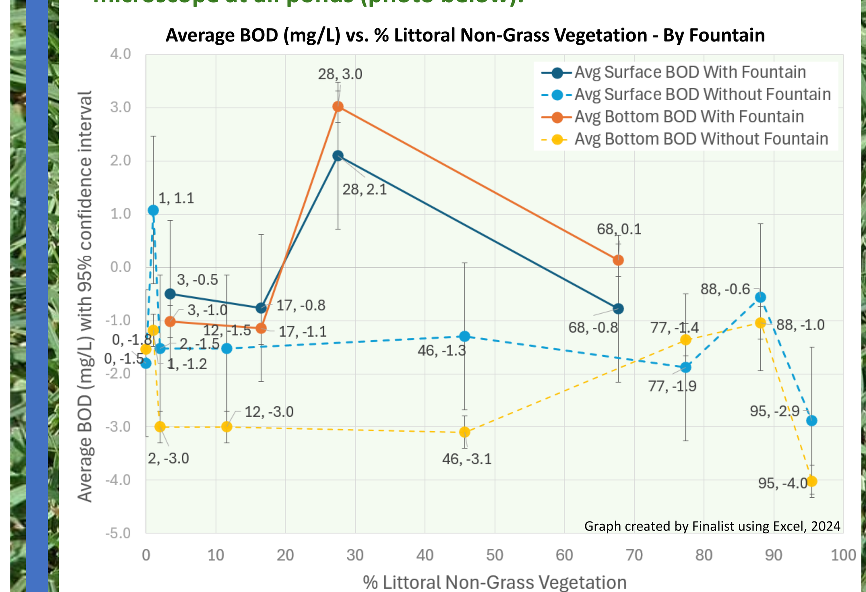
- Alkalinity (KH) measures the hardness of water and is dependent upon how many carbonates are in the water. When alkalinity is high the water is harder.
- Fish like alkalinity between 95 to 150 ppm[8]. If alkalinity is >300 ppm, fish can experience stress, reproductive problems, and have swim bladder problems.

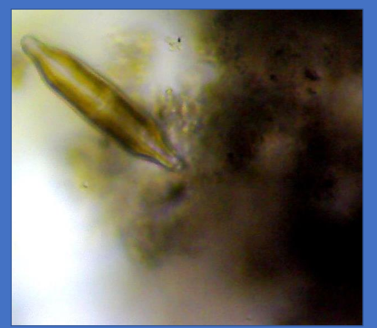
  Collected data shows **ideal alkalinity at a non-grass vegetation range of about 20% to 50%.** No relationship was found between alkalinity and ponds having a fountain.
- Alkalinity is a buffer for pH and helps keep pH stable. If alkalinity falls below 20ppm, larger shifts in pH can occur.
- **The right plot shows ponds with higher alkalinity have pH within the ideal zone.**



Biochemical Oxygen Demand (BOD)

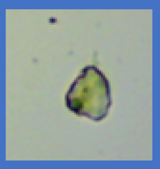
- BOD (Biochemical Oxygen Demand) follows the same pattern as DO, including the effect of a fountain. Higher BOD means microorganisms are using most of the oxygen which makes it difficult for larger aquatic animals to survive[8].
- The ideal range is <5 mg/L[8], which was found in all the data samples.
- **Ponds without fountains have more negative BOD than the ponds with a fountain, but this was not found to be statistically significant.**
- BOD is measured by placing the sample in complete darkness for five days and then measuring DO. The five-day measurement is subtracted from the original measurement. **The only way to get negative BOD is if something produces oxygen during the five days of darkness. Algae was suspected and was found under a microscope at all ponds (photo below).**





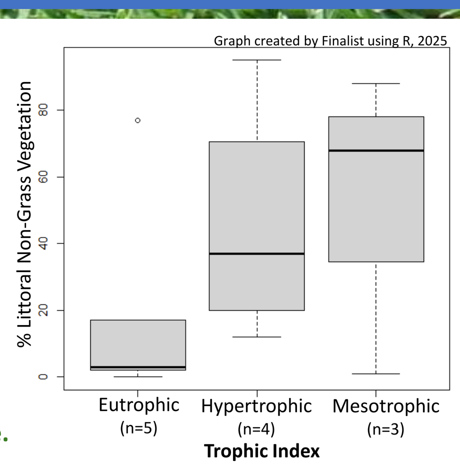
(Left) Protista swimming in lots of algae in a water sample from a pond with negative BOD. Photo taken by Finalist at 40X magnification, 8/17/2024.

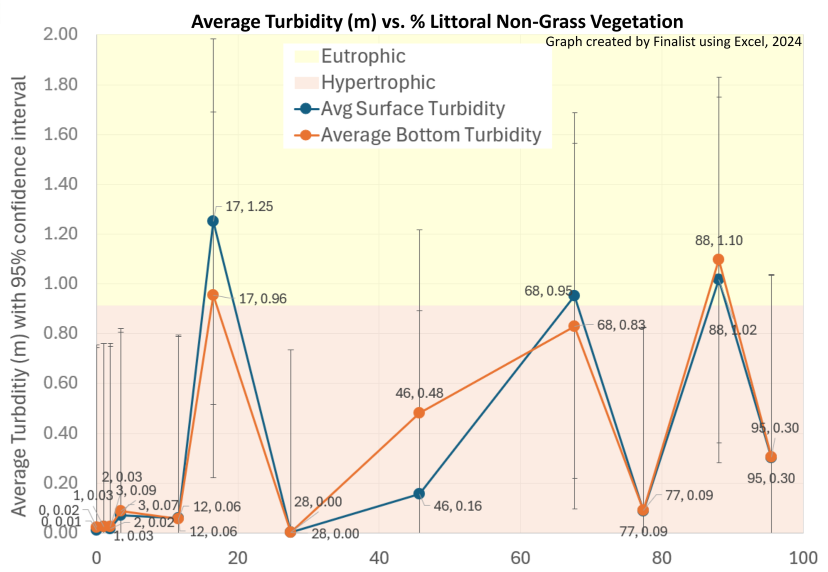
(Right) Algae in a water sample from a pond with negative BOD. Photo taken by Finalist at 40X magnification, 8/17/2024.

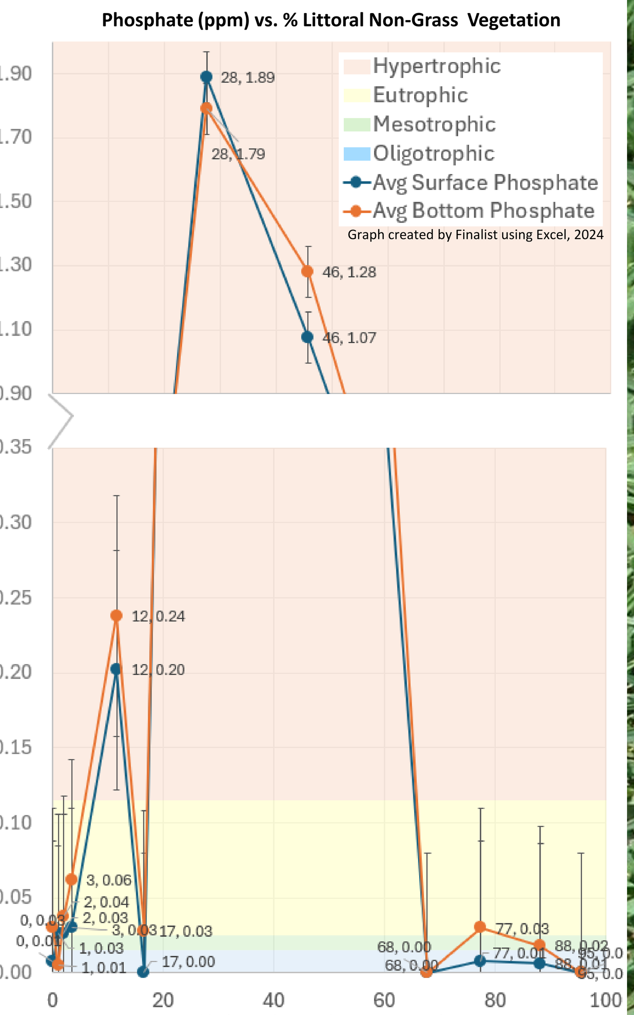


Phosphate and Turbidity

- Phosphate was not detected at many ponds during the first trial, indicating the pond would be oligotrophic, but this cannot be the case. Turbidity was added to the study and the two variables provided enough data to determine the trophic index[4].
- **No pattern with percent littoral non-grass vegetation was found for phosphate, turbidity, and temperature.**







ROV (remotely operated vehicle) built and designed to collect water samples from the top and bottom of ponds. Photo taken by Finalist, 8/13/24.

Sources of Error

Sources of error in this experiment:

1. **ROV limitations:** The ROV could not reach the bottom of Lake Friendswood (9.1m deep). The ROV could only descend 3.65 m due to the pool noodles required to make the cord buoyant enough to steer the ROV (reduce drag).
2. **DO Measurement Collection:** The DO meter must be constantly stirred during measurement readings, however, faster stirring results in higher DO measurements. Speed was kept as constant as much as possible.
3. **Dive Computer:** A dive computer was used to measure pond depth. However, the dive computer did not register (start dive) until a depth of 0.941 m was reached. Which means ponds shallower than that do not have an accurate depth measurement.
4. **Turbidity Scale:** The scale used to measure turbidity was subjective resulting in high error for that measurement. The research project was out of funding to purchase a more accurate turbidity meter.
5. **Water Quality Meters:** Each water quality meter has a published source of error.

Water Quality	Surface 2-Sigma Error	Bottom 2 –Sigma Error
pH	0.11	0.05
TDS (ppm)	2.28	0.89
EC (µs/cm)	6.78	2.83
Temp (°C)	0.09	0.09
DO (mg/L)	0.57	0.30
Phosphorus (ppm)	0.08	0.08
KH (ppm)	11.54	11.37
Turbidity (m)	0.73	0.73
BOD (mg/L)	1.82	1.38

Calculated 2-Sigma Standard Deviations For Water Qualities Studied. Table created by Finalist in PowerPoint, 2024.

Confidence Intervals

To quantify error, 5 samples from the surface and bottom of Rustic Oaks Pond were collected. This pond was selected due to the statistically significant difference in DO between the bottom and the surface. Standard deviation was calculated and 95% (2-sigma) confidence intervals were used throughout this project.

Conclusion

- The hypothesis was disproved by data in the experiment. Trees and shrubs around retention ponds in League City and Friendswood area provide both advantages and disadvantages for marine life. **Data shows that there is an ideal littoral of non-grass vegetation between ~15-30% for this geographic area.**
- The highest amount of DO (dissolved oxygen) was found in that littoral range, meaning there is more oxygen for marine life. The same percent of littoral with non-grass vegetation had ideal alkalinity levels (95-150 ppm) and pH (7.5-8.5).
- At the highest amount of vegetation, DO dropped below levels sustainable for marine life (3 mg/L or lower). The significant number of trees around the littoral results in more disadvantages than advantages due to large amounts of organic matter which fell into the pond and decayed[3]. Ponds with increased organic debris also eventually accumulate material that resists decay and fill up, turning into a bog[2]. However, data supports that some amount of vegetation around the littoral is important to prevent erosion, provide shelter for fish, shade and removing nutrients and contaminates (such as phosphorus)[3].
- **There was no correlation between the percent of non-grass vegetation to the trophic index of the ponds. The student expected non-grass vegetation to help filter phosphorus. However, all the ponds besides two had storm water run-off pipes.** People use phosphate in their yards for fertilizer. When it rains, the phosphate gets in the water and goes into the storm runoff pipes and into the retention ponds. The problem is when this happens, the water does not have a chance to go through the littoral which would help filter out the phosphate. The two ponds without a storm run-off pipe had very little phosphate (0-0.02 ppm).
- **The best way to make a pond healthy for marine life is to add a fountain.** Every pond with a fountain had DO above 6 mg/L, including hypertrophic ponds. This makes sense because fountains help aerate the pond. Every pond with a fountain also had pH at ideal levels (7.5-8.5). Most of the ponds without a fountain had a negative BOD, which means there is algae in the pond which can result in lower oxygen levels. Perhaps the fountain helps agitate the water and prevent too much algae growth.

Next Steps

- Data was collected Aug-Nov during the warmest months when ponds are most likely to be anoxic and affected by algae blooms. However, this conclusion should be verified during the rest of the year.
- This conclusion could be affected by errors in the experimentation including inaccurate measurements. It is also limited by the number of ponds within the 15-30% littoral non-grass vegetation range. This conclusion should be verified by studying more ponds with this amount of littoral vegetation.

Community Impact

- League City and Friendswood should consider funding fountains in retention ponds and adjusting the littorals to be closer 15-30% non-grass vegetation to ensure healthy habitats for local wildlife. The Finalist also contacted City Officials regarding the potential TDS concern at Heritage Park.

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ROV collecting a water sample from an Eutrophic pond with 17% littoral non-grass vegetation. Pond was aerated by three fountains. Photo taken by Finalist, 11/2/2024.