Utah Lake Water Quality Study (ULWQS)
Science Panel
March 15, 12:00 PM to 3:00 PM
Virtual Meeting
Meeting Summary - FINAL

ATTENDANCE:
Science Panel Members: Michael Brett, Janice Brahney, Soren Brothers, Greg Carling, Mitch Hogsett, Ryan King, James Martin, Theron Miller, Michael Mills, and Hans Paerl

Steering Committee Members and Alternates: Eric Ellis, Erica Gaddis, and John Mackey

Members of the Public: Jeff Budge, Tina Laidlaw, LaVere Merritt, Dan Potts, David Richards, John Wolfe

Utah Division of Water Quality (DWQ) staff: Scott Daly, Jeff DenBleyeker, Jodi Gardberg, and Nicholas von Stackelberg

Technical Consultants: Zach Aanderud, Gabriella Lawson, Josh Lemonte, and Michael Paul

Facilitation Team: Heather Bergman and Samuel Wallace

ACTION ITEMS

Who	Action Item	Due Date	Date Completed
Scott Daly and Heather Bergman	Organize a meeting with Ryan King, Hans Pearl, and Zach Aanderud to discuss the Science Panel comments on the bioassay study.	April 15	
	Organize a meeting with Mike Brett, Mitch Hogsett, Janice Brahney, James Martin, and Theron Miller to provide input and direction to Josh Lemonte on the phosphorus-binding study.	April 15	
	Organize a meeting with Mitch Hogsett, Ryan King, and Hans Pearl to talk with Janice Brahney and Soren Brothers about the paleolimnology and paleoecology studies.	April 15	
	Organize a meeting with Mitch Hogsett, Mike Brett, Theron Miller, and Ryan King to provide initial direction to Mike Paul and Kateri Salk on the carbon, nitrogen, phosphorus budget study.	April 15	
Scott Daly	Send the algaecide report to the Science Panel.	March 31	
Science Panel Members	Review the bioassay study and send comments to Zach Aanderud.	March 22	

Who	Action Item	Due Date	Date Completed
Science Panel Members	Review the strategic research priorities document before the next Science Panel meeting.	Next meeting	

DECISIONS AND APPROVALS
No formal decisions or approvals were made during this meeting.

FACILITATOR INTRODUCTION
Erica Gaddis, DWQ, introduced Heather Bergman and Samuel Wallace from Peak Facilitation. Her comments are summarized below.

- Heather Bergman and Samuel Wallace from Peak Facilitation Group are replacing Paul De Morgan and Dave Epstein as the facilitators for the ULWQS. Paul De Morgan and Dave Epstein did a great job, but the DWQ oversaw a competitive bidding process and selected Peak Facilitation Group as the new contractor for the ULWQS.
- Heather Bergman and Samuel Wallace will facilitate the ULWQS Science Panel and Steering Committee meetings as the work for 2021 begins to ramp up.

GROUND RULES AND PROCESS COMMITMENTS OVERVIEW
Heather Bergman, Peak Facilitation Group, gave an overview of the Science Panel ground rules and process commitments. The ground rules and process commitments of the Science Panel are listed below.

- The Science Panel process commitments are:
    - Seek to learn and understand each other's perspective
    - Encourage respectful, candid, and constructive discussions
    - Seek to resolve differences and reach consensus
    - As appropriate, discuss topics together rather than in isolation
    - Make every effort to avoid surprises
- The Science Panel ground rules are:
    - Focus on the task at hand
    - Have one person speaking at a time
    - Allow for a balance of speaking time by providing succinct statements and questions
    - Listen with respect

BIOASSAY STUDY UPDATE
Dr. Zach Aanderud, Brigham Young University (BYU), updated the Science Panel on the bioassay study. Dr. Aanderud's presentation summarizes his interpretation of the findings and does not reflect any interpretations made by Science Panel members. His presentation can be found at minute 13:03 of the meeting recording. The key points from his presentation are organized into two sections (methodology and results) and summarized below.

Methodology

- Dr. Zach Aanderud and his research team conducted the bioassay tests in three locations on Utah Lake: main body west, main body east, and Provo Bay. The bioassays were grown in a common garden in cubitainers. Each cubitainer contained three liters of water and was exposed to different levels of nutrient treatment.
- Researchers measured the mean chlorophyll-a and phycocyanin (a pigment exclusive to cyanobacteria) levels between the nutrient-treated cubitainers and control cubitainers. The different nutrient treatments included:

- A phosphorus amendment: an addition of 0.10 mg of phosphorus per liter above background concentrations
- A nitrogen amendment: an addition of 0.72 mg of nitrogen per liter (meant to achieve a 16:1 molar ratio (i.e., Redfield ratio) of dissolved inorganic nitrogen (DIN) to soluble reactive phosphorus (SRP))

Results

- One of the bioassay study's primary tasks was to identify when limitations are occurring and where they are occurring in Utah Lake.
- For cyanobacteria (measured by changes in phycocyanin levels), the results of the study indicated that:
  - In the summer treatments, phosphorus limited cyanobacteria growth in the main body east and Provo Bay sampling locations.
  - Nitrogen limited cyanobacteria growth in the main body west location in the summer treatments.
  - Nitrogen and phosphorus co-limited cyanobacteria growth in the spring treatments in the main body west site. They also co-limited cyanobacteria in the early summer treatments in Provo Bay.
  - Cyanobacteria did not respond to added nutrients in the late summer or fall bioassays.
- For phytoplankton (measured by changes in the chlorophyll-a levels), the results of the study indicated that:
  - Nitrogen and phosphorus co-limited phytoplankton growth in the main body east and main body west locations, especially in the summer, late summer, and fall.
  - Nitrogen limited phytoplankton growth in Provo Bay, with some co-limitation by nitrogen and phosphorus.
  - During almost any season, nutrients (either nitrogen or nitrogen and phosphorus) limited phytoplankton growth.
- Researchers measured the DIN to SRP ratio at the end of the incubation time to determine whether the added phosphorus was biologically available. The results indicated that the added phosphorus was biologically available in the water column. The researchers came to this conclusion because the DIN and SRP consistently declined with treatment (i.e., the addition of nitrogen resulted in lower phosphorus concentrations, and the addition of phosphorus resulted in lower nitrogen concentrations).
- When researchers added both nitrogen and phosphorus to the cubitainers, the DIN to SRP ratio remained close to 16:1, indicating that the phytoplankton was using the nitrogen and phosphorus at a rate that maintained the 16:1 ratio. These results indicate that phytoplankton is most likely biogeochemically co-limited by nitrogen and phosphorus.
- Researchers diluted some of the cubitainers in the main body east location with a synthetic water solution to determine what nitrogen and phosphorus concentrations would curb phytoplankton and cyanobacteria activity. The results of the dilution experiment indicated that:
  - A DIN concentration of less than 0.14 mg/L and an SRP concentration of less than 0.06 mg/L is needed to curb phytoplankton activity in the spring.
  - The nutrient level needed to curb cyanobacteria activity is an SRP concentration of less than 0.005 mg/L.
  - The decline in SRP when DIN was relatively available led to a decline in phycocyanin concentrations.

- The DIN concentration in Utah Lake across the three sampling locations falls beneath the nitrogen concentration needed to curb phytoplankton activity (0.14 mg/L) during the summer. The SRP concentration across the three sampling locations is above the SRP concentration needed to curb phytoplankton activity (0.06 mg/L). These results indicate that managers should focus on getting SRP concentrations under the value needed to curb phytoplankton activity.
- Researchers collected data on how added nutrients impacted the cyanobacteria nitrogen fixation rate. They found that adding nitrogen and phosphorus increased the nitrogen fixation rate in the main body east location in the early summer. In the Provo Bay location, the nitrogen and phosphorus addition did not dramatically impact nitrogen fixation rates. In the main body west location, the nitrogen and phosphorus additions did not noticeably impact nitrogen fixation rates. In the dilution studies, the nitrogen fixation rate increased dramatically for each dilution over a five-day period.
- The cyanobacteria species Aphanocapsa, Dolichospermum, Merismopedia, Aphanizomenon, and Microcystis were associated with nutrient limitations. The phytoplankton species Aulacosiera, Desmodesmus, and unicellular and colonial greens were also associated with nutrient limitations regardless of the season.
- In Provo Bay, there was a well-established community of phytoplankton and cyanobacteria. In the main body east and west, new species would appear throughout the seasons. Many species had seasonal trends. The addition of nutrients led to the Microcystis species showing up earlier than they do in the lake.
- Researchers looked at cyanotoxin concentrations in relation to the nutrient additions. They did not find a strong relationship between the two, but there were seasonal trends. For example, the cylindrospermopsin toxin showed up early in the spring in the cubitainers. Microcystin appeared in the early summer and summer in the main body east and west locations. High anatoxin-a levels were associated with summer and later summer.
- Researchers conducted a grazer bioassay in the early summer. In the main body east and west locations, adding grazers led to non-detectable levels of phycocyanin in the cubitainers. Grazers also led to a dramatic reduction in phytoplankton in the main body east and west locations. Adding grazers to the Provo Bay cubitainers led to a reduction in phytoplankton concentrations but an increase in cyanobacteria. Researchers concluded that microscopic grazers have a large impact in Utah Lake.

Science Panel Questions
Science Panel members asked clarifying questions on the bioassay study. Questions are indicated in italics with corresponding answers in plain text.

What method did researchers use to add zooplankton to their cubitainers?
The researchers did not filter during the sample collection for the zooplankton bioassay. For the other bioassays, researchers used a 0.9-micron mesh to filter zooplankton.

Would a 0.9-micron mesh filter out the phytoplankton?
It may not have been a 0.9-micron mesh. Researchers did not see phytoplankton being retained on the mesh, but they did see zooplankton.

Since Provo Bay is enriched with nitrogen and phosphorus, it does not make sense that adding nutrients to Provo Bay samples would change nitrogen fixation rates. One potential explanation is that cyanobacteria and phytoplankton within thick aggregates cannot access nutrients in the water *column under normal circumstances. Why were nitrogen-fixation rates responsive to added nutrients in the Provo Bay samples?*

- Provo Bay in the early summer had a higher phycocyanin concentration than the main lake. One potential answer to this question is that more nitrogen-fixing organisms are present in Provo Bay than in the main lake.
- Utah Lake is productive, and there are ways to add and decrease nutrients. There is still a need for future studies on nitrogen fixation. Future studies could include a better dilution bioassay study with a wider range of nitrogen and phosphorus changes. This study could help identify if there is a threshold for the nitrogen-fixation rate.
- Nitrogen-fixation rates should be higher in the summer and later summer because that is the time when some nitrogen-fixing species become more prevalent.

It makes sense that nitrogen fixers would increase their nitrogen fixation rate in response to added phosphorus but not to added nitrogen. The results of the study indicate an increased rate of nitrogen fixation in response to added nitrogen. Why would the rate of nitrogen fixation increase in response to added nitrogen?

The Microcystis population does not seem to show up in the species chart. Does it make up a large portion of the biomass?
The Microcystis population shows up in the time-series graph.

Is it possible that as a single-cell organism, Microcystis cells are escaping counts?
Zach Aanderud and his students had a methodology for counting, and the students did a good job following that method. The time-series graph better shows the data on the Microcystis populations. There were various incubation times in the study. Most of the nitrogen and phosphorus limitations were associated with faster-growing species. More species, such as diatoms, would appear with longer incubation times.

As the researchers adjusted the individual nutrients, did the nitrogen and phosphorus ratio stay at the Redfield Ratio?

Since the cubitainer is in the floating zone, could the turbidity settling affect the phytoplankton and cyanobacteria responses over the first 48 hours?

- The cubitainer method is not ideal. The researchers had photosynthetically active radiation (PAR) for all the bioassay studies, so they used a system to block out the PAR. The researchers add sodium bicarbonate to account for turbidity as well.
- The cubitainers are also moving with the water, so they are not still. The bioassay studies also occurred in Provo Bay, where there is less movement overall.

Could larger zooplanktons impact the efficiency of grazing, especially with filamentous cyanobacteria?

- There seems to be a size ratio associated with zooplankton and cyanobacteria. The researchers would see the larger zooplankton on the Wisconsin net when they collected the sample, but there were not many. It was difficult to get an accurate biomass value for them. Smaller zooplankton seems to have a larger impact in Utah Lake.
- The bioassay studies have valid conclusions, but there is an outstanding question about the relationship with sediment, zooplankton, cyanobacteria, and phytoplankton.
- Researchers did not directly count zooplankton; instead, they used DNA extraction and enumeration methods.

The algal data should be expressed with biovolume instead of cell counts. How would the data change if it was expressed as biovolume instead of cell counts?
In the bioassay study, cost prevented researchers from determining biovolume estimates. Calculating biovolumes would have accounted for a large percentage of the study's cost. Other researchers have calculated average biovolume metrics in Utah Lake over the past ten years, excluding biovolume estimates for green algae. In the next iteration of the study, Zach Aanderud could calculate the biovolumes using the average biovolumes observed in Utah Lake.

Science Panel Comments
Science Panel members provided comments on the bioassay study. Their comments are summarized below.

- There may be a way to hierarchically aggregate the nitrogen and phosphorus ratio estimate across the main body east and west sampling sites. Hierarchically summarizing that data will help uncover whether the variability of the nitrogen and phosphorus is due to the small sample size or if the results are seasonally dependent. Zach Aanderud added an aggregate table for the dilution bioassay and time-series graph.
- The consistent depletion of phosphorus in response to the addition of nitrogen uncovers an important point about the bioavailability of SRP. The bioassay study shows that the simplest answer is that the phosphorus is bioavailable.
- In Provo Bay, nitrogen fixers potentially address a nitrogen deficiency due to the amount of biomass in Provo Bay. A plot of nitrogen fixation per unit chlorophyll or phycocyanin could help investigate this relationship.
- The fact that there was less nitrogen stimulation in the summer suggests that nitrogen fixation is an important nitrogen source overall in the system. There are more nitrogen-fixers in the summer, late summer, and fall. The biggest nitrogen fixer will likely be Dolichospermum. Aphanocapsa may fix nitrogen.
- The report should better clarify the confusion around phytoplankton, eukaryotic algae, and cyanobacteria.
- Turbidity could have affected the phytoplankton and cyanobacteria response in the bioassay study. Other collected data suggests that the Secchi depth goes from 17 to 18 feet in the summer to 120 feet in the winter, suggesting the turbidity settles in the lake as a whole when there is no wave action.

Next Steps for the Bioassay Study

- The contract agreement between Zach Aanderud and DWQ is up at the end of April. The goal is to put Zach in a position to finalize the report at the end of April and give the Science Panel one more time to review the study.
- Science Panel members should provide comments in the next week. Then, a task group of the Science Panel can meet to go over the Science Panel comments. Hans Paerl and Ryan King volunteered to join a task group to review the bioassay comments. Heather Bergman and Scott Daly will organize a meeting with Ryan King, Hans Pearl, and Zach Aanderud to discuss the Science Panel comments on the bioassay study.
- Zach Aanderud can focus on comments from this meeting in the meantime, including incorporating feedback on the nitrogen-fixation rates and biovolume calculations.

Public Questions
Members of the public asked questions on the bioassay study. Questions are indicated in italics with corresponding answers in plain text.

Were there any phytoplankton or cyanobacteria species present that produce compounds that impact fish flavor or texture, such as geosmin?
A diverse group of cyanobacteria produces these compounds. The first step to determining whether these compounds are present is if the fish tastes or smells bad. The compounds affect the taste and odor of the fish but do not make them unsafe to eat.

When researchers added zooplankton to the bioassay, were they added at the same relative abundance across locations?
The method for adding the zooplankton was to not filter the water samples. There would be different relative concentrations of the grazers for each location.

Was it important that phytoplankton could not interact with iron in the sediment?
One of the goals of the bioassay study was to separate the water column dynamics from the sediments.

Public Comments
Members of the public provided comments on the bioassay study. Their comments are summarized below.

- David Richards has written reports on zooplankton on Utah Lake that may be helpful. The studies conclude that zooplanktons are the major top-down control in Utah Lake.
- Some of the zooplankton species in the slide deck were mislabeled.

P-BINDING (P-BINDING) STUDY

Dr. Josh Lemonte, BYU, provided an overview of their work plan for the P-binding study. His presentation can be found at 1:10:25 of the meeting recording. The key points from his presentation are summarized below.

- The P-binding research team involves Dr. Steve Nelson, Dr. Greg Carling, Dr. Kevin Rey, undergraduate research assistants, Masters's degree students, and Dr. Josh Lemonte, the project lead.
- The overarching objective is to inform the charge question, "what is the role of calcite' scavenging' [i.e., binding] in the phosphorus cycle?" Utah Lake is calcite rich, which plays a large role in the phosphorus cycle. Under the overarching objective, there are five study objectives:
    1. Create a reaction network of processes involving the chemical species of phosphorus in Utah Lake
    2. Characterize the chemical speciation of phosphorus in the water column and sediment under a series of specified water quality conditions representing the existing and potential future conditions in Utah Lake
    3. Characterize phosphorus scavenging and release from the water column and sediments under a series of specified conditions
    4. Evaluate the kinetics of phosphorus sorption and desorption of phosphorus onto sorbing surfaces and evaluate desorption hysteresis (i.e., the speed or irreversibility of desorption and under what conditions) for different conditions in Utah Lake
    5. Evaluate the predictive relationships to characterize the binding of phosphorus onto sorbing surfaces in the water column and sediments
- For objective one, researchers will use the GeoGhemists' Workbench. The initial reaction network will be based on data from existing reports and pertinent, published information. The researchers expect to have the first draft of this process and a literature review by the week of March 22, 2021.

- For objective two, researchers will be collecting samples at five sites across Utah Lake. The researchers will take water column samples at the surface (one to ten centimeters down), mid-depth, and just above the sediment (one to ten centimeters). The researchers will extract cores to sample the sediment. They will also install multi-level redox sensors to track how redox shifts in the sediments over time. This sampling will occur down one-meter. They might deploy discrete depth piezometers and core water samplers.
- For objective three, researchers will use advanced automated biochemical microcosm reactors to experiment on the water samples. The reactors will allow the researchers to control the pH and redox to create a state of equilibrium at specific pH zones. This experimenting will show how redox plays a role in the release and sequestration of phosphorus.
- For objective four, researchers will also use the reaction system to look at the sorption and desorption of phosphorus onto surfaces. They will also model the systems for calcite, iron, manganese, and oxides. The research team will figure out which sediment constituents may be driving desorption. They will conduct batch sorption to determine the sorption capacity and Langmuir co-efficient to feed into models. One limitation of batch sorption is that it may miss information in a closed system, so researchers will conduct stirred-flow reactions to collect time-resolved data with limited back reactions.
- For objective five, researchers will use experimentally obtained data from objective four to determine Langmuir fits. Feedback from the Science Panel members on what parameters to consider in the Utah Lake model would be helpful.
- Overall, the researchers will be taking field samples and analyzing them geochemically and mineralogically. They will then conduct laboratory experiments to determine the kinetics, sorption capacity, and mineralization. They will share the data with the Science Panel members.
- The research team is conducting a literature review. The literature review focuses on the speciation (aqueous and solid), mineralogy, and environmental parameters driving the phosphorus cycle.
- The research team will deliver the draft literature review and preliminary reaction network during the week of March 22. They will provide a draft sampling and analysis plan (SAP) on April 2 and a final technical literature review memorandum and references on April 9. They will finalize the SAP on April 23 and begin fieldwork.

Science Panel Comments

Science Panel members provided comments on the P-binding study. Their comments are summarized below.

- An interesting aspect of this study is looking at what mineral complexes phosphorus is forming in the lake and how likely it is that those mineral complexes will be resolubilized and become biologically available. There may be some interesting dynamics with colloidal phosphorus in the water column. The Utah Lake SRP values are high, suggesting the phosphorus is bioavailable. The SRP may not be phosphate.
- The bioassay study suggests that most of the SRP is bioavailable because the addition of nitrogen and nitrogen and phosphorus drove phosphorus down to detection levels. There may be an equilibrium issue, which causes the sediment to act as a phosphorus pump, releasing SRP into the water column. The P-binding study will help answer some of these questions from the bioassay study.
- The P-binding study's emphasis should be to help determine what should be in the model instead of looking at the model to inform the P-binding study.

Next Steps for the P-Binding Study

Mike Brett, Mitch Hogsett, Janice Brahney, James Martin, and Theron Miller volunteered to join a task group to provide input and direction to Josh Lemonte on the P-binding study. Scott Daly and Heather Bergman will organize a meeting with Mike Brett, Mitch Hogsett, Janice Brahney, James Martin, and Theron Miller to provide input and direction to Josh Lemonte on the P-binding study.

Public Questions

Members of the public asked questions on the P-binding study. Questions are indicated in italics with corresponding answers in plain text.

Historically, Utah Lake had hundreds of tons of mollusks filtering out the phosphorus from the water column. Will the P-binding study look at how the loss of this ecosystem service impacts the lake?
The researchers are not planning on talking about the loss of the ecosystem services provided by mollusks. Some researchers are interested in this question and will be looking at it in an ad-hoc manner. However, the study will not quantify the loss of the ecosystem service compared to the historical record.

UTAH LAKE PALEOLIMNOLOGY STUDY UPDATE

Dr. Janice Brahney, Utah State University, provided an update on the Utah Lake paleolimnology study. Dr. Brahney's presentation summarizes her interpretation of the findings and does not reflect any interpretations made by Science Panel members. Her presentation can be found at 1:43:54 of the meeting recording. The key points from her presentation are summarized below.

- Lab closures due to COVID have delayed the Utah Lake paleolimnology study.
- In 2018, researchers collected three cores from three different sampling locations: Bird Island (A, B), Goshen Bay, and Provo Bay. In 2019, researchers collected cores from two sampling locations: North Utah Lake and North Provo Bay. In 2020, researchers recollected a core from Provo Bay because the original Provo Bay core was not representative of a continual deposition process.
- The Bird Island core shows distinct changes in the sediment. The Goshen Bay core has a switch from darker to lighter sediments. The North Utah Lake core is homogenous, with some color changes occurring down the core.
- Researchers used the initial core description and other factors, including fossil presence, to identify different facets in the core. There are similarities in the timing of fluctuations. There are four distinct units in the cores. In Goshen Bay and Provo Bay cores, vegetation and shells are present; in the Bird Island and North Utah Lake cores, vegetation and shells are not present.
- Researchers are dating the cores with cesium-137 because there is a clean record of cesium-137 in the cores. They are also using carbon-14 to date vegetation in older sediments. The Goshen Bay core has been completely dated. The dating of the other cores has been delayed due to COVID and instrument malfunctions. The goal is to date the other cores in the next couple of months.
- Researchers are using Bayesian age-depth modeling based on the depth of the core. They are also using sequential regime shift detection tests to identify distinct changes throughout the sediment record.
- There are three distinct events that researchers are looking at in the cores: the settlement of Utah Lake, the introduction of carp, and the installation of wastewater treatment. They are also using the population of Utah County as an indicator of waste production.
- The pigment data for the Goshen Bay indicates a massive increase in production (measured through the concentration chlorophyll-a) at the introduction of carp into Utah Lake. The

highest level of production has occurred in modern times. There was a decrease in preservation (measured through the concentration of phaeophytin-a) after the carp introduction, representing a shift from stable sediments to more mixture in the water column.

- There was an increase in cyanobacteria pigments over time in the Goshen Bay core, with the highest pigment concentrations occurring more recently. In the Goshen Bay Core, there was an increase in diatom pigment following the introduction of carp, followed by a decline.
- The Bird Island core pigment concentrations were similar to the Goshen Bay core pigment concentrations. One difference is that the diatom pigments in the Bird Island core increased following the carp introduction and have increased up-core instead of decreasing.
- The Provo Bay core shows the general trend of increasing cyanobacteria populations and decreasing diatom populations. The data for this core is still being processed.
- The researchers conducted eDNA tests on the vegetation. The eDNA results indicate that the vegetation before the introduction of carp included a high percentage of hardstem bulrush. Following the introduction of carp, cyanobacteria representation increased in the eDNA results.
- The fossils in the Goshen Bay core indicate an increase in Cladocera following the carp introduction. The next steps for the Cladocera counting are to measure their size and determine the different species present. Other results include a decrease in Ostracodes populations after the carp introduction and more frequent appearances of vegetation fragments in the core before the introduction of carp.
- There is a greater representation of epiphytes, which are diatoms that grow on plants, in the historical record than in the modern record in the Goshen Bay and Bird Island cores.
- Researchers plotted the ratio of planktonic species to benthic species according to the core depth. In both the Goshen Bay and Bird Island cores, larger, pollution-tolerant species replaced the smaller benthic species over time.
- Researchers looked at how phosphorus loading and how phosphorus-binding in sediments changed over time. They measured the concentration of exchangeable, iron oxide-bound, alumni-bound, and organic phosphorus present in the cores. They are also measuring the concentration of calcite and recalcitrant present. There is particular interest in measuring calcite-bound phosphorus because calcite is a good phosphorus scavenger.
- The study data suggests the following conditions for Utah Lake for different periods:
  - **Pre-regime shifts (1640-1869):** The evidence in the cores suggests more macrophytes and gastropods, lower pigment concentrations, more stable sediments, higher carbon to nitrogen ratios, and more nitrogen-15 present, which suggest more natural conditions.
  - **Post-regime shift (1869-1945):** The evidence in the cores suggests an increase in algal pigments, an increase in cyanobacterial eDNA, a decrease in the carbon to nitrogen ratio, which indicates that organic material is derived from plankton instead of plants, and a decrease in sediment stability.
  - **Continued eutrophication (1945-present):** The evidence in the cores suggests an increase in isotopically-enriched nitrogen-15, a decrease in diatom pigments, and the ongoing increase of cyanobacteria pigments.
- The next step for the study is to complete analyses now that laboratories are opening up.
- Researchers only had enough money to analyze four cores. The preliminary core analyses for Provo Bay did not have good results because of the core quality. Science Panel members should provide input on whether the remaining funding should be used to analyze the North Utah Lake core or the new Provo Bay core.

Science Panel Questions
Science Panel members asked questions on the paleolimnology study. Questions are indicated in italics with corresponding answers in plain text.

Can people see the slide deck for the presentation?
The data is not published yet, so there will have to be further discussion on whether the slide deck can be shared broadly.

Is the nitrogen-15 coming from the wastewater treatment plants different than the ambient nitrogen-15 from the streams? Could higher nitrogen-15 concentration mean the system has moved into a state of denitrification?
Both are possible. Wastewater treatment discharges are generally enriched nitrogen-15. There is no data on the discharges going into Utah Lake.

Did researchers plot diagnostic pigments over chlorophyll to better understand how the relative proportion of cyanobacteria has increased?
Not yet. There are a couple of potential indices using pigment ratios to represent light stress.

Would researchers have to look at phaeophytin pigments along with chlorophyll to get a total chlorophyll concentration?
Yes. However, researchers wanted to show them separately to look at the signal through time. Normally, more phaeophytin is present lower in the core, but it is the complete opposite in the collected cores, potentially due to the carp disturbance.

What is the pattern of the percent organic carbon in the Provo Bay core relative to the introduction of carp and wastewater?
The data suggests there was a big die-off that led to the accumulation of plant debris and shells. Before that die-off, the shells and plant matter were more evenly distributed. The even distribution suggests a stable water level, which allowed vegetation to establish over an extended period.

The data suggests a decline of percent organic carbon to predevelopment levels. What do the researchers think of that decline?
There is more organic matter in the historical sediments than in the present sediments. The shift from macrophyte production to algae production is one explanation for the decrease of organic matter.

Can researchers infer the time scale for the sediment mixing based on the cesium-137 data?
- There is some blurring in the data during mixing. Janice Brahney will need to consider how to account for the blurred data.
- If researchers had access to a core that did not experience sediment resuspension, they could look at the curve's shape to see how it flattened it out. The input of the isotopes would also flatten out the curve.

Science Panel Comments
Science Panel members provided comments on the paleolimnology study. Their comments are summarized below.
- The fact that more nitrogen fixation is occurring in Utah Lake would make the nitrogen-15 values coming from external sources more important. The isotope signal for nitrogen fixation is zero.

- The North Utah Lake core would probably follow similar patterns to other offshore cores, so funding should be allocated towards analyzing the Provo Bay core instead of the North Utah Lake core.

Public Questions
Members of the public asked questions on the paleolimnology study. Questions are indicated in italics with corresponding answers in plain text.

The addition of the dam on the outlet of Utah Lake and the pump house impacted the stability of Utah Lake water levels. Did the sampled cores go far back enough to look at the impact of increased fluctuations in lake levels on lake ecology?
The cores go fairly far back in time. Once researchers have a chronology on the cores, they can look for those signatures.

The loss of native fish taxa and mollusk taxa likely contributed to changes in the limnology along with the carp disturbance. Did the loss of the native fishes and mollusks contribute to changes in the limnology?
Janice Brahney can talk with David Richards about this inquiry offline.

UTA LAKE PRIMARY PRODUCTION STUDY UPDATE
Dr. Soren Brothers, Utah State University, provided an update on the Utah Lake primary production study. Dr. Brothers' presentation summarizes his interpretation of the findings and does not reflect any interpretations made by Science Panel members. His presentation can be found at 2:12:34 of the meeting recording. The key points from his presentation are summarized below.

- The key findings from the primary production study include:
    - The primary production in Utah Lake in 2018 was 550 grams of carbon per meter squared; 99% of the primary production was planktonic.
    - A stable clear-water macrophyte community would likely require a mean Secchi depth greater than one meter and a chlorophyll-a concentration of less than 20 micrograms per liter. Under these conductions, phytoplankton would likely still dominate the primary production.
    - Higher primary production with clear water conditions may feature lower algal biomass accumulation in the water column due to higher grazing.
- One of the study's main goals was to locate *Chara aspera* oospores' macrofossil remains in nearshore sediment cores. *Chara aspera* is a clearwater indicator algal species reported to historically exist in Utah Lake. It grows in the sediment surface, which helps reduce resuspension. *Chara aspera* is especially common in hard-water lakes. They also produce oospores, which can be found in sediment remains directly at the location of plant growth.
- Researchers took sediment cores to confirm whether *Chara aspera* existed and to what extent. They retrieved 20 sediment cores from seven different locations, including two sites that researchers re-visited to collect deeper core samples. The researchers did not identify any oospore remains in any of the cores. Potential reasons that they did not find oospores include:
    - The cores were not deep enough to reach the time when *Chara aspera* was present.
    - The cores were not in the same physical location as the historical *Chara aspera* communities, which were normally found in deeper parts of Utah Lake.
- The next step for the oospore analysis is to collect longer cores, further offshore. The best way to do that would be to go to the coring transect by boat and collect cores that are 30-50 centimeters deep.

- The second goal of the study was to look at the phytoplankton primary production in the lake. The researchers used Phytotools to account for high resuspension rates and chlorophyll-a concentrations. They also used in-lake data and literature estimates for photosynthesis-irradiance curve parameters to see how quickly algae respond to light and at what point they are light-saturated. They paired that data with periphyton primary production models based on water clarity. They paired that modeling approach with diel dissolved oxygen curves, using offshore curves from DWQ monitoring stations and nearshore curves. This gives an idea of gross primary production and ecosystem respiration.
- The study results indicated a good agreement between the seasonal models and measured primary production. The rough estimate for the primary production is 550 grams of carbon per meter squared each year, 99% of which is from planktonic production. This result is a rough estimate.
- The literature review indicated that 70% of the lake's sediment surface should have light access for benthic production to occur. There are regime shifts and limnological feedback loops; systems severely affected by sediment resuspension systems rely on benthic production to reduce sediment resuspension.
- Secchi depths of at least one meter are needed to achieve light access for 70% of the sediment surface. A chlorophyll-a concentration of less than 20 micrograms per liter is needed to achieve that water clarity.
- Phytoplankton productivity generally dominates Utah Lake. This result should not be surprising, considering June suckers are adapted for a pelagic food web.
- The researchers collected primary production data from May to June in 2019. The gross primary production in the offshore monitoring stations was much higher than in the nearshore monitoring stations.
- The net ecosystem production was negative in the nearshore zone. A net ecosystem production value less than zero means there is more organic matter drawdown than production. Potential explanations for this dynamic include degrading macrophyte material or periphyton interacting more with groundwater than the water column oxygen.
- There is more mineralization in the nearshore zone paired with higher gross primary production. This result indicates an inverted trophic primary pyramid, often associated with healthy benthic primary producer communities. In this situation, grazers are constantly eating highly productive biomass. A more productive system does not mean "swampy" conditions if grazers are consuming primary producers.
- This study's next steps could include a longer time series of littoral versus offshore aquatic metabolism rates, investigations into periphyton and submerged macrophyte dynamics, or a detailed measurement into photosynthesis-irradiance parameters for Utah Lake algal communities.
- The primary conclusions from the study are:
    - Utah Lake's current primary productivity is typical/high-end for eutrophic shallow lakes.
    - Models indicate that an 80-centimeter increase in mean Secchi depth would result in a higher total primary production and maintain phytoplankton dominance.
    - The conditions required for self-stabilizing clear-water feedback effects via benthic gross primary production may be associated with lower algal biomass and a greater food web use of organic matter.

Next Steps for the Paleolimnology and Paleoecology Studies
Mitch Hogsett, Ryan King, and Hans Paerl volunteered to talk with Janice Brahney and Soren Brothers about the paleolimnology and paleoecology studies. Heather Bergman and Scott Daly will organize a meeting with Mitch Hogsett, Ryan King, and Hans Pearl to talk with Janice Brahney and Soren Brothers about the paleolimnology and paleoecology studies.

Public Questions
Members of the public asked questions on the primary production study. Questions are indicated in italics with corresponding answers in plain text.

Did the researchers measure the phragmites' primary production in the littoral zones?
Any emergent or floating macrophytes were not associated with the study because they exchange carbon with the atmosphere, not the lake. However, they could be driving the net ecosystem production results. Emergent macrophytes are loading carbon in the system, so they would drive down net ecosystem production.

There is a mutualistic positive feedback loop between grazers and primary producers (i.e., as grazing increases, production increases). Did researchers measure how much primary production zooplankton grazing took up?
The diel oxygen curves look at the oxygen being produced and the oxygen being consumed. The curves do not show where the oxygen is going. Most typically, the basal food web drives the primary production (i.e., bacteria and algae). Zooplankton can affect respiration rates but only at a small percentage.

GENERAL MANAGEMENT UPDATES
Erica Gaddis, DWQ, updated Science Panel members on Utah Lake management activity. Her comments are summarized below.

- The DWQ originally tasked the Science Panel members to engage in Phase 1 and 2 of the ULWQS. Some Science Panel members have indicated they are interested in staying engaged through Phase 3. The timeline for the ULWQS is to begin moving into the implementation planning phase this year. The goal is also to wrap up the field studies and modeling this year.
- All publicly owned treatment work facilities have been upgraded or on track to be upgraded. Payson City recently requested $23 million to build a new treatment plant.
- In 2020, two different companies treated three marinas using several algaecides. The cost was $2,5000 to $5,000/acre on 57 acres. The treatments were effective for a couple of days, but the cyanobacteria bounced back within a week. The legislator has appropriated more funding for treatments. DWQ will be working with the Department of Natural Resources, Utah Lake Commission, and local health departments to figure out what treatments would be helpful. The hope is that the Science Panel will help inform the management solutions.
- There was a bill to create a new Utah Lake Authority. The legislature did not pass it, but it will likely return in the upcoming legislative session. The bill would create a new authority with bonding and taxing ability to make meaningful progress on restoring the health of Utah Lake.
- The Utah Lake Commission approved the management goals. The ULWQS Steering Committee will begin to engage in scenario planning soon.

Science Panel Questions
Members of the public asked questions on the general management update. Questions are indicated in italics with corresponding answers in plain text.

What algaecides were used for treatment?
Copper sulfate. Scott Daly will send out the algaecide report to the Science Panel.

STRATEGIC RESEARCH PLAN (SRP) PRIORITIES OVERVIEW
Mike Paul, Tetra Tech, provided an overview of the SRP priorities with the Science Panel members. Their comments are summarized below.

- The Science Panel will need to consider whether they want to pursue any new request for proposals (RFP) and whether they need to identify new research priorities. The Science Panel has already collected a lot of information to support developing answers to the charge questions.
- On the Google Drive, there is a document called the Strategic Plan Work Summary. Mike Paul went through the document and identified where there are information gaps to answer the charge questions. He also identified progress on the Science Panel's research priorities, including the upcoming limnocorral research proposed by Timpanogos Special Service District (TSSD). Science Panel members should review the strategic research priorities document before the next Science Panel meeting to discuss any new RFP or research priorities needed to answer the charge questions.
- Science Panel members should consider which research priorities require field data and focus on getting those studies completed this year.

PUBLIC COMMENTS
Members of the public provided comments. Their comments are summarized below.

- The Science Panel is doing great work, but the hope is that the work does not lead to Utah Lake becoming a cement pond.
- The fluctuations in water levels since the construction of the dam and pump house represented a dramatic change to Utah Lake. The Science Panel should focus on how the fluctuation of water levels has impacted the lake's ecology and limnology.

NEXT STEPS

- Mike Paul and Kateri Salk have made progress on the carbon, nitrogen, and phosphorus (CNP) study. They are populating the conceptual models and updating the external mass balance for CNP. There is a need to check-in on the study. Mitch Hogsett, Mike Brett, Theron Miller, and Ryan King volunteered to provide initial direction to Mike Paul and Kateri Salk on the CNP budget study. Scott Daly and Heather Bergman will organize that meeting.
- The Science Panel settled on a model gaps memo and put out an RFP for the next phase of modeling work. James Martin and DWQ staff worked on the RFP. The Utah State Procurement Office should release the RFP soon. They will post the RFP for four weeks, depending on responses. Once there are bids, the five independent Science Panel members will review the proposals
- TSSD awarded the limnocorral project to BYU researchers. They are developing a final research plan now to begin the study in April. The Science Panel will discuss the work plan at the next couple of Science Panel meetings.
- Scott Daly put together a Science Panel engagement schedule, which is in the Google Drive. There is a lot to do in the upcoming months. The list includes more discussion on the bioassay, P-binding, CNP, and limnocorral studies. It also includes a discussion on atmospheric deposition, model evaluation, and the analysis report. There will need to be either more frequent meetings or longer meetings to accommodate this work schedule.

- Most Science Panel members said they preferred meeting more frequently rather than having longer meetings. Some Science Panel members said they would prefer to have longer meetings, but they are willing to meet more frequently to make progress on the studies.

PUBLIC ENGAGEMENT DISCUSSION
Before the Science Panel meeting, Heather Bergman met with the ULWQS Steering Committee and Science Panel members that volunteered their time to talk with her. Some Science Panel and Steering Committee members commented that there is an opportunity to improve public engagement during meetings. Following the Science Panel meeting, members of the public were invited to share their thoughts on improving the public engagement section of Science Panel meetings.