Utah Lake Nutrient Cycling Studies: Limnocorral Usage and Experiments

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2022 Intermountain Engineering, Technology and Computing (IETC) | 978-1-6654-8653-8/22/$31.00 ©2022 IEEE | DOI: 10.1109/IETC54973.2022.9796864

Abstract—**Limnocorrals are a tool that can be used to create simplified water columns, or mesocosms, in which to conduct experiments and to help further understand aspects of the water column such as nutrient cycling. Six limnocorrals were installed in Utah Lake in 2021 and monitored closely from May through November. While the limnocorrals performed well as mesocosms, there were structural issues, and the corrals were significantly damaged. Methods were developed to strengthen the limnocorrals, mitigate damage, and reinstall the corrals. All experiences with the limnocorrals, what types of damage they experienced, how this was addressed, and information on the performance of the limnocorrals was reported. Performance was evaluated by comparing the geochemical environment of the corrals with the lake, and by performing studies to quantify water residence time in the corrals.**

Keywords—Limnocorral, Utah Lake, Nutrient Cycling.

I. Introduction

The three-year research project started in April 2021 to help us understand what processes govern nutrient concentrations in the Utah Lake (UL) water column. A unique research tool, limnocorrals, was used to perform this research. The focus of this paper is to explain limnocorrals, present the issues we encountered when using them, and relay our experiences and recommendations on the use of the corrals to study the nutrient cycles within a lake.

II. Background

Limnocorrals consist of large, flexible, woven columns attached to floats that extend from the surface of water to the bottom, creating a tight seal. This isolated water column allows scientists to study lake processes, such as lake eutrophication and water chemistry, under controlled conditions.

Using limnocorrals to create mesocosms isolates certain environmental processes in order to observe, analyze, and test various components within a complex ecosystem. For example, mesocosms can be used to measure responses to natural variables (such as temperature and salinity), to study dose response relationships, and to measure the growth and survival of various living organisms [1]. Mesocosms are used to test scientific hypotheses and develop future theories [2, 3].

Advantages of using a mesocosm study include its relatively low cost, the speed of data collection, and the ability to replicate results [2, 4]. Additionally, data collected in mesocosm experiments can be extrapolated to larger systems [5, 6]. Quality data can only be achieved, however, if the mesocosm is appropriately designed in scale and time duration [7, 8]. If these requirements cannot be met, data may be harder to extrapolate and the results might be skewed. To prevent questionable data, mesocosm studies should be designed using available background knowledge of the system and verified with subsequent whole-ecosystem studies [8].

A. Proposal and Execution

The Utah Lake Nutrient Cycling Study was developed to 1) better understand nutrient cycling in Utah Lake and 2) evaluate the performance of treatments that have potential to offer holistic and long-term solutions to reduce the intensity, duration, and frequency of future harmful algal blooms (HABs) in UL. Six limnocorrals were installed in the north end of UL, near the outflow of the Timpanogos Special Service District.

Figure 1 Limnocorral Construction

The limnocorrals were relatively large to ensure the resulting mesocosm could be used to control study parameters while retaining some of the natural complexity of the lake. The limnocorrals were ten meters in diameter with an area of approximately seventy-nine square meters.

Five limnocorrals were installed in an area representative of the lake, which was approximately 2 meters deep. The sixth limnocorral was placed less than 100 meters from the shore in approximately 1 meter of water initially. The initial volume of the deep corrals was about 1,900 cubic meters, or 500,000 gallons, of water. After their construction and installation in April of 2021 and throughout the summer, lake depth fell about one meter, causing the water volume inside each corral to decrease noticeably. Data collection and scientific research continued in spite of these changes.

Throughout the summer and into the early fall weekly measurements were taken with our ProDSS probe and water samples were collected for laboratory analysis. The water samples were collected from four distinct quadrants inside the limnocorrals, as seen in Figure 2, as well as from two nearby locations of the lake to determine if conditions inside the corrals mirrored that of the lake.

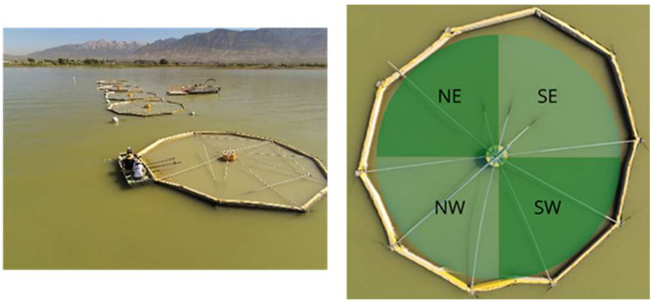

Figure 2 Limnocorral Quadrants and Sampling Locations

A statistical analysis of the spatial data within the limnocorrals was performed to determine the variability within a corral, and to determine if sampling could be minimized in subsequent years. Preliminary results indicated that there was no statistical significance from quadrant to quadrant. An ANOVA analysis was used to compare the distribution of each quadrant within a corral and determine if it was statistically different from the samples taken in another quadrant.

This initial analysis indicates that water within the limnocorrals is well mixed, and that a single sampling location per corral can be used in subsequent work. A more complete statistical analysis will be performed before the field season begins in 2022.

Data taken within the limnocorrals was also compared to the data taken at two nearby background locations within the lake. Preliminary results indicate that corrals two through six are similar to the values measured in the lake background locations in terms of temperature and general process variables. During the first year, we performed minimal experiments in the corrals. Our comparison with background values used data solely from when no experiments were actively performed in the limnocorrals. This analysis supports the idea that mesocosms created in the corrals are representative of the lake and can be used to better understand lake processes. Corral one, located in shallow water at a depth of 0.6 m (~2 feet) by the end of the sampling season, did not match the lake background data. This shallow enclosure created a separate swamp-like environment that did not match the surrounding lake area. For Phase II, we will evaluate installing both a background and experimental corral in the shallow areas to assure quality data collection.

Figure 3 Limnocorral Installation

III. Construction and Structural Issues

Before deploying them to Utah Lake, we constructed the six limnocorrals on the north shore of UL (Figure 1). Materials used for a single corral included a flexible woven skirt, ten yellow floaties, a series of ten metal struts to act as a support for a carp fence (to keep fish and birds out of the corrals), and a long metal chain inserted into the bottom of the skirt to secure it to the bottom of the lake. These materials can be seen in Figure 1. After evaluating the impacts the carp net posed on sampling, we decided not to install the nets, but left the center float and supporting poles in place to assist with corral rigidity. After construction, we towed the corrals from the shore to an area of Utah Lake with a water depth between 5 and 6 feet (Figure 3). There, ocean professionals attached the flexible anchor system to the corrals. The limnocorral float junction points were reinforced and connected directly to the anchors on the lake bottom. This allowed corrals to move with the waves but remain attached in the same position of the lake.

Due to high winds (the strongest reaching speeds of 51 miles per hour) and large waves generated by the winds, many of the corrals experienced damage and began to come apart or disassemble. The center struts and attached spokes, whose initial purpose was to support a mesh cover (which was not installed), loosened and then began to rip the flexible woven skirts until large holes were formed. Not only did these tears in the skirts continue to grow the longer the spokes stayed in them, but some spokes sank low enough to get stuck in the muddy lake bottom. When strong winds blew and created waves which affected the corrals, water came over the floats and entered the corrals because they could not properly move with the waves. The anchoring system, which was designed to be flexible, created further problems, as the flexibility allowed the limnocorrals to move too much and too easily in the water. Another problem was discovered when the thread used to sew and hold the skirts to the border (which was held by a carabiner to the floats) began to unravel, causing the skirts to drop. The thread was not strong enough to support the weight of the woven skirt, especially when the skirts were blown about by changing current and stronger, larger waves than were originally anticipated. With these corrals literally falling apart at the seams, additional water was let in and out of the limnocorrals (Figure 4).

Figure 4 Unraveled Corral

Water entering and exiting the corrals through rips, holes and tears means that the corrals were not creating an isolated mesocosm, and the statistical evaluation of the difference between corral environmental and the nearby lake showed the corrals were compromised. Additionally, it became difficult to take samples and collect data within the broken corrals. Sample collections were stopped from specific corral quadrants because these corrals and quadrants no longer "existed," as shown in Figure 4. The process of gathering samples–which involved anchoring a small skiff to a floatie in each quarter of each corral in order to maintain position while sampling–likewise increased in difficulty. Without a stable limnocorral to anchor to, researchers were required to paddle to maintain the same position in the water and probes experienced greater movement, which again posed the threat of lesser data accuracy.

Figure 5 Dismembered Corrals

After close examination and thoughtful discussion, we removed the damaged limnocorrals from the lake. The woven skirts were detached from the bottom of the lake, raised, and tied to the limnocorral floaties. This assured that they would remain intact and not disrupt the lake bottom as we removed the corrals. A pontoon boat was used to gently tow the damaged corrals to shore. Once at shore, we took the corrals from the lake, and redesigned and rebuilt them to better withstand the conditions of UL. Design improvements included rethreading the corrals with stronger material to help the skirt stay attached, adding reinforcing beams around the perimeter of the corrals, and removing the center struts to create a more flexible limnocorral that could shift to the waves easier than before. Figure 6 shows the corrals from initial installation, to before removal in late July, the remaining corrals while others were undergoing adjustments, and after re-installation in early August. The redesign and reinforcement proved beneficial in the integrity of each corral.

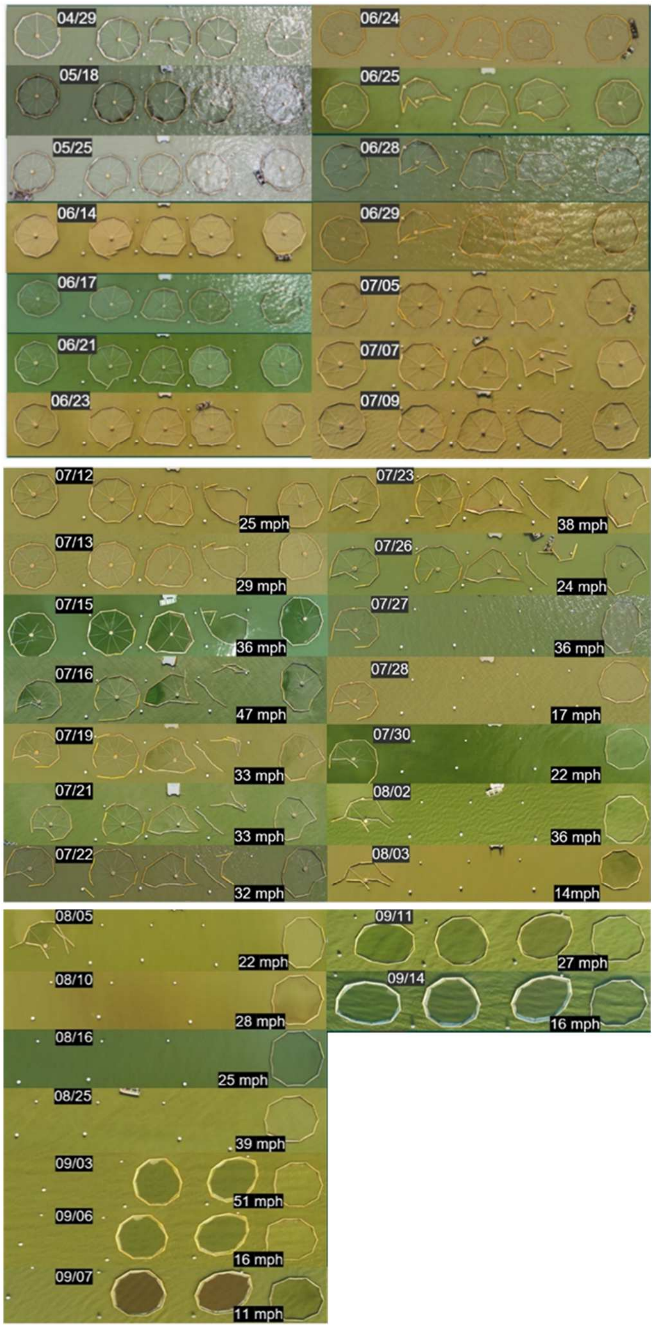

Figure 6 Time-lapse of Limnocorrals

IV. EXPERIMENTS

Throughout the summer of 2021, we collected water samples in each quadrant within each of the six corrals as well as two background locations in the lake. An analysis of these water samples was conducted using Inductively Coupled Plasma Spectroscopy (ICP), Ion Chromatography (IC), and wet laboratory tests for nitrate, nitrite, ammonia, reactive phosphorus, total phosphorus, total nitrogen, chemical oxygen demand, total suspended solids, volatile suspended solids, total dissolved solids, and total organic carbon. Additionally, we used YSI ProDSS multiparameter water sondes to measure conductivity, specific conductivity, salinity, total dissolved solids, temperature, resistivity, chlorophyll (RFU), turbidity, dissolved oxygen, and pH. The sondes–or probes–were used to measure a single location near the surface of each quadrant at approximately 0.1 m depth, as well as to measure these parameters in a vertical profile for each corral. These consistent measurements throughout the summer provided an extensive baseline for the next two phases of the Utah Lake Nutrient Cycling Studies.

An isolation experiment was performed to determine how well a functioning corral behaved and to estimate the residence time of the water within a corral. To perform this study, we used 10 ml of rhodamine dye and applied it to two corrals for replication. Periodic water samples were taken and analyzed using a spectrofluorometer to measure mixing within the corrals. The spectrofluorometer can measure rhodamine to a low parts-per-billion (ppb) level. With the newly fixed limnocorrals, we found that these corrals had a low level of mixing between themselves and the lake. It took three to four days for the rhodamine to no longer be detected within the limnocorral, giving an estimated residence time of 2-3 days; in reality, this could be longer as other processes, such as sunlight, could have depleted the rhodamine. Plans are underway to conduct additional experiments this summer to refine this number.

Figure 7 Rhodamine Dyed Corrals

A two-three day mixing time shows that the corrals are isolated from the lake to some degree, but not completely. This is good, as we do not want to deplete oxygen or build-up or deplete background chemicals during an experiment. Some level of isolation is desired to provide a simplified environment, but we want to replicate the lake environment to the extent possible. Complications with complete isolation include creating an environment that is not reflective of the Utah Lake water column inhibiting our ability to extrapolate the findings of the Utah Lake Nutrient Cycling Studies. Preliminary data indicates that the limnocorrals provide a good balance between complete and partial isolation ensuring that the results of this study will be able to be extrapolated.

V. Conclusion

Limnocorrals were used in the Utah Lake Nutrient Cycling Study to study the water column of UL. The relatively low cost, speed of data collection, and ease of replication make these limnocorrals an invaluable tool in understanding the water column of the lake. From our experience with the limnocorrals this past summer, we learned that factors such as structural design, threading, and permeability are important to consider to ensure valid data. Despite initial structural issues, the corrals allowed us gather good baseline data and to run experiments for the next two phases of the study.

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This work was funded by the Timpanogos Special Service District.