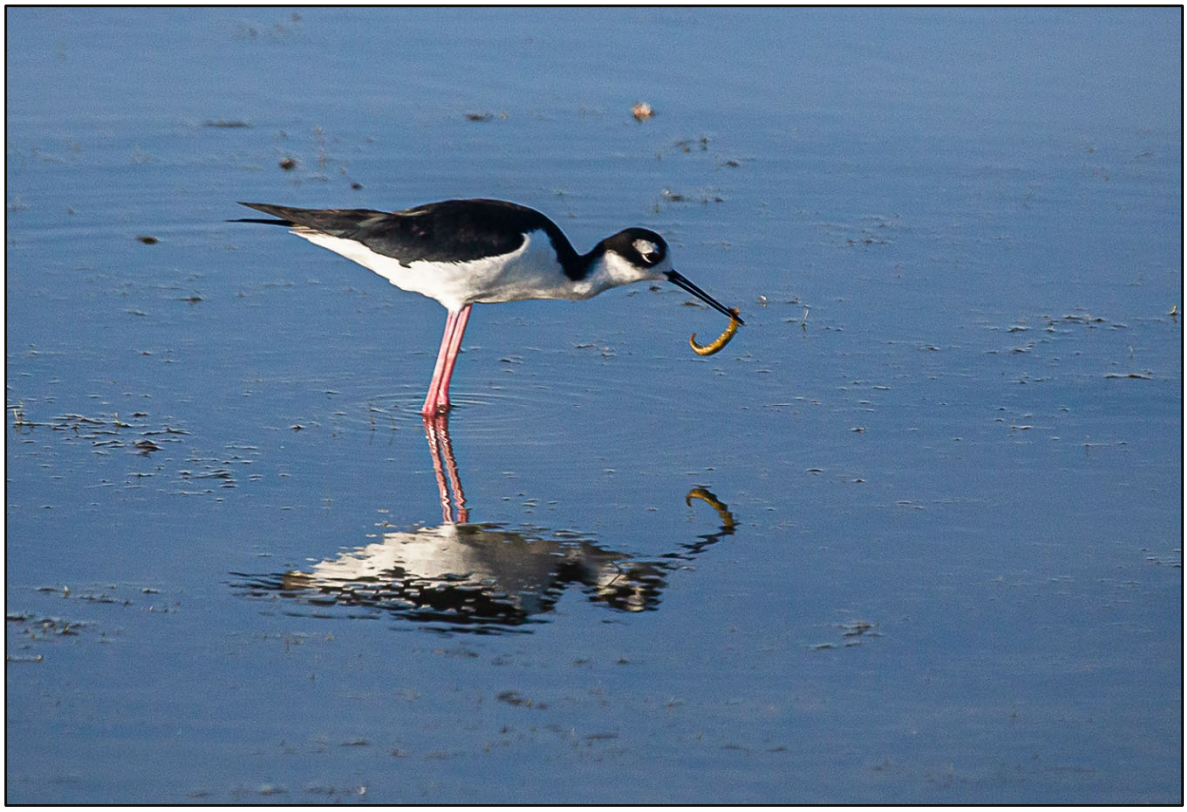
Final Report to the Utah Division of Forestry, Fire & State Lands

Impacts of Eutrophication on Benthic Invertebrates & Fish Prey of Birds in Farmington and Bear River Bays of Great Salt Lake

Trip Armstrong and Wayne A. Wurtsbaugh
Utah State University
December 2019



Black-necked stilt feeding on a chironomid larvae in Bear River Bay
Photo by Rogen Mellentin

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Executive Summary

Farmington Bay's watershed is primarily in the heavily populated metropolitan Salt Lake City, and consequently, it receives approximately 50% of its inflow from nutrient-rich wastewater releases. The high nutrient loads make it eutrophic and reducing the loading has been suggested to reduce blooms of toxic cyanobacteria. However, the bay also supports thousands of wading birds and waterfowl, and there is concern that reducing nutrient inflows might reduce the production of bottom-dwelling insects and other invertebrates that the birds rely upon.

To assess whether the high nutrient loads are necessary to support high densities of birds, we compared the invertebrate populations and fish in Farmington Bay with the invertebrates and fish in Bear River Bay, which is less polluted. We sampled five times in 2017-2018, at 9 substations in each of the bays (Figure A). These were located along freshwater—>saline gradients, and along deep (~3 ft; 1 m) to shallow (0.1 m) stations. During the study, the drought and water development caused both bays to be shallow, and intruding water from hypersaline Gilbert Bay resulted in only slight salinity gradients, although salinities reached 3.6% on two dates at the north end of Farmington Bay. A small deep brine layer with low oxygen concentrations was usually present at the northern deep station in Farmington Bay. Aquatic plants were abundant at Stations 1 and 2 in Bear River Bay, but in Farmington Bay, and Station 3 in Bear River Bay, filamentous algae were dominant, albeit in small amounts (Figure B, C).

Figure A. Sampling design for water quality and benthic invertebrates in Bear River and Farmington Bays. In each bay, three stations (1, 2, 3) were sampled along a salinity gradient. At each station, three substations (a, b, c) were sampled along the depth gradient from the deepest (a), to shallower stations (b – 0.3 m; c – 0.1 m).

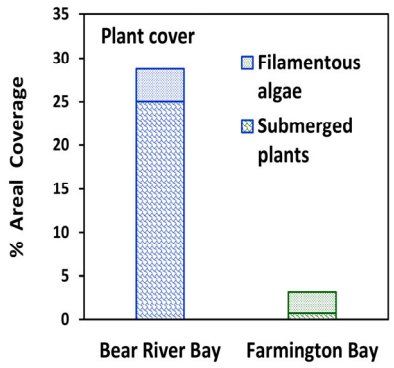

Figure B. Mean plant cover by submerged plants and filamentous algae in Bear River and Farmington Bays during the study.

Figure C. Typical summer habitat in Bear River Bay Sta. 1 and 2 (left) and Farmington Bay (right).

During the study, Farmington Bay was much more eutrophic than Bear River Bay (Figure D), with phosphorus and nitrogen concentrations 6 and 4-fold higher, respectively. Chlorophyll concentrations in the water, a measure of phytoplankton abundance, were approximately 5-fold higher in Farmington than in Bear River Bay. Benthic organic matter, a measure of food available to many bottom-dwelling invertebrates, was 1.7-fold higher in Farmington than in Bear River Bay.

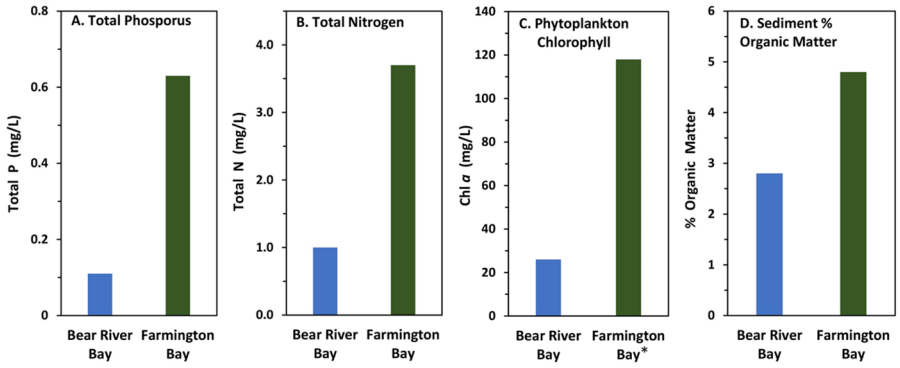

Figure D. Mean eutrophication metrics in Bear River and Farmington Bays during the 2017-18 study.

The diversity of invertebrates was higher in Bear River Bay (52 taxa) than in Farmington Bay (36 taxa). Beetles and gnats provided the greatest number of taxa (Figure E). Taxa present in Farmington Bay were generally pollution-tolerant species.

The biomass of benthic invertebrates was high in both bays (Figure F), with a mean of 3.3 g m^{-2} in Bear River Bay and 3.1 g m^{-2} in Farmington Bay, but these differences were not significant

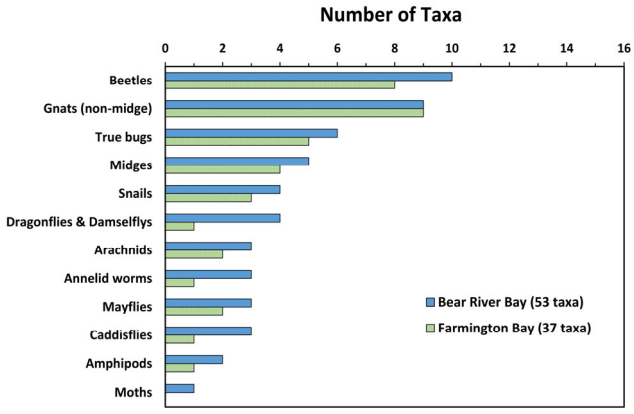

Figure E. Diversity of benthic invertebrates in Bear River and Farmington Bays.

(p = 0.50). In Bear River Bay there was no significant change along the limited salinity gradient from the inflow Station (1) to the Station nearer Gilbert Bay (Figure F) However, in Farmington Bay there was a strong gradient in abundance and biomass, with a mean biomass of 6.7 g m^{-2} near the inflow and only 0.35 g m^{-2} at the station closest to Gilbert Bay. The decreasing biomass along the south to north

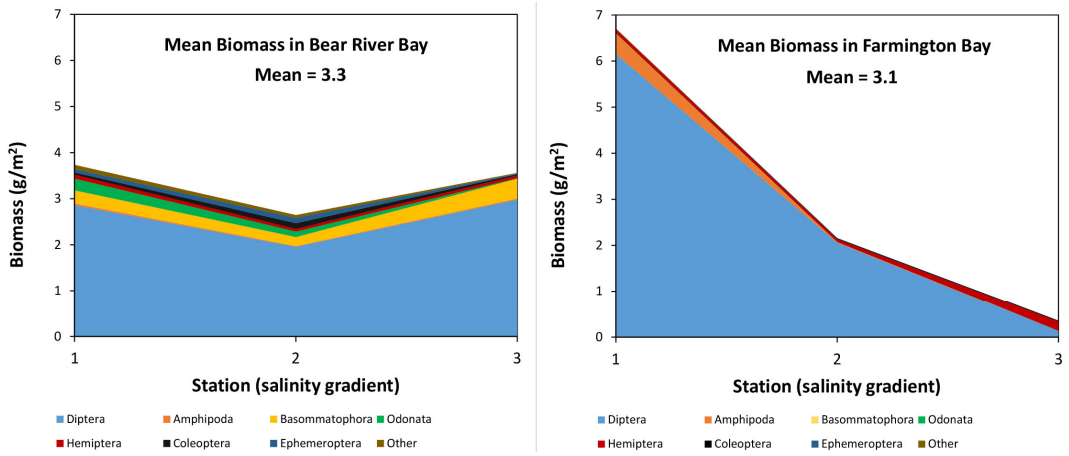

Figure F. Mean relative biomass of different taxonomic groups at each of the three stations in both bays. Values are averaged across all five sampling events.

transect was correlated with increasing salinities and/or salinity variability and decreasing phosphorous ($p < 0.00$). Benthic invertebrate biomasses in both bays was high from June-September, but low during May and October.

With one exception, there was no correlation between the different nominal sampling depths (deep, 0.3m, 0.1m) and invertebrate biomass. However, the biomass of invertebrates was very low (mean 0.14 g m^{-2}) beneath the deep brine layer at the deep substation (3A) in Farmington Bay, where only air-breathing or low-oxygen taxa were present.

The biomass of invertebrates in both bays was consistent with those in other saline lakes that have been surveyed (Figure G). Among the 120 saline lakes surveyed globally, there was no significant relationship between salinity and biomass, and some very high biomasses were recorded in Gilbert Bay and other saline lakes with salinities above 10%. Consequently, salinity, per-se, may not be the causal factor decreasing invertebrate abundances at the north end of Farmington Bay.

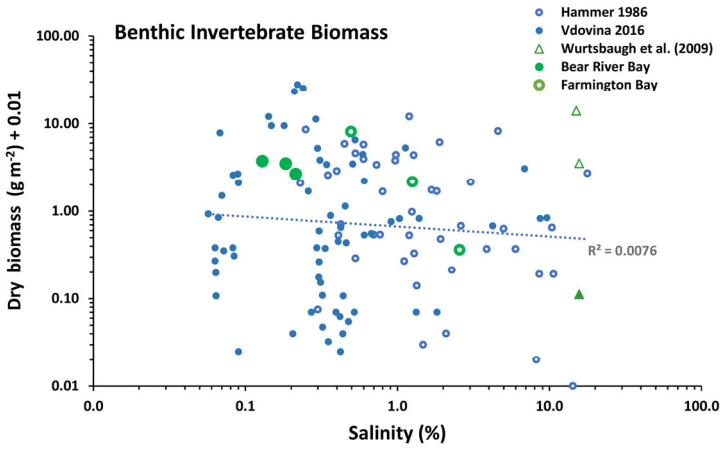

Figure G. Biomasses of benthic invertebrates in lakes world-wide. Green symbols are data from Great Salt Lake, including the present study. Note that there was no significant correlation between salinity and invertebrate biomass totals.

One possibility for the decreasing abundance there is that salinity was not stable, varying from 0.6 to 3.8% on the different dates sampled.

The invertebrate data demonstrate that very high biomasses of invertebrate prey for birds can occur in the less-polluted Bear River Bay, and this is consistent with the higher density of birds there than in Farmington Bay (Wurtsbaugh 2018). However, the strong gradient in invertebrate biomass in Farmington Bay suggests that high nutrient loading may partially support the abundances of gnats and other taxa that feed on the high concentration of organic matter in the sediments at the south end of the bay. However, overall, the eutrophication in Farmington Bay does not support higher densities of benthic invertebrates, or the birds that feed on them.

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Introduction

Because of abundant water and high nutrient levels, estuaries and wetlands are among the most productive ecozones on earth (Begon et al. 2005), and that high productivity supports dense bird populations. Bear River Bay and Farmington Bay on the eastern side of Great Salt Lake (Utah) are wetland estuaries supporting hundreds of thousands of birds (Paul and Manning 2002; Wurtsbaugh 2018; Sorenson and Hoven 2019 (in press)). Nutrient loading to both bays was likely naturally high because of inputs from the Bear River into its' namesake bay, and the Jordan River and creeks flowing into Farmington Bay. However, secondary-treated wastewater discharging directly into Farmington Bay boosts phosphorus loading to approximately 2.5 g m^{-2} yr^{-1} with much of it coming from wastewater discharges from greater metropolitan Salt Lake City (Wurtsbaugh et al. 2012).

As a consequence of this extremely high nutrient loading, Farmington Bay is hypereutrophic with reported mean chlorophyll concentrations ranging from 115 to 141 µg L^{-1} (Wurtsbaugh et al. 2012; Marden et al. 2015). In contrast, Bear River Bay is less eutrophic with most of its water coming from the Bear River, with better water quality (Wurtsbaugh et al. 2012; Ch2m Hill 2015).

Recommendations to reduce nutrient loading to Farmington Bay have met with concerns that load reduction might decrease the production of benthic invertebrates (insect larvae, etc.) that are an important source of food for the bird community. In order to test whether lowered nutrient loading compromises the production of invertebrates, we conducted a study in 2017-2018 to compare the benthic invertebrate communities in the two bays. A secondary objective was to determine if the anoxic, hydrogen-sulfide rich deep brine layer in Farmington Bay eliminates benthic invertebrates. If so, this would provide insights on how the larger deep brine layer in Gilbert Bay influences the invertebrate community of Great Salt Lake.

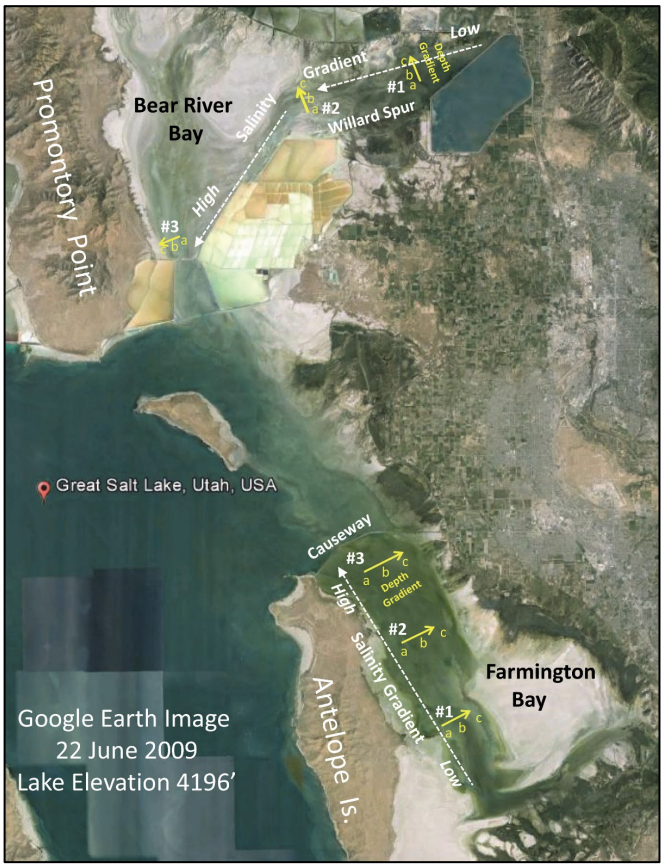

Figure 1. Sampling design for water quality and benthic invertebrates in Bear River and Farmington Bays. In each bay, three stations (1, 2, 3) were sampled along a salinity gradient. At each station, three substations (a, b, c) were sampled along the depth gradient from the deepest (a), to shallower stations (b – 0.3 m; c – 0.1 m).

Study sites—When the lake is at an elevation of 1280 m (4200 ft.) Bear River Bay covers 212 km^2 and Farmington Bay covers 312 km^2 (Johnson et al. In Press). However, during our study both bays were considerably reduced in size due to drought and water withdrawals from the tributaries (Wurtsbaugh et

al. 2017). Bear River Bay has two sections: the eastern Willard Spur bounded on the north by the Bear River Migratory Bird Refuge, and the remainder of the bay that extends northward along Promontory Point on the west, and the Refuge on the east. Both bays are very shallow: at a lake elevation of 1280 m, the mean depth in Bear River Bay is only 0.6 m and Farmington Bay is only 1.1 m.

In recent years, Willard Spur has been entirely freshwater (Ch2m Hill 2015). Saltwater from Gilbert Bay can enter into Bear River Bay (Foote 1991), but during our study, this exchange was limited. There is appreciable bi-directional flow exchange between Farmington Bay and Gilbert Bay, and consequently, the salinity in the northern end of this bay is highest near the bridge on the causeway to Antelope Island. Salinities as high as 9% have been recorded in the surface waters at the north end of Farmington Bay (Wurtsbaugh et al. 2012). The denser high-salinity water from Gilbert Bay underflows the fresher water of Farmington Bay, forming a monimolimnion. This is referred to locally as a "deep brine layer". At higher water levels the deep brine layer can cover approximately 50% of the bottom of Farmington Bay (Wurtsbaugh et al. 2012). The high-density water in the deep brine layer only mixes with the surface water during high-wind events. The decomposition of organic matter in the deep, dense layer depletes oxygen, and the resulting redox conditions produce toxic hydrogen sulfide that causes odor problems ("Lake stink") in metropolitan Salt Lake City when winds mix the bottom waters to the surface (Wurtsbaugh and Marcarelli 2004; Wurtsbaugh et al. 2012).

Previous studies on the ecology of Bear River Bay have been associated primarily with the bird communities of the Bear River Migratory Bird Refuge (e.g. Kadlec and Smith 1984; Huener and Kadlec 1992; Barras and Kadlec 2000). Recent work focused on the impacts of a small wastewater treatment plant discharge into the bay (Cavitt 2006; Hoven and Miller 2009; Ch2m Hill 2015). Gwynn (2002) reported on the morphometry and water quality in Farmington Bay.

Both bays have the same Beneficial Use classification (Class 5, Great Salt Lake) by the State of Utah -- *Protected for infrequent primary and secondary contact recreation, waterfowl, shore birds and other water-oriented wildlife including their necessary food chain (EPA 2014).*

Figure 2. American Avocet feeding in shallow water of Bear River Bay (Sta. 3c).

Sampling Design & Methods—We established three transects along the salinity gradients in each bay (Figure 1; Appendix 1). In Bear River Bay, we originally anticipated two sampling transects in the main bay and one in Willard Spur, but because of the low water level at the start of the study in July 2017 we located two transects in Willard Spur and one in the larger part of the bay. On each transect, there were three substations along a depth gradient (a, b, c: 0.8-1.2 m, 0.3 m and 0.1 m) perpendicular to the longitudinal gradient. The actual depths of stations sampled on each date is shown in Appendix 2. The deep station at the north end of Farmington Bay included the deep brine layer (if one was present), and the shallow, 0.1-m stations, were areas where wading birds such as American Avocets (*Recurvirostra americana*) forage (Figure 2).

The temporal sampling design included two field collections in July and October of 2017, and three sampling efforts in May, June and September 2018. Dates are given in Appendix 3.

Multiple parameters were measured along each transect:

- Eutrophication metrics: Secchi depth; total N and P concentrations; chlorophyll *a* of phytoplankton.
- Organic matter content of the sediments, measured as ash-free dry mass (AFDM) of sediments, was used as an indicator of food available for many of the benthic invertebrates. Two replicate samples were taken from the top 1-cm at each substation.
- Temperature, oxygen and conductivity profiles were measured with a probe at the deepest station, and mid-water measurements at the 0.2-m and 0.1-m substations
- In each bay three recording sondes were deployed approximately one week prior to invertebrate sampling at intermediate depth substations (b) along the depth transect. These recorded salinity, temperature and oxygen at 30-minute intervals. One sonde in each bay was equipped with a pH sensor. Our initial hypothesis was that salinity and oxygen concentrations will be two of the two dominant factors influencing the abundances of different taxa.
- At each substation the relative percent cover of submerged aquatic vegetation was estimated visually, and samples were taken back to the laboratory for taxonomic identification.
- Benthic invertebrate samples were taken using a Ponar dredge dropped directly over our airboat's gunwales. These were taken to provide quantitative estimates of taxonomic composition and biomass of benthic invertebrates. The Ponar had a 1-mm meshed sieve at the top, so it also sampled some zooplankton as it descended. We initiated the study in July with a lightweight Eckman dredge but switched to the heavier Ponar so that it could penetrate the submerged aquatic vegetation in Willard Spur. At each substation two Ponar samples were taken from opposite sides of the boat and pooled. The airboat was then moved 100 m and the Ponar sampling was repeated for a replicate sample. Consequently, this design resulted in 18 invertebrate samples in each bay on each date. The invertebrate samples were preserved in 70% ethanol.

In the laboratory, the invertebrates were counted and classified to species or genus-level in order to allow accurate estimates of pollution-tolerance metrics. Lengths of 25 (if present) individuals in each taxa were measured with a micrometer at time of identification. Lengths were converted to biomass of each taxon using standard length-weight regressions (Benke et al. 1999). Taxonomic richness was calculated using the raw taxonomic identifications.

- Fish sampling. Fish were sampled only on one date to provide at least some data on their presence or absence in the two bays. We conducted the fish surveys in June 2018 using multi-mesh gill nets at the deepest section of each of the stations in both bays (we were unable to place nets in station #3 in Bear River bay as the water was only 0.2-m deep at the time of sampling).

More detailed methods are given in Appendix 4.

Results

Water depth and hydrology—The benthic invertebrate surveys were done when Gilbert Bay was near its record low, with elevations varying from 4194.6 feet in July 2017 to 4192.8 feet in Sept. 2018 (Figure 3a, b). Consequently, Bear River Bay and particularly Farmington Bay were very shallow. The deepest station (#1a) in Bear River Bay varied from 0.60 m in July 2017 to 0.36 m in Sept. 2018. In Farmington Bay the deepest station (#3a) varied from 1.1 m to 0.5 m over this period. By the end of the study, the shallow station (3) in Bear River Bay could not be reached by airboat and a few weeks later it was completely dry (Figure 29 – in Discussion).

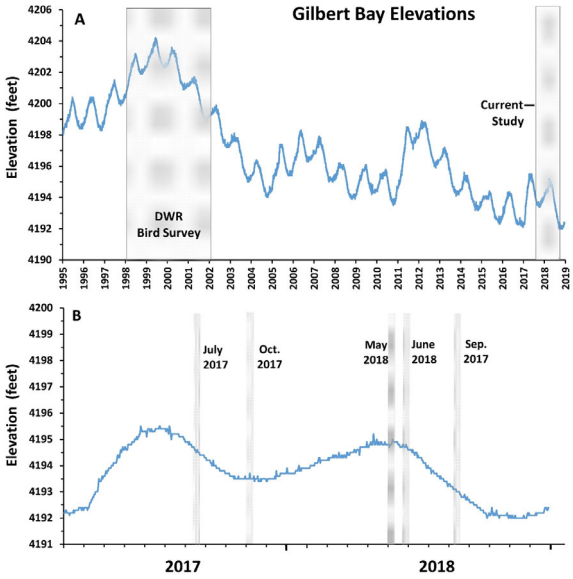

Figure 3. Elevations of Great Salt Lake (Gilbert Bay) during the study. A. 1995-2019 elevation record, showing the period of the Division of Wildlife Resources Great Salt Lake Bird Study (Paul and Manning 2002) and the current invertebrate study. B. Details of lake elevation during the five invertebrate sampling events. By the end of the invertebrate study the lake was near its record low elevation. Elevation data from USGS Saltair gaging station.

At the shallow stations in Farmington Bay (1, 2) a northerly current was noted on some dates. In September, a water velocity of 0.17 m/sec was measured at Station 2a where the depth was 0.2m.

Vegetation cover—There were large differences in the amount and types of periphyton and macrophytes in the two bays (Figure 4). In Bear River Bay macrophytes were just beginning to emerge in May; the percent of the substrate covered by them varied from only 0-26% at the different stations (Figure 5a). By June and July macrophyte and filamentous algae covered 50-90% of the substrate in Willard Spur (Sta. 1 & 2), but only reached 37% at Sta. 3, the shallow and more saline site close to the connection with Gilbert Bay. Dominant species in Willard Spur were shortspike watermilfoil (*Myriophyllum sibiricum*) and sago pondweed (*Stuckenia pectinate*). Macrophyte cover declined markedly in September and was near zero by October at all sites in Bear River Bay.

In Farmington Bay, vegetation cover was much lower (Figure 5b), with a mean of only 6% at Station 1 closest to the inflow from the Jordan River and wastewater discharges. There were very few macrophytes and vegetation cover was primarily by the filamentous algae, *Cladophora* (Figure 4b).

Figure 4. Left: Sonde deployment at Station 2b on 6 July 2017 in thick macrophyte beds. Note the thick stands of aquatic macrophytes. Right: Taking a core sample for organic matter measurement at Station 2b (0.2 m depth) on 12 July 2017. Note the submerged and floating filamentous algae. Photo by Suzan Tahir.

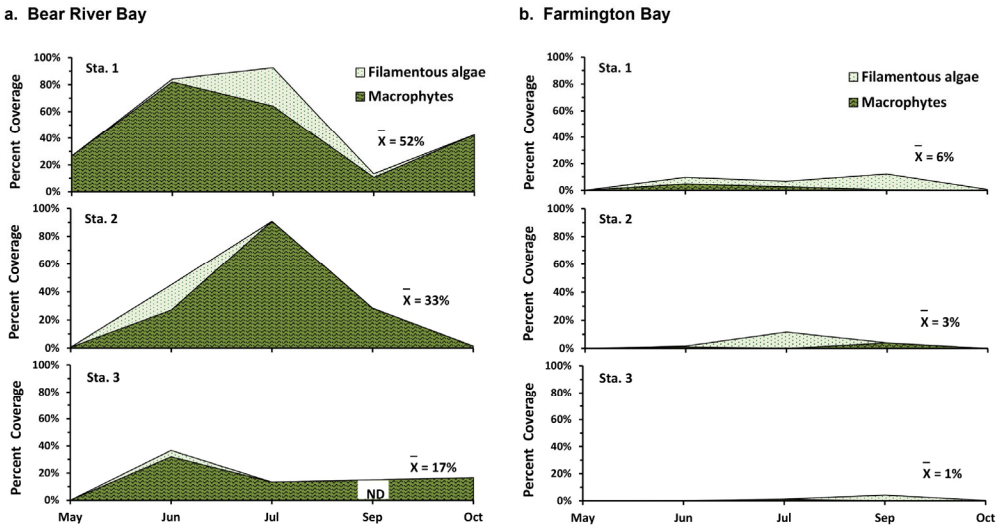

Figure 5. Percent of the substrate covered by macrophytes or filamentous algae in Bear River Bay (a), or Farmington Bay (b) during the five sampling events. Data from the three depth substations were pooled for this presentation.

***Water Quality*—**Salinities in the bottom waters of the two bays increased from the inflow areas to their connections with Gilbert Bay (Figure 6). Salinities at all stations in Bear River Bay were usually less than 0.2%, with a maximum of 0.5%. Salinities in the bottom waters of Farmington Bay were greater than in Bear River Bay, particularly at Station 3 near the north end of the bay where salinities reached 3.6% in May and July. Surprisingly, salinities were lowest in the fall in Farmington Bay. This was likely due to the northernly flow of water in the bay and low elevations in Gilbert Bay that minimized the intrusion of the hypersaline water. When the bay was somewhat deeper in the spring, it is likely that the bi-directional flow at the Antelope Island Causeway bridge increased, allowing the hypersaline water from Gilbert Bay to intrude, and mix with the fresher water of the bay.

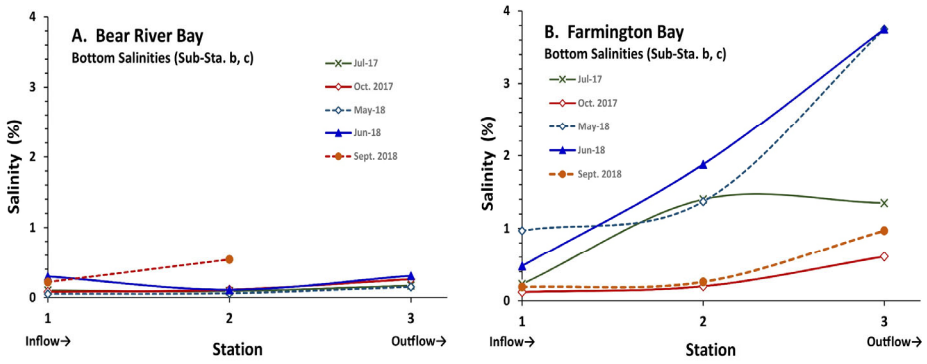

Figure 6. Bottom-water salinities along the estuarine salinity gradients at the shallow substations (b, c) in the two bays during the 2-year study. Station 1 was closest to the inflow river, and Station 3 was closest to the connection with hypersaline Gilbert Bay (salinity ca. 15%). A. Bear River Bay; B. Farmington Bay. Note the generally higher salinities in Farmington Bay, and the gradients in salinity from the inflows to the outflows of both bays.

A deep brine layer was usually present at the northern end of Farmington Bay (Sta. 3a), but when the bay's depth decreased to 0.5 m, it disappeared (Figure 7). Bottom water salinities in the deep brine layer were 5-7% (Figure 7a) and the layer was hypoxic (Figure 7b). The higher salinities and low oxygen levels at this station had large effects on the benthic invertebrate community (see below).

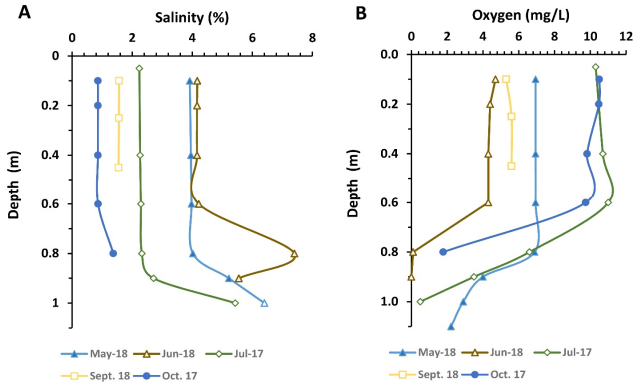

Figure 7. Vertical profiles of salinity (a) and oxygen concentrations (b) in Farmington Bay at Station 3, the deepest station and the one closest to Gilbert Bay. Note the deep brine layer starting at 0.7- 0.8 m, and the hypoxia near the bottom. The magnitude of the deep brine layer was diminished as the bay became shallower, and absent in September 2018 when the depth had decreased to <0.5 m.

At the 0.3-m deep stations where sondes were deployed, there were large diel swings in oxygen and temperature (Figure 8a, b). Diel changes are shown for the July 2017 period. In the two stations in Willard Spur where aquatic vegetation was abundant, oxygen levels declined to zero or close to zero each night, and

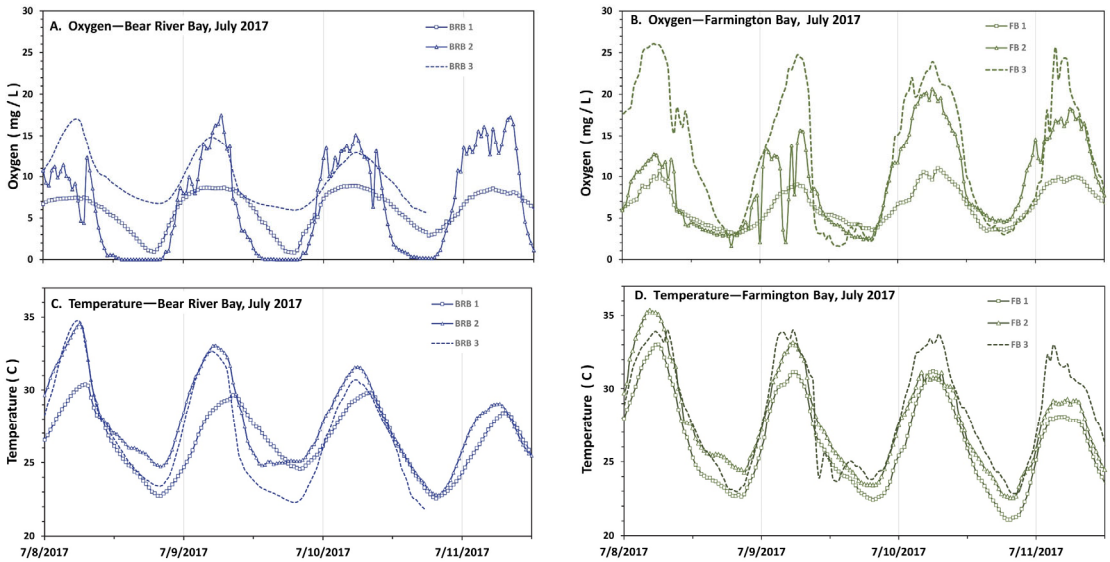

Figure 8. Diel variations in oxygen and temperature measured with sondes recording at 30-minute intervals during July 2017. Above: Diel variation in oxygen concentration in Bear River (A) and Farmington (B) Bays at Stations 1b – 3b. Below: Temperature variations at the same stations.

then increased greatly during the day due to photosynthesis. At Station 3 in Bear River Bay where submerged vegetation was absent, there were large diel fluctuations, but oxygen levels remained above 6 mg/L during the night. In Farmington Bay, where submerged aquatic vegetation was largely absent, oxygen concentrations declined to about 1.5 mg/L at night and increased considerably during the day. The diel swings were extreme at Station 3b near the north end of Farmington Bay and near the outfall of the North Davis Sewer Improvement District (note that during our study there was no surface water flow from this treatment plant). Oxygen concentrations there reached over 25 mg/L during late afternoon, and then declined to about 1.6 mg/L when respiration in the water column and sediment utilized the accumulated oxygen.

In July, temperatures fluctuated as much as 10°C each day, reaching over 32°C in both bays during the sonde deployments (Figure 8c, d). Temperatures at Stations 2 and 3 in both bays were warmer than the station near the inflow (Sta. 1).

Figure 9 summarizes all the sonde data from the three stations in each bay. Mean temperatures and day-to-night ranges over the 4 to 6-day intervals varied little between stations or bays but there were large seasonal and diel changes (Figure 9a). Mean temperatures varied from near 15°C in May and October but were near 27°C in July. However, the range of temperatures at a site ranged by 10-20°C on most dates. High temperatures were usually above 30°C from June-September and reached over 34°C at several substations. Afternoon temperatures measured with a hand probe (YSI) were 2-4°C warmer at the shallowest substations (c) than at the substations where sondes were deployed (b), indicating

that critical temperatures for invertebrates may be exceeded at times in the very shallow fringes of the bays.

The compiled sonde data showed that ranges in oxygen concentrations were all high (Figure 9b). Minimum oxygen concentrations frequently were below 1 mg/L, particularly in the Willard Spur section of Bear River Bay (Sta. 1, 2). The upper range in oxygen concentrations were higher in Farmington Bay, resulting in mean concentrations that were generally higher as well.

Mean pH values were generally between 8.5 and 9.0 in both bays (Figure 9c). However, pH values ranged from a low of 7.6 in Bear River Bay (May) to 10.0 in Farmington Bay (June). The amount of pH data was limited, however, because only 1 sonde in each bay was equipped with these sensors, and sondes failed on some dates.

Nutrient levels were significantly higher in Farmington Bay than in Bear River Bay (Figure 10; $p < 0.001$), likely because of the significant wastewater discharges into the former. Averaged over the entire bays and both seasons, total nitrogen levels were about 3.7-fold greater, and total phosphorus was nearly 6-fold greater in Farmington than in Bear River Bay. In Farmington Bay there was a significant increase in nitrogen from the station closest to the inflow (#1) to near the north end of the bay (#3), perhaps due to nitrogen fixation along the gradient. In contrast, total phosphorus decreased along the gradient (Fig. 10b; $p = 0.079$), perhaps due to uptake by periphyton. In contrast to Farmington Bay, neither TN nor TP in Bear River Bay had a strong gradient along the flow path.

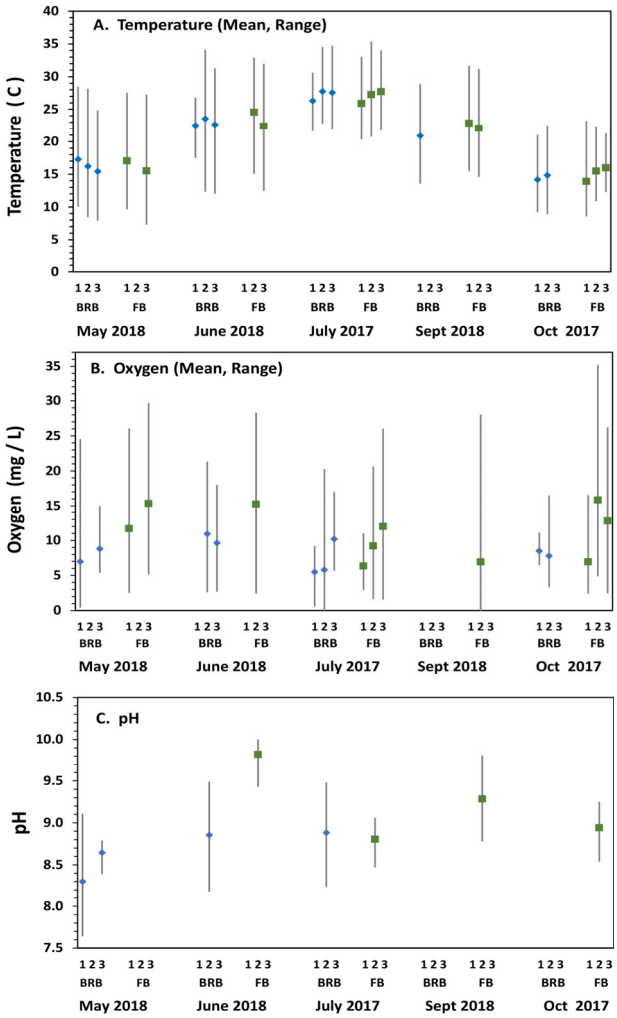

Figure 9. Mean and ranges of temperature (A), oxygen (B) and pH (C) recorded with sondes deployed at 0.2 – 0.3 m along the transects. For example, the numeral 1 indicates data from sondes at Station 1b in either Bear River Bay (BRB; blue diamonds) or Farmington Bay (FB; green squares). The sondes recorded data for 5-6 days prior to benthic invertebrate sampling during each of the five months of 2017-2018. The figure summarizes 7207 records for these parameters, logged at 30-minute intervals. Sonde failure, or calibration issues, resulted in missing data for some stations and intervals.

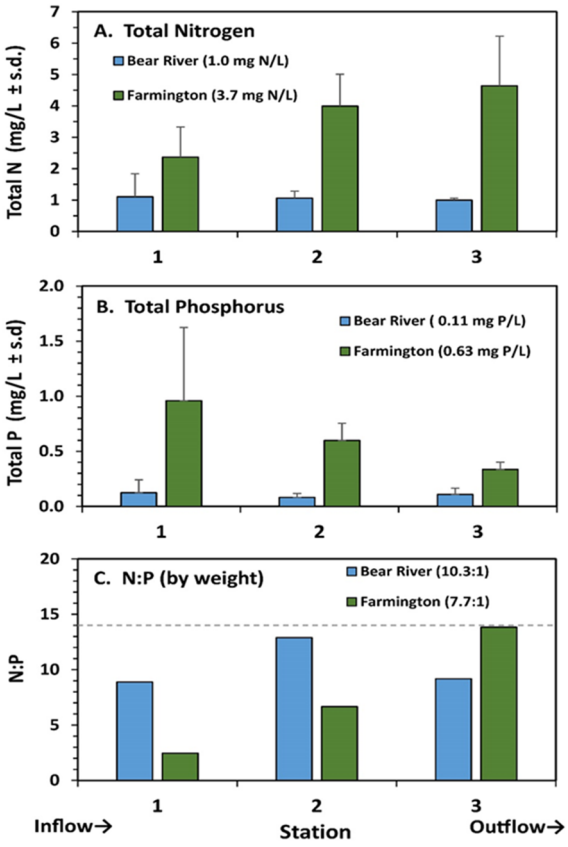

Figure 10. Mean nitrogen (A) and phosphorus (B) concentrations, as well as N:P ratios (C) measured on five dates at the deepest substations (a) along the inflow (Sta. 1) to outflow (Sta. 3) gradient in Bear River and Farmington Bays. Total N and Total P were significantly higher in Farmington Bay ($p < .0001$; 2-way ANOVA). There was a significant increase in TN along the inflow to outflow gradients ($p < 0.033$), but a significant interaction term between Bay and Stations ($p < 0.020$), indicated this increase only occurred in Farmington Bay. There was no statistically significant change in TP along the inflow to outflow gradient ($p = 0.079$), but there was a suggestion of decreasing TP along the gradient in Farmington Bay. The dotted line in C shows the ratio (14:1) below which N is likely the limiting nutrient for algal growth (Downing and McCauley 1992).

Ratios of N:P (Figure 10c) indicated that phytoplankton in both bays were likely limited by nitrogen. This was particularly true at the south end of Farmington Bay (Sta. 1) closest to the wastewater discharge from Central Davis Sewer District. However, in Farmington Bay the increasing N concentrations and the decreasing P concentrations along the gradient resulted in an N:P ratio of 14:1 at the north end of the bay (Sta. 3), indicating nearly balanced nutrient levels for algal growth.

Sediments in Farmington Bay had, on average, 70% higher concentration of organic matter than sediments in Bear River Bay (4.8% vs. 2.8%; Figure 11,

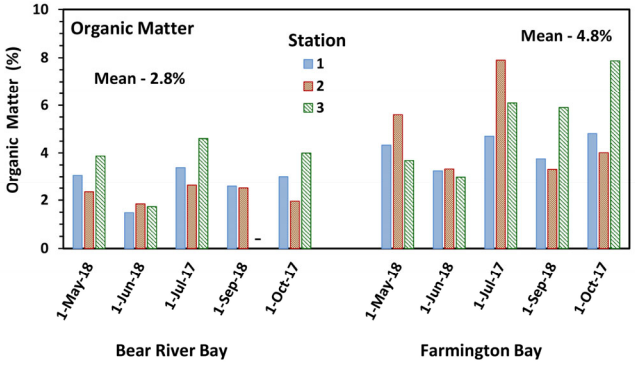

Figure 11. Mean percent organic matter (ash-free dry mass) of the three substations along the inflow (Sta. 1) to outflow (Sta. 3) stations in Bear River and Farmington Bay. Station 3 in Bear River Bay was inaccessible in Sept. 2018. Organic matter content was significantly higher in Farmington Bay than in Bear River Bay (2-way ANOVA, $p < 0.000$). Measured organic content may have been significantly lower in June 2017 than in other months, but this may have been due to an analytical error. Within bays, only Sta. 3 in Bear River Bay was significantly higher than the other stations (2-way ANOVA, $p < 0.035$).

Appendix 5). Within bays, only Sta. 3 in Bear River Bay was significantly higher than the other stations ($p < 0.035$).

Secchi depths in Farmington Bay averaged 0.32 m with a range of 0.22 - 0.70 m (Appendix 6). Most of the measurements there were at the deep station (#3a) at the north end of the bay where the water was sufficiently deep for measurements. Low Secchi depths of 0.17-0.28 were measured during spring runoff (May 2018) in Bear River Bay, but on other dates the Secchi disk was always visible on the bottom, and consequently, a measurement could not be made.

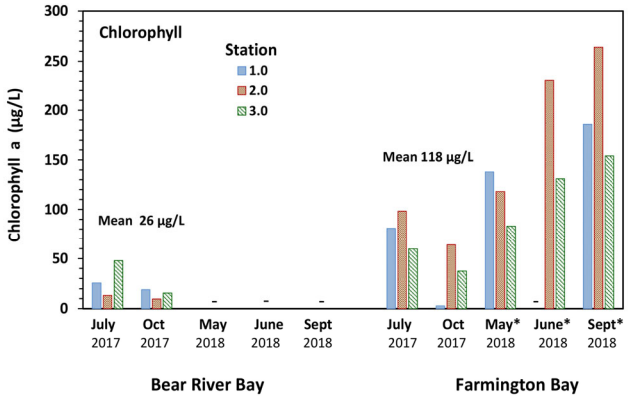

Figure 12. Chlorophyll *a* concentrations at the deep substation (a) along the three transact stations (1-near inflow; 2-near outflow of the bays). Values for Farmington Bay in 2018 were estimated using the correlation between Secchi depths and chlorophyll concentrations (Carlson 1977).

Mean chlorophyll levels in the phytoplankton were high in both bays, but concentrations were much higher in Farmington Bay (~118 µg/L) than in Bear River Bay (27 µg/L) (Figure 12; Appendix 7). Chlorophyll concentrations measured in 2018 were anomalously high in both bays, likely the result of periphyton mixed into the water column by the airboat. Consequently, we believe the measurements in July and October 2017 are more representative of trophic conditions in the bay. In those months, mean phytoplankton chlorophyll in Farmington Bay (45 µg/L) was nearly double that of Bear River Bay (26 µg/L). Using a correlation between Secchi depth measurements and chlorophyll (Carlson 1977) we estimated mean chlorophyll concentrations of 129 µg/L (range 34-181) in Farmington Bay during the five seasonal measurements, higher than the mean 2017.

***Benthic invertebrates*—**Our study identified a total of 57 unique taxa from the two bays in this study; 21 of these taxa were found only in Bear River Bay, 5 were only found in Farmington Bay, and 32 taxa were found to be present in both bays (Figure 13; Appendices 8, 9). In addition to these differences, our study also identified similarities (biomass), and differences (abundance, richness, tolerant individual abundance) between the benthic communities in each of the bays.

Benthic macroinvertebrate biomass was slightly higher overall in Bear River Bay (mean = 3.3 g/m^2) than in Farmington Bay (mean = 3.1 g/m^2; Figure 13; Appendix 10). We designed this study in order to identify potential differences not only between the two bays, but also to determine if benthic invertebrate biomass changes within each bay along either saline or depth gradients. Although biomass at each sampling location varied during the 5 sampling events, biomass between stations in Bear River Bay tended to be somewhat consistent. Benthic invertebrate biomass in Bear River Bay remained similar between the three different depth locations within each station ($p=0.59$), and also remained similar as salinity varied from Station 1 to 3 ($p=0.27$). In Farmington Bay, however, biomass decreased significantly ($p=0.008$) at stations further north. The southern-most station in Farmington Bay had the highest instantaneous biomass (26.5 g/m^2) in the month of June. In contrast, the highest biomass value

obtained in Bear River Bay was 18.9 g/m^2 at station 1 in June. In some cases (e.g. July 2017), there were very few invertebrates present at Station 3 in Farmington Bay. In part, this was due to the presence of a deep brine layer (monimolimnion) at station 3a, where biomass was low (see below) and the community was dominated by midges.

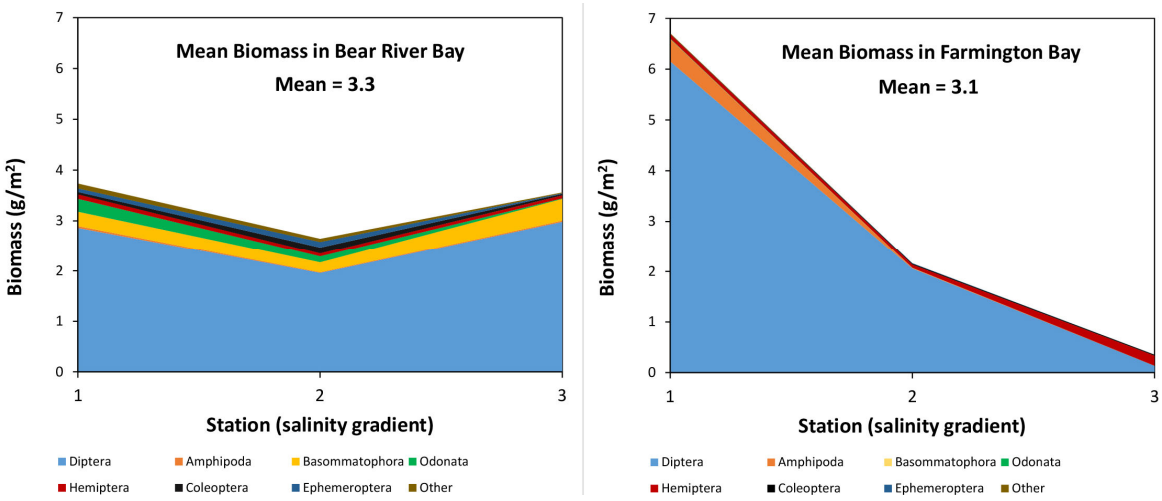

Figure 13. Mean relative biomass of different taxonomic groups at each of the three stations in both bays. Values are averaged across all five sampling events.

Although some samples from Bear River Bay were dominated (in biomass) by beetles, and some samples in Farmington Bay were dominated by amphipods, dipterans (mostly chironomidae - midges, gnats) comprised the majority (70%) of invertebrate biomass collected in both bays during the sampling periods (Figure 13). Stations in both bays tended to be dominated by collector-gatherers (midges, gastropods, oligochaetes, and certain mayflies), and predator groups (predatory midges, mites, biting flies, beetles, corixids, and dragonflies). These communities remained generally stable during the study, although there was some relative change along the salinity gradient in each bay. Dipterans (mostly midges), were the dominant contributor to biomass in all stations in both bays.

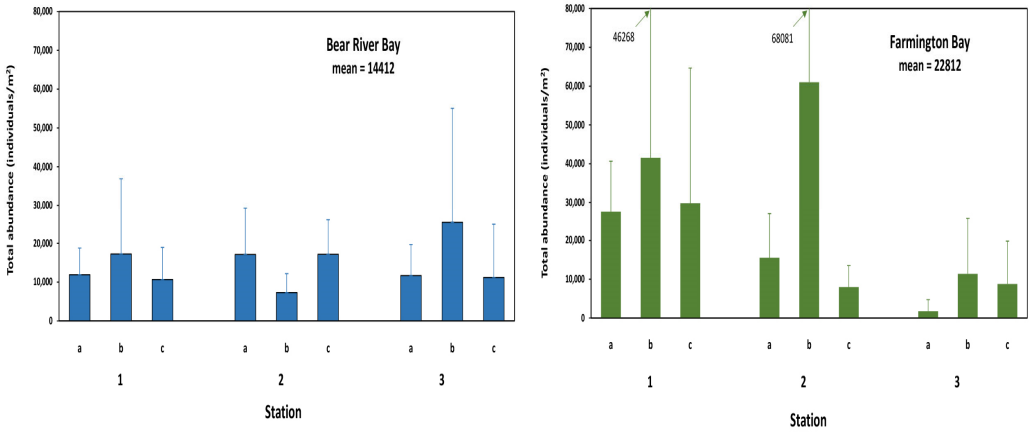

Figure 14. Mean invertebrate abundance (individuals/m^2) at each sampling location during the 5 sampling events. Stations ranged from lower to higher salinity (1 – 3); substations range from deeper to shallower (a – c).

In contrast to the similar mean biomass values found in both bays, the mean number of organisms found was higher in Farmington Bay than in Bear River Bay (Figure 14). Total abundance in Farmington Bay was 1.6x higher than in Bear River Bay over the sampling period (BRB mean = 14,400 ind./m^2, FB mean = 22,800 ind./m^2). The size frequency data (Figure 15) indicate that individuals >10mm comprised a larger proportion of the benthic community in Bear River Bay than in Farmington Bay, partially explaining the discrepancy between biomasses and densities in the two bays.

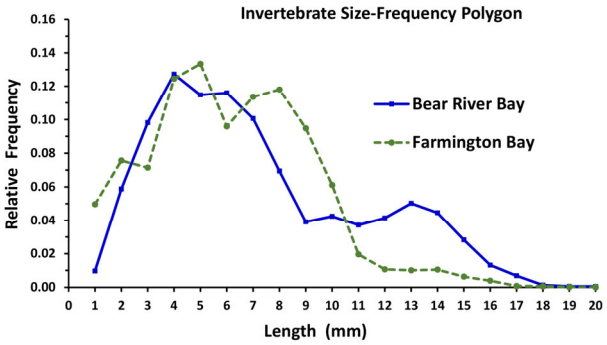

Figure 15. Size frequency plot showing organisms ranging from 1-20mm in length. Note that there were a few invertebrates measured with greater lengths that are not included in this plot. A two-sample Kolmogorov-Smirnov test indicates that the two sets of frequencies come from the same distribution (D = 0.19048, p = 0.8407).

Richness (absolute number of unique taxa identified in a sample) is another metric in which the two studied bays differed from each other. Bear River Bay samples had about 1.5x higher richness than Farmington Bay samples during the sampling period (Figure 16, 17). Evenness was slightly higher in Bear River Bay (0.59) than in Farmington Bay (0.46), which further supports the idea that the benthic community in Bear River bay is somewhat less dominated by a small number of taxonomic groups (e.g. Chironomids). That taxa are more evenly distributed in Bear River Bay than in Farmington Bay is further supported by the

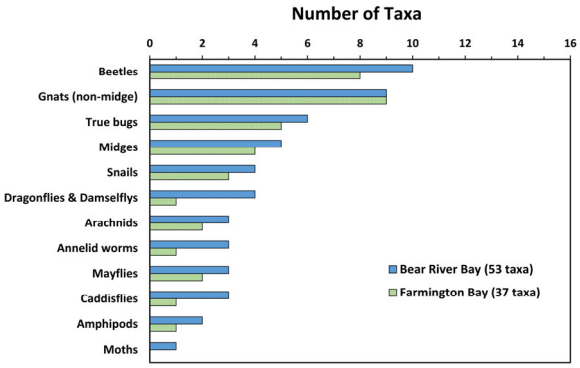

Figure 16. Major benthic invertebrate taxa found in Bear River and Farmington Bays.

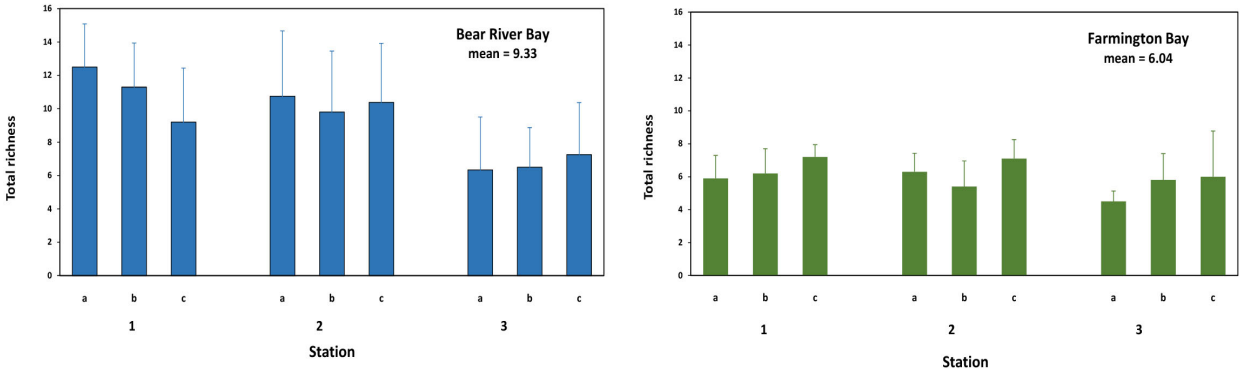

Figure 17. Benthic invertebrate richness in both bays. Richness is the total number of unique taxa identified at each location. Values represent means across all 5 sampling months.

larger diversity (i.e. number of unique taxa) identified in the Bear River bay samples (52 versus 36). A complete list of taxa encountered in both bays is provided in Appendix 9.

In general, Farmington Bay invertebrate communities show higher pollution tolerances. Intolerant benthic invertebrate taxa are those taxa that have relatively limited physiological ability to withstand thermal and chemical changes in the environment. Intolerant taxa are more easily extirpated when physical or chemical conditions go beyond the range of natural variability. Tolerant taxa are those taxa that possess a greater ability to thrive in altered physical or chemical conditions. The Farmington Bay benthic samples contained, on average, 5.25 times as many pollution-tolerant individuals as did the Bear River Bay samples.

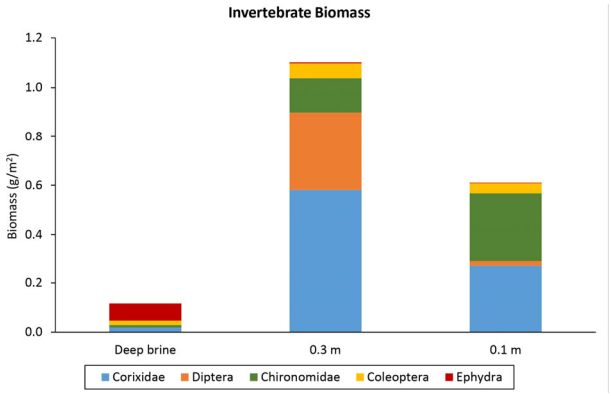

Figure 18. Mean biomasses along the transect at Station 3 in Farmington Bay (northernmost) during the months in which a deep brine layer was present (May, June, July, October).

Abundances and biomasses of benthic invertebrates in the deep brine layer (Substation 3a) at the north end of Farmington Bay were very low (Figure 18). The taxa present there were primarily air-breathing Corixids, Chironomus spp. (taxa with hemoglobin capable of extracting low-level oxygen), and salt-tolerant brine fly larvae (*Ephydra* spp.).

Seasonal changes in biomass were observed within both bays as well (Figure 19). Farmington and Bear River Bay biomass values peaked during June and were lowest in October. Farmington Bay invertebrate biomass declined dramatically from June to July, rising slightly in September before declining in October. In contrast, after experiencing peak biomass in June, Bear River Bay invertebrate biomass slowly declined until October.

To determine the important factors driving the benthic community differences between the two bays, we started with generalized linear mixed-effects models using combinations of several independent variables we measured, and biomass as the dependent variable. We built models using month and location as the random effects, and combinations of salinity, depth, total nitrogen, total phosphorous, filamentous algae cover,

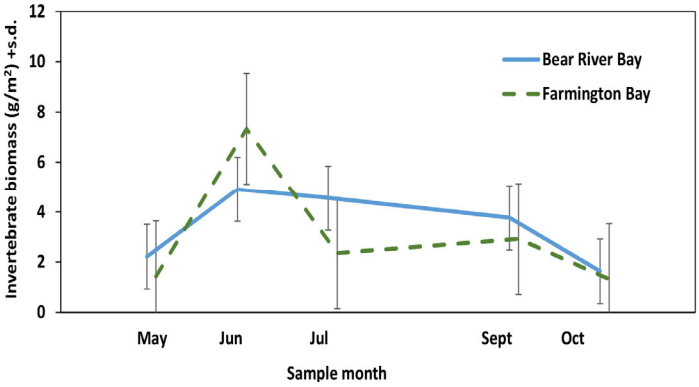

Figure 19. Benthic invertebrate biomass in each bay during the duration of the sampling period. Values are means across stations and substations.

macrophyte cover, and ash-free dry mass as the fixed effects. Variables were log transformed as necessary in order to meet the assumptions of normality of variance. To determine the most parsimonious model, we iteratively ran the model removing one effect at a time, and then compared each reduced model result to the full model result using ANOVA. The mixed effects model did not identify bay or month as important to explaining biomass during this study. Finally, we ran a linear regression using the same fixed-effects predictors found in the mixed effects models.

	Coef	SE	t	P
(Intercept)	1.95	0.84	2.31	0.02
log(TP)	1.07	0.24	4.55	0.00
log(TN)	-0.57	0.38	-1.51	0.14
log(Salinity + 0.1)	-0.73	0.23	-3.18	0.00
log(AFDM)	-0.48	0.37	-1.29	0.20
log(Depth)	-0.1	0.22	-0.44	0.66
log(Filem + 0.1)	-0.05	0.09	-0.57	0.57
log(MacroP + 0.1)	0.08	0.06	1.25	0.22

Table 1. Multiple regression results. Observations = 84, Dependent variable = Biomass, Adjusted R squared = 0.35. TP = total phosphorus; TN = total nitrogen; AFDM = % organic matter; Filem = % filamentous algal cover; MacroP = % macrophyte cover.

Table 1 shows that most variables did not correlate with benthic invertebrate biomass. Season, depth, filamentous algae cover, macrophyte cover, total nitrogen, and ash free dry mass had little impact on benthic invertebrate biomass. Only salinity and total phosphorous accounted for much of the variability in biomass, yet these two variables together only accounted for about one third of the variability in biomass (Adjusted R-square = 0.35). Although variability was high, the data suggest that biomass decreased by a factor of 0.48 with each 1% increase in salinity, and each 1 mg phosphorous per liter increase caused a doubling in benthic invertebrate biomass. These results support the idea that water chemistry differences between the two bays is a significant factor that drives benthic community dynamics, even to a greater degree than does fluctuating lake depths and seasonal changes throughout the year.

Figure 20. Above— Retrieving a gill net in Bear River Bay, 20 June 2018. Below —Weighing a carp captured in the gill net. Note extensive macrophyte cover in the bay (Stations 1 and 2).

Fish abundance—Our limited fish surveys provided some information on the presence of different species in each bay (Figure 20). To our knowledge, fish abundance had never been measured in Farmington Bay. Our ten overnight net sets captured a total of 107 fish, represented by three different species (Utah chub, n=80; Common carp, n=25; Green sunfish, n=2). Most fish were

captured in Farmington Bay at station #1 (n=74), and 72 of these were Utah chub (the other two fish from Farmington Bay were common carp).

No fish were captured in the more northerly (and more saline) stations in Farmington Bay (Figure 21). Fish were captured at both of the station sampled in Bear River bay. Common carp catch-per-unit-effort values were similar between the two stations in Bear River bay, although chub were only captured in the eastern-most pair of nets. No station-station comparisons are possible in Farmington bay as fish were only found in the most southerly net sets. In Bear River Bay, carp represented 89% of the biomass captured, whereas in Farmington Bay Utah chub composed 96% of the biomass captured. Catch per unit effort for the two bays is shown in Figure 21, and lengths and weights of all fish captured are shown in Appendix 11.

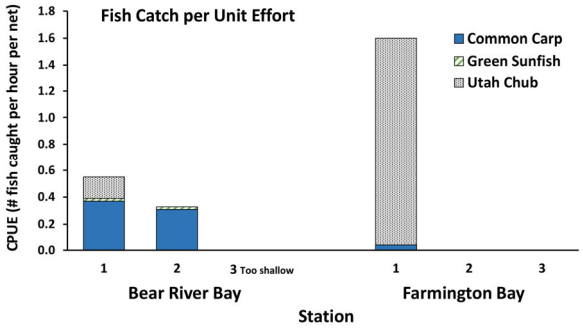

Figure 21. Fish caught per net per hour in both bays. Station 3 in Bear River Bay was too shallow to access (or deploy net); nets deployed at Stations 2 and 3 in Farmington Bay did not capture any fish. Nets were not placed in the western-most station in Bear River Bay, as the water levels were too low to support airboat passage.

Although sample sizes are too small to enable us to draw detailed conclusions, there are two key observations that emerge from our gill net sets. The first is that Bear River bay appears to support higher densities of common carp than does Farmington bay, and the second is that southern Farmington Bay supports much higher densities of Utah chub than elsewhere in Farmington bay, or in Bear River Bay (Figure 20). We should note that Great Blue Herons were present at the nets in Farmington Bay and Western Grebes were present at the Bear River Bays nets, and these may have taken some fish before the gillnets were retrieved.

Discussion

Eutrophication in the two bays—As expected, eutrophication metrics indicated that Farmington Bay was more productive than Bear River Bay. This is the result of the heavy nutrient loading to the bay from greater metropolitan Salt Lake City. Our sonde data, however, indicated relatively similar diel swings in oxygen in the two bays, although maximum concentrations frequently reached higher levels in Farmington than in Bear River Bay. Organic matter (ash-free dry mass) in the sediments was higher in Farmington Bay than in Bear River Bay, perhaps a consequence of the heavier nutrient loading that promotes phytoplankton and periphyton growth. However, benthic invertebrate biomass was not correlated with organic matter in the sediments (see below), so the importance of this metric is problematic. Another potential reason for lower organic matter content in Bear River Bay is that high spring flows there may wash organic matter out (J. Ostermiller, Utah DWQ, personal communication). High flows in spring are limited in Farmington Bay because water is diverted via the Goggin Drain

directly into Gilbert Bay. This diversion also likely reduces the flushing of nutrients from the bay with the lower nutrient content water derived from spring runoff.

The shallowness of both bays during the study points to benthic algal production as being more important than production of phytoplankton in the water column. This has been overlooked in studies of eutrophication, not only in Great Salt Lake, but worldwide (Vadeboncoeur et al. 2002). Benthic primary production dominates in shallow systems where sufficient light penetrates to the bottom. This depth is approximately 2-3 Secchi depths, and in both Farmington and Bear River Bays we often could not measure a Secchi depth because the disk reached the bottom prior to disappearing. Consequently, the majority of the algal production in both bays almost certainly occurs in the attached periphyton, or in the case of Bear River Bay, in the macrophytes (Vadeboncoeur et al. 2008). When Farmington Bay was deeper, low Secchi depths (< 0.3 m) prevented light from reaching the bottom, thus likely shifting the balance of primary production into the water column (Wurtsbaugh et al. 2012). Future work on Great Salt Lake needs to address the important benthic production in the lake, and how eutrophication and water levels influence this process.

Invertebrate biomass, eutrophication and salinity – In a review of 342 measurements available for lakes, (Rasmussen and Kalff 1987) found that the biomass of benthic invertebrates in the profundal (deep) and sublittoral zones of lakes were positively correlated with both total phosphorus and chlorophyll concentrations in the water column, although variability was high and these predictive variables only explained 20-47% of the variance. In the littoral zones of lakes that would be most like the environments we studied, there were no significant correlations between eutrophication metrics and invertebrate biomass. They attributed this to the high heterogeneity in the littoral zone, and the difficulty of quantitatively sampling there.

The benthic plant abundance in Farmington Bay was much lower in Farmington than in Bear River Bay, and researchers have found that this negatively influences the biomass of benthic invertebrates. For example, Hornung and Foote (2006) found that invertebrate biomass was strongly correlated with macrophyte abundance in a freshwater boreal lake. Pieczyńska et al. (1988) found that eutrophication in a Polish Lake caused the loss of macrophytes in the deeper water because of a decrease in water transparency (Secchi depth) from 3.0 to 1.1 m. In the shallowest areas where the macrophytes were not affected, invertebrate biomass was unchanged by the eutrophication. However, due to the loss of macrophytes in deeper water, there was an overall 85% decrease in the benthic invertebrates in the lake. In other systems, the loss of macrophytes results in a shift from larger species to an abundance of small chironomids, amphipods and oligochaetes. However, in a subsequent paper, Pieczyńska et al. (1998) found that benthic invertebrates, especially chironomidae, rapidly colonized filamentous algal mats in shallow water, partially compensating for the loss of invertebrates associated with macrophytes. However, in a South African Lake, eutrophication caused a major decrease in macrophytes followed by a 73% decrease in the biomass of benthic invertebrates, despite an abundance of algal mats that

developed (Davies 1982; Kalff 2002). Consequently, the importance of algal mats we observed in Farmington Bay (Figure 4b) and Station 3 in Bear River Bay is uncertain.

Our results suggest that invertebrate biomass may be positively influenced by the eutrophication entering the southern portion of Farmington Bay. The mean biomass value along the southernmost station in Farmington Bay was approximately 2x higher than the mean biomass values obtained in Bear River Bay, while the mean phosphorous values in Farmington Bay were 5x higher than in Bear River Bay. Total phosphorous in Farmington Bay decreased from south to north, and benthic invertebrate biomass reflected these decreases. In contrast, the total phosphorous values in Bear River Bay remained relatively consistent between stations, as did the benthic invertebrate biomass. However, the results of our regression analysis indicate that total phosphorous concentrations explained only a small portion of the variance of invertebrates in both bays ($r^2 = 0.24$). When separated by bay, phosphorous had a much weaker effect on biomass in Bear River Bay, and explains much less of the variability, than in Farmington Bay. This suggests that although phosphorous is an important contributor to benthic biomass, there are other, more important factors. Some of these factors are likely associated with the dynamic conditions of lake hydrology (resulting from inflow changes in both bays). The total phosphorous and organic matter results suggest that invertebrate populations respond to these changes at temporal and spatial scales that our study design did not adequately measure.

Although benthic invertebrate biomass in Farmington Bay was correlated with phosphorus, the biomass was not correlated with a more proximal factor, organic matter in the sediments (AFDM). The organic matter is a source of food for many macroinvertebrates, so a lack of correlation makes the direct influence of phosphorus loading problematic.

Perhaps unsurprisingly, salinity had a negative effect on biomass in both bays. Similar to phosphorous, however, the effect was much weaker in Bear River Bay resulting from the low variability in salinity between stations and through time. In Farmington Bay, however, large differences in salinity from south to north were associated with a steep drop in biomass. The northernmost station biomass was only a small fraction of the invertebrate biomass measured in the southern portion of the bay closer to the inflows. However, research in other salt lakes around the world has shown that some midge taxa in particular can continue to thrive with salinities as high as 10% (Figure 22; Hammer 1986; Wurtsbaugh 2009; Vdovina and Bezmaternykh 2016; Shadrin et al. 2017). Midges were the dominant taxon in both numbers and biomass

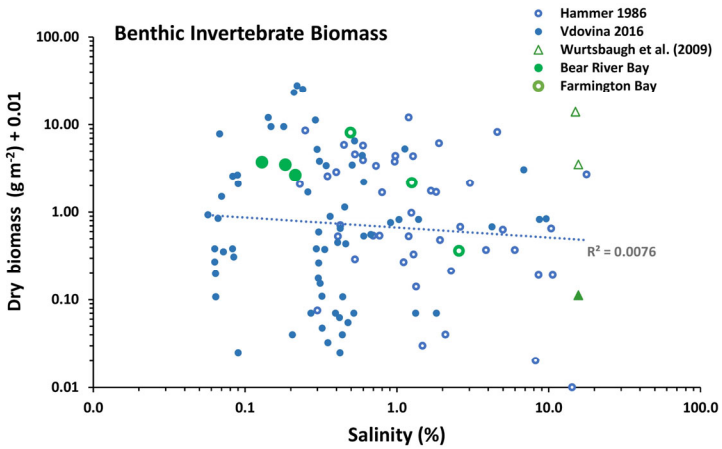

Figure 22. Biomasses of benthic invertebrates in lakes world-wide. Green symbols are data from Great Salt Lake, including the present study. Note that there was no significant correlation between salinity and invertebrate biomass totals.

in both bays. In the much more saline portions of northern Farmington Bay, air-breathing corixids dominated the biomass in some samples. That neither bay reached salinities above 4% during this study, and the fact that invertebrate biomass showed a decline with increasing salinity, suggest that it is perhaps not absolute salinity values that are negatively impacting the invertebrate community. Salinity varied spatially and temporally in both bays primarily as a result of spring runoff, and the relative elevations of Farmington and Gilbert Bays that determine how much hypersaline water can enter from the later. It is possible that the dynamic nature of salinity levels in both bays prevent communities from stabilizing in either composition or abundance. As each taxon responds differentially to changing conditions in a given location, less tolerant individuals are extirpated, and more tolerant taxa can potentially increase in abundance.

Seasonal benthic invertebrate biomass differences also existed between the bays. Bear River Bay invertebrate biomass peaked during the June sampling period, and then gradually declined throughout the remaining months of the study. Although the Farmington Bay invertebrate biomass also peaked in the month of June, July sampling showed a marked decrease in biomass, which then rose slightly in September and then decreased again in October. The higher seasonal variability in Farmington Bay biomass corresponds with the spatial variability this study also measured. Although both bays experience peak biomass during the spring bird migrations, the southern portion of Farmington Bay contained much higher biomass than the northern portion. The recent study by Gray (2012) found that peak invertebrate biomass in Willard Spur occurred during July. This slight seasonal difference from our results also suggests that interannual precipitation and flow variability have the potential to significantly influence both phenology and abundance of benthic invertebrates in the Great Salt Lake. The benthic samples from May were comprised (in biomass) by >94% chironomids, but as the summer progressed, this number dropped to 62%, and then increased in the fall to 79%. Amphipods increased to 19% (peak in June) during the summer, as did snails (peak in July). Beetles, bugs (corixids), and damselflies contributed very little to biomass in the spring, but slowly increased to between 3-8% during the summer and into fall. Gray also found that midges comprised about 86% of invertebrate biomass in March, however that study found midges declined to about 8% in August, during which time corixid biomass increased to 55%.

Figure 23. Yellow-headed blackbird (*Xanthocephalus xanthocephalus*) and swarms of adult chironomids in Bear River Bay. May 2016.

Invertebrate richness and abundance – Overall, both bays had similar biomasses, but varied greatly in abundance. Farmington Bay samples had about 1.5x as many benthic invertebrates as did Bear River Bay samples during the 2-year study (Figure 14). The frequency distributions of invertebrate size classes (Figure 15) show that Bear River Bay contained about 4x as many invertebrates that are >10mm in length than Farmington Bay contains. These size class frequency differences are likely partly because of the 1.5X higher taxonomic richness of the Bear River Bay invertebrate fauna. Although the Farmington

Bay samples were dominated by midges (chironomids) and, at times, corixids, Bear River Bay samples had many more large-bodied taxa such as beetles (Coleoptera), damselflies (Odonata), and caddisflies (Trichoptera). Most of these taxa were absent in all the Farmington Bay samples. Many of these large taxa are intolerant of highly eutrophic conditions like those occurring in Farmington Bay. The larger organisms in Bear River Bay may favor bird abundances there, since shorebirds, at least, feed selectively on larger prey (Sánchez et al. 2006).

We attribute some of this decreased richness in the Farmington Bay invertebrate community to the greater instability that exists in lake conditions there (particularly salinity and temperature). Diel temperature fluctuations ranged more than 15°C (27°F) and often peaked at temperatures well above the upper thermal tolerance values of many invertebrate families identified in our study (Yuan 2006; Dallas and Rivers-Moore 2012; Stewart et al. 2013). The majority of these critical thermal maxima are <30°C, with only a few ranging as high as about 40°C. Furthermore, Dallas and Rivers-Moore described aquatic invertebrate response to thermal increases as most often consisting of a loss of ability to stay attached, increased immobility, and a lack of response to external stimulus. Sustained temperatures at peak values in both bays could lead to loss of mobility, and eventually mortality if organisms are unable to migrate to cooler water or find local microrefugia.

Figure 24. American Avocets flying over Farmington Bay.

Gray (2012) also found that eutrophication led to decreased benthic invertebrate richness and shifts in relative abundance. The benthic invertebrates we found in Farmington Bay tend to have higher tolerance values than those found in Bear River Bay, which indicates that these taxa have a greater ability to withstand the chemical and physical changes that occur regularly in that bay. Bear River Bay conditions tended to remain more stable during the study, which may lead to increased colonization and richness in the benthic fauna. We also speculate that shifting inflows into Bear River Bay can transport both organic material as well as invertebrates, which would further contribute to patchy distributions. In general, Farmington Bay is a more challenging environment for many invertebrate taxa, but those fauna that can survive there can do quite well and exist in high densities. At the far northern portion of Farmington Bay (Station 3), where salinity and temperature were variable and highest, the benthic community was extremely depauperate and simplified. Some of the samples collected consisted of only midges and Trichocorixa that prey on midges. A previous study found that corixid predation depressed the abundance of brine shrimp in Great Salt Lake (Wurtsbaugh 1992) and corixid predation pressure may also depress benthic invertebrates, since chironomids are one of their favored prey (Scudder 1976). Experimental work would be needed, however, to verify if corixid predation is a dominant factor depressing chironomid larvae in the northern, more saline portion of Farmington Bay. It is also worth

noting, that despite differences in benthic invertebrate abundance and richness between the two bays, that more than 70% of all invertebrate biomass we sampled from the Great Salt Lake was made of midges (chironomids). The general dominance of midges in the benthic invertebrate biomass aligns well with the biomass values found in the previously mentioned 2011 study of Gray (2012).

Deep brine layer—During our study the shallowness of Farmington Bay greatly limited the magnitude of the deep brine layer. Nevertheless, on four of the five dates sampled, salinity was higher, and oxygen was much lower at the bottom of the bay at Station 3a. Benthic invertebrate biomass beneath the deep brine layer was only about 14% of that at the shallower substations along the northern transect, and the dominant taxa in the deep layer were air-breathing corixids, brine fly larvae or hypoxia-tolerant gnat larvae. In years when Farmington Bay is deeper and the deep brine layer was even more developed, the complete anoxia and presence of high concentrations of toxic hydrogen sulfide likely precluded any macroinvertebrates from existing in the deep waters in the northern half of the bay (Wurtsbaugh and Marcarelli 2006). Collins (1980) found that the extensive deep brine layer in Gilbert Bay precluded *Ephydra* larvae from living there, and that internal waves (seiching) killed the larvae even above the equilibrium depth. Consequently, the deep brine layers in both bays likely greatly reduce the production of invertebrate prey for birds, at least in the years when they cover large portions of the bays.

Fish—Although our sampling was limited, the gillnetting established that fish are quite abundant in Farmington Bay (at least at the southern end), and confirmed earlier reports of fish abundance in Bear River Bay (Moore and Wurtsbaugh 2012; Penne 2012). These studies are consistent with our observations of large carp in both bays when sampling. Although carp were captured in both bays, Utah chub was the dominant species in Farmington Bay. Since these species are important prey of piscivorous birds, and at least a limited sport fishery exists in Willard Spur, more work needs to be done to establish if water quality is adequate to protect the warm water fish species living in both bays.

Figure 25. Wiper bass captured in Willard Spur gillnetting in October 2011 (see Moore and Wurtsbaugh 2012).

Bird diets and distribution relative to invertebrate and fish abundance— The diets of many of the different bird species utilizing Bear River and Farmington Bays have been poorly characterized, if at all. The available data shows that the species that have been studied feed heavily on gnat larvae (Figure 26), and expected finding given the prevalence of this taxon in both bays (Figure 13). Among the invertebrate-feeding birds, Hemiptera, which includes corixids, were second in importance. Hemiptera represented a relatively small portion of the available biomass in both bays (Figure 13), but they are, in

general, much larger than gnat larvae, and thus may be selectively preyed upon. Brine fly larvae and adults were also important prey of the several bird species. Piscivorous White Pelicans and Great Blue Herons fed primarily on suckers and minnows, but the sample size of these two bird species was very low, making it difficult to draw conclusions. Pintail and Cinnamon Teal fed heavily on vegetation, but again sample sizes were very small, limiting our ability to characterize their diets. We found no data on 36 other bird species that utilize Great Salt Lake (Appendix 11). Most previous analyses of bird diets at Great Salt Lake have focused on species captured in Gilbert and Ogden Bays where salinities are high. Consequently, brine shrimp and brine flies dominate the diets of these birds (Roberts 2013). The much greater diet diversity of birds utilizing the Bear River and Farmington Bay estuaries points to the importance of a variety of prey taxa that utilize the freshwater to hypersaline continua. Note that the diet data assembled for Figure 25 was collected at a variety of lake elevations and consequently, a variety of salinities in the two bays.

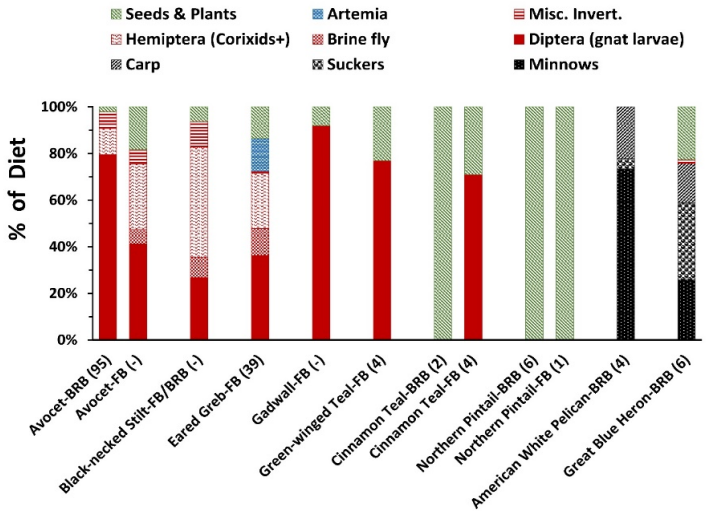

Figure 26. Percent composition of the diets of birds collected in Bear River and Farmington Bays. Data were derived from (Roberts 2013), Barber and Cavitt (No date) and Osmundson (1990). In most cases, values represent % of diet by weight or volume. Note that the sample sizes (x) of many of the species are were very small or not given. See Appendix 12 for details.

The 1997-2001 Waterbird Survey conducted by the Utah Division of Wildlife Resources (Paul and Manning 2002) provides additional insights on how eutrophication may be influencing bird populations. Wurtsbaugh (2018) reanalyzed their data to provide species abundances on an areal basis, thus facilitating comparisons between Bear River and Farmington Bays. This analysis showed that overall bird abundances were nearly twice as high in Bear River Bay than in Farmington Bay (72 vs 39 birds/km^2), and the higher abundance in Bear River was consistent for all groups except Phalaropes and Eared Grebes (Figure 26).

However, when specific habitats were analyzed, some differences emerged. In the open waters, bird densities were 2-times higher in Bear River than in Farmington Bay, and since the open waters represent a large portion of the areas of each system, Figure 27 emphasizes densities there. In the shoreline habitat, bird densities were almost equal in the two bays, but in Bear River Bay waterfowl were dominant, whereas in Farmington Bay shorebirds dominated. This points to the importance of food production in the shallow shoreline areas of Farmington Bay. During our study, large number of

American Avocets and other shorebirds were observed on the southwestern shore of Farmington Bay where invertebrate prey abundance was very high.

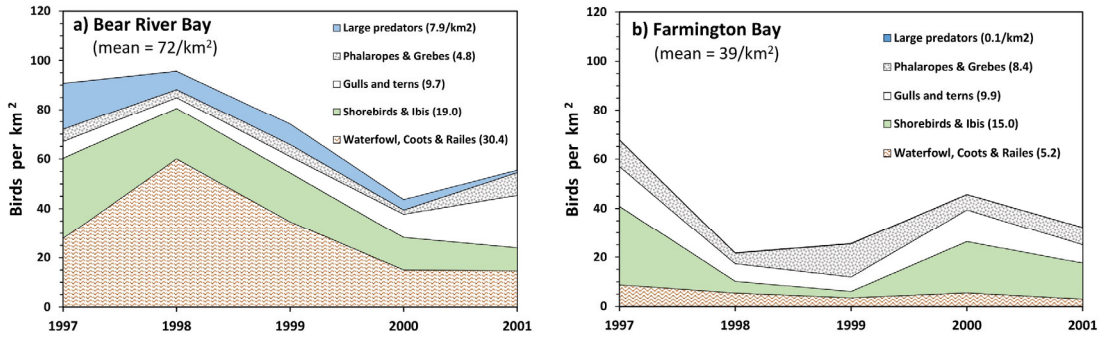

Figure 27. Summary of waterbird densities in Bear River Bay and Farmington Bay for the five years of the Utah Division of Wildlife Resources bird surveys. Reanalyzed by Wurtsbaugh (2018). For this analysis, the total birds counted in all the survey areas were divided by the total area of all of the habitats (open water, shoreline, wetland) combined. Numbers in parentheses show mean densities of each group for the entire period.

Another relevant study on birds was a comparison of densities in the *open water* of Farmington Bay with water of similar depth in Gilbert Bay (Wurtsbaugh et al. 2012). Densities of Eared Grebes, Phalaropes and gulls were much lower in the open waters of Farmington than in Gilbert Bay (Figure 28). During their study water depths at the north end of Farmington Bay were 1.5-1.8 m, and a deep brine layer covered the deeper waters in the northern half of the bay where they sampled. Consequently, at times the development of the deep brine layer in Farmington Bay may play an important role in regulating the abundance of birds, at least in the open waters.

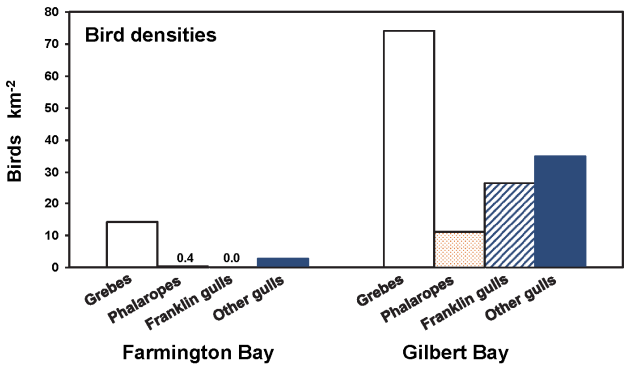

Figure 28. Bird densities estimated in the open water areas of Farmington and Gilbert Bays on five dates between March and December (2002-2003). Farmington Bay densities were estimated in the northern half of the bay where a deep brine layer was present (see Wurtsbaugh et al. 2012).

Lake dessication—Although eutrophication and the deep brine layer may influence benthic invertebrate abundances and the birds that feed on them, the greatest threat to these communities is the dewatering of Great Salt Lake (Wurtsbaugh et al. 2016; Wurtsbaugh et al. 2017). Lake levels have declined approximately 11 feet due to the diversion of water for agriculture and other uses, and this, combined with drought, has exposed approximately 50% of the bed of Great Salt Lake. In shallow Farmington and Bear River Bays, the reduction is even higher, with 70-80% of their beds exposed. Plans to divert more water from the Bear River (Utah Division of Natural Resources 2019) may decrease the lake level by approximately 1 foot, and this would have devestating effects on Farmington Bay and

particulary Bear River Bay which are already at extremely low levels (Figure 29). While the Utah Division of Water Resources has modeled impacts on additional water diversions on the lake as a whole, no effort has yet been made to estimate the impacts on Farmington and Bear River Bays, the most critical bird habitat in the system.

Figure 29. Sonde stranded on the bed of dessicated Bear River Bay (Station 3b) after the water dropped and made airboat access to it impossible. Date: 9 Sept. 2018.

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Appendix 1: Transect locations. Locations of deep stations in each bay. After sampling at the deep substation, we motored perpendicular to the shore, heading N or NW in Bear River Bay, and E in Farmington Bay to sample the 0.3 m ("b") and 0.1 m ("c") substations.

	Bear River Bay		
Name	*Utah DWQ Equiv.*	*Latitude*	*Longitude*
BRB 1a	WS 4a	41 24'06"	-112 07'38"
BRB 2a	WS 12a	41 22'11"	-112 15'59"
BRB 3a	-	41 17'13"	-112 21'50"
	Farmington Bay		
FB 1a	-	40 56'15"	-112 05'48"
FB 2a	-	41 00'00"	-112 08'50"
FB 3a	-	41 03'28"	-112 12'36"

Appendix 2. Depths (m) of the stations sampled during the 2017-2018 survey.

	Station and Substations								
	1			**2**			**3**		
	a	b	c	a	b	c	a	b	c
				Bear River Bay					
	0.66	0.32	0.11	0.23	0.20	0.16	0.37	0.21	0.09
May 2018	0.80	0.39	0.11	0.23	0.22	0.11	0.40	0.36	0.13
June 2018	0.58	0.34	0.11	0.20	0.23	0.10	0.20	0.10	0.06
July 2017	0.77	0.30	0.09	0.25	0.24	0.11	0.29	0.30	0.10
Sept. 2018	0.36	0.23	0.13	0.21	0.15	0.10	-	-	-
Oct. 2017	0.65	0.20	0.10	ND	0.11	0.12	0.32	0.22	0.10
				Farmington Bay					
	0.48	0.27	0.10	0.52	0.25	0.12	0.92	0.25	0.12
May 2018	0.65	0.31	0.10	0.68	0.34	0.12	1.04	0.27	0.13
June 2018	0.37	0.22	0.11	0.46	0.29	0.12	0.94	0.21	0.11
July 2017	0.48	0.30	0.10	0.64	0.34	ND	1.10	0.24	0.09
Sept. 2018	0.26	0.26	0.09	0.18	0.14	0.11	0.50	0.23	0.11
Oct. 2017	0.42	0.27	0.11	0.42	0.30	0.12	0.80	0.32	0.14

Appendix 3: Sampling dates. Benthic invertebrate and limnological sampling dates in the two bays during 2017 and 2018. Sondes were deployed approximately 1 week prior. Gill nets for fish sampling were deployed in each bay the afternoon before the sondes were deployed in June 2018.

Bear River Bay	Farmington Bay
14-Jul-17	12-Jul-17
2-Oct-17	3-Oct-17
3-May-18	1-May-18
26-Jun-18	27-Jun-18
10-Sep-18	11-Sep-18

Appendix 4: Details of Methods used in the study

Eutrophication metrics: Secchi depths were measured with a 30-cm black and white disk, lowered until it disappeared, raised until it reappeared. The mean of these two depths was recorded as the Secchi depth. Most stations were too shallow to record a Secchi depth.

Total nitrogen (TN) and total phosphorus (TP) samples were analyzed using a persulfate digestion followed by analysis for nitrate (cadmium reduction) and phosphate (ascorbic acid molybdenum reaction) using an Astoria autoanalyzer (Astoria Pacific International, Portland OR). Respective TN and TP detection limits were 0.006 and 0.003 mg L-1. When salinities were higher than seawater, they were diluted to 3.5% prior to analysis. The TN and TP analyses were done in the Biogeochemistry Laboratory of Dr. Michelle Baker, Utah State University.

Chlorophyll *a*, a surrogate measure for total phytoplankton biomass, was analyzed by filtering 10-ml aliquots on 25-mm Gelman A/E filters with a nominal pore size of 1 µm. The filters were frozen to help lyse the phytoplankton cells. Within three weeks the filters were extracted in 95% ethanol overnight, and the chlorophyll concentrations were measured with a Turner 10AU fluorometer (Turner Designs, Sunnyvale, CA) using a non-acidification technique (Welschmeyer 1994). In 2018 when many of the stations became very shallow, the wake of the airboat disturbed the sediments, moving periphyton into the water column. This apparently resulted in extremely high and inaccurate measures of chlorophyll concentration. Consequently, we relied on the 2017 concentrations measured at the deep station of each transect.

Salinity: Salinity was measured using a hand-held refractometer or by measuring conductivity. Conductivity readings were converted to salinity using the empirical relationship developed during our studies on the bays:

$$\text{Salinity (\%)} = 0.0638 * \text{Specific Conductivity (mS)}$$

Ash-free dry mass: **AFDM** was measured as the metric to determine the amount of organic matter in the sediments. Two 5-cm diameter core samples were taken approximately 100 m apart, and the top 1-cm of material was exuded and stored frozen in a plastic bag. The sediments were then dried at 50˚ C for 4-7 days until a consistent dry weight was achieved for each sample (note: July 2017 samples may have contained a residual amount of water in each sample, as multiple dry weights were not recorded). Dried samples were then combusted at 550˚ C for 2 hours, cooled, and reweighed. % AFDM was calculated as:

100* (dry weight – ashed weight) / dried-weight.

Invertebrate sampling and processing:

Field sampling. The Ponar dredge used in five of the six sampling events measured 6" x 6" and collected a sample area of 231 cm^2. The dredge had a 1-mm mesh covering the top. Consequently, some larger invertebrates (e.g. brine shrimp, corixids) were sampled as the dredge descended. The dredge weighed 6.8 kg, allowing it to readily penetrate macrophytes into the underlying sediments. The Eckman dredge used in the first (July) sampling event also measured 6" x 6". In the field dredge samples were sieved through bucket sieves with 0.5-mm mesh to remove as many sediments as possible.

Laboratory processing. Preserved material from benthic macroinvertebrate samples were poured through a 2-mm sieve stacked on a 0.5-mm sieve. Sample material was rinsed thoroughly in fresh water in order to separate animals from macrophytes and sediment. An appropriately sized separator bar was placed into the 0.5-mm sieve to divide the material in half. Stems and other materials were cut along the centerline prior to splitting the sample (if needed). This process of halving was repeated as many times as necessary to ensure a 300-count subsample of benthic macroinvertebrates. All larger benthic macroinvertebrates remaining in the 2-mm sieve were also removed and identified. In more than half of the samples processed from both bays, >50% of invertebrates remained in the 2-mm sieve (attached to macrophytes), which resulted in 60% of samples being sorted at 100%. Sorted animals were then identified to the standard accepted level of resolution for western taxa (genus, in most cases) (Safit 2008).

Body length (or head capsule width) was measured using an optical micrometer for 25 individuals (if available) from each taxon within a sample. Biomass was calculated using published regression coefficients (a, b) applied to the equation $W=aL^b$, where W is the dry weight (mg) and L is either body length or head capsule, depending on taxon (Benke et al. 1999). Biomass per unit area was calculated by scaling appropriately for area of the sampler (.0525 m^2) and by proportion of sample processed by the taxonomists. Biomass calculations were completed for individual taxa, species, genus and family identifications, but here we present data at the order level (or Phylum for oligochaetes). We chose this aggregation in order to simplify visualization of results. Abundance values were calculated using identical scaling methodology.

Fish sampling: Fish were sampled only on one date to provide at least some data on their presence or absence in the two bays. We conducted the fish surveys in June 2018 using multi-mess gill nets at the

deepest section of each of the stations in both bays (we were unable to place nets in station #3 in Bear River bay as the water was too shallow (only 0.2-m deep at the time of sampling). All sets were conducted for approximately 24 hours and were placed in pairs about 100 m apart (total number of nets = 10). Gill nets used in all surveys were identical and were sinking monofilament nets 24-m long and 1.8-m tall. Each net had 8 panels with bar mesh sizes of 38, 57, 25, 44, 19, 64, 32, and 51-mm (knot-to-knot). Nets were set so that they were oriented perpendicularly to the potential water movement in each of the bays. This arrangement was chosen to optimize the capture of fish generally moving along these inflow currents. Mean net depth was 0.62 m, and mean time of set was 23.6 hours. Nets were anchored to the lake-bottom at both ends. Every captured fish was weighed to the nearest gram and measured to the nearest millimeter (total length).

Appendix 5. Organic matter (%) in the top 1-cm of the sediments of Bear River and Farmington Bays during 2 years. Stations were located along the inflow (Sta. 1) to outflow (sta. 3) salinity gradients in each bay. Substations were located along depth gradients from the deepest (a) to the shallowest (c; nominally 0.1 m).

	Station and Substation									
	1			2			3			Mean
	a	b	c	a	b	c	a	b	c	
Bear River Bay										
Jul-17	3.3	3.0	3.8	2.3	2.5	3.1	4.6	5.3	3.9	3.5
Oct-17	2.6	2.5	3.9	2.4	2.0	1.4	2.9	5.5	3.5	3.0
May-18	3.5	3.0	2.7	1.7	2.7	2.7	2.3	4.4	4.9	3.1
Jun-18	1.6	1.7	1.2		1.4	2.5		1.8	1.7	1.7
Sep-18	2.3	2.8	2.6	2.1	2.5	2.9				2.5
Mean	2.7	2.6	2.8	2.1	2.2	2.5	3.3	4.3	3.5	2.8
Farmington Bay										
Jul-17	5.8	4.3	4.0	9.0	4.6	10.0	7.2	5.0	6.1	6.2
Oct-17	5.5	4.6	4.3	5.9	2.5	3.6	9.3	9.3	5.1	5.6
May-18	4.8	3.6	4.6	6.3	3.2	7.3	3.3	3.7	4.1	4.5
Jun-18	2.6	2.7	4.5	4.5	3.1	2.4	4.3	2.1	2.6	3.2
Sep-18	4.5	3.1	3.6	4.0	2.7	2.9	6.9	4.7	6.1	4.3
Mean	4.6	3.7	4.2	5.9	3.2	5.3	6.2	4.9	4.8	4.8

Appendix 6. Mean Secchi disk transparency measurements in Bear River and Farmington Bays on the study dates. On many dates and at several stations the water was too shallow, and the disk reached bottom before it disappeared. The Secchi depth in Bear River Bay on Sept. 2018 was likely influenced by sediment suspended by the airboat.

	Bear River			Farmington Bay		
	1	2	3	1	2	3
Date						
May-18	0.28		0.17	0.27	0.30	0.38
Jun-18					0.19	0.28
Jul-17						0.70
Sep-18	0.15?					0.25
Oct-17				0.22	0.20	0.40

Appendix 7. Mean chlorophyll *a* concentrations in Bear River and Farmington Bay on five dates in 2017 and 2018. Some of the values at the shallowest stations and substations collected in 2018 are likely erroneously high due to sediment resuspension by the airboat (see Methods).

	Station and Substation											
	1				2				3			
	a	b	c		a	b	c		a	b	c	Mean
	Bear River Bay											
Oct-17	26	76		43	13	12	13	13	48	54	29	32
Jul-17	19	56	11	29	10	31	5	15	16	10	15	19
May-18	117	73	122	104	101	110	17	76	121	193	117	108
Jun-18	9	398	23	143	7	11	9	8		14	15	72
Sep-18	222	806	1041	689	1230	2585	588	1643				1123
Mean	85	336	340	243	301	778	84	368	71	86	54	244
	Farmington Bay											
Oct-17	81	91	73	82	98	97	71	88	60	87	36	77
Jul-17	3	10		6	64	62	59	62	37	48	28	39
May-18	948	378	299	542	334	506	331	390	171	209	213	377
Jun-18	25	419	416	286	592	478	453	507	663	550	216	423
Sep-18	55	53	290	133	264	572	93	310	940	185	188	293
Mean	247	210	270	241	294	374	217	295	412	234	148	267

Appendix 8. Summary of Classes and other major taxonomic categories of benthic invertebrates identified from Bear River and Farmington Bays. Numbers indicate the unique number of taxon identified within each group. A complete listing is available in Appendix 9.

Taxon	Common name	Bear River Bay	Farmington Bay
Arachnida	Mites	3	2
Clitellata	Worms	3	1
Gastropoda	Snails	4	3
Coleoptera	Beetles	9	8
Diptera	Flies (non-midge)	9	8
Chironomidae	Midges	5	4
Ephemeroptera	Mayflies	3	2
Hemiptera	True bugs	6	5
Leidoptera	Butterflies	1	0
Odonata	Dragonflies	4	1
Trichoptera	Caddis flies	3	1
Amphipoda	Scuds	2	1

Appendix 9. Taxonomic list for all invertebrate taxa identified in both Farmington (FB) and Bear River Bays (BRB) during the July and October sampling periods.

Phylum	Class	SubClass	Order	SubOrder	Family	SubFamily	Tribe	Genus	Final ID	Bay
Annelida	Clitellata	Lumbriculata	Hirudinida	Erpobdelliformes	Erpobdellidae				Erpobdellidae	BRB
Annelida	Clitellata	Lumbriculata	Hirudinida		Glossiphoniidae				Glossiphoniidae	BRB
Annelida	Oligochaeta	Oligochaeta							Oligochaeta	BRB, FB
Arthropoda	Arachnida	Acari	Trombidiformes	Prostigmata	Arrenuridae			Arrenurus	Arrenurus	BRB, FB
Arthropoda	Arachnida	Acari	Trombidiformes	Prostigmata	Hygrobatidae				Hygrobatidae	BRB
Arthropoda	Arachnida	Acari	Trombidiformes						Trombidiformes	BRB, FB
Arthropoda	Branchiopoda	Sarsostraca	Anostraca	Artemiina	Artemiidae			Artemia	Artemia	FB
Arthropoda	Insecta	Pterygota	Coleoptera	Polyphaga	Curculionidae				Curculionidae	BRB, FB
Arthropoda	Insecta	Pterygota	Coleoptera	Adephaga	Dytiscidae	Hydroporinae	Hygrotini	Hygrotus	Hygrotus	BRB, FB
Arthropoda	Insecta	Pterygota	Coleoptera	Adephaga	Dytiscidae				Dytiscidae	BRB, FB
Arthropoda	Insecta	Pterygota	Coleoptera	Adephaga	Haliplidae			Haliplus	Haliplus	BRB
Arthropoda	Insecta	Pterygota	Coleoptera	Polyphaga	Helophoridae			Helophorus	Helophorus	BRB
Arthropoda	Insecta	Pterygota	Coleoptera	Polyphaga	Hydraenidae			Ochthebius	Ochthebius	FB
Arthropoda	Insecta	Pterygota	Coleoptera	Polyphaga	Hydraenidae				Hydraenidae	BRB, FB
Arthropoda	Insecta	Pterygota	Coleoptera	Polyphaga	Hydrophilidae	Hydrophilinae	Berosini	Berosus	Berosus	BRB
Arthropoda	Insecta	Pterygota	Coleoptera	Polyphaga	Hydrophilidae	Hydrophilinae	Hydrophilini	Enochrus	Enochrus	BRB, FB
Arthropoda	Insecta	Pterygota	Coleoptera	Polyphaga	Hydrophilidae				Hydrophilidae	BRB, FB
Arthropoda	Insecta	Pterygota	Diptera	Nematocera	Ceratopogonidae	Ceratopogoninae	Palpomyiini	Bezzia	Bezzia	BRB, FB
Arthropoda	Insecta	Pterygota	Diptera	Nematocera	Ceratopogonidae	Dasyheleinae		Dasyhelea	Dasyhelea	BRB
Arthropoda	Insecta	Pterygota	Diptera	Nematocera	Ceratopogonidae				Ceratopogonidae	BRB, FB
Arthropoda	Insecta	Pterygota	Diptera	Nematocera	Chironomidae				Chironomidae	BRB, FB
Arthropoda	Insecta	Pterygota	Diptera	Nematocera	Chironomidae	Chironominae			Chironominae	BRB, FB
Arthropoda	Insecta	Pterygota	Diptera	Nematocera	Chironomidae	Orthocladiinae			Orthocladiinae	BRB, FB
Arthropoda	Insecta	Pterygota	Diptera	Nematocera	Chironomidae	Prodiamesinae			Prodiamesinae	BRB
Arthropoda	Insecta	Pterygota	Diptera	Nematocera	Chironomidae	Tanypodinae			Tanypodinae	BRB, FB
Arthropoda	Insecta	Pterygota	Diptera	Brachycera	Dolichopodidae				Dolichopodidae	BRB, FB
Arthropoda	Insecta	Pterygota	Diptera	Brachycera	Empididae	Hemerodromiinae	Hemerodromiini	Chelifera	Chelifera	BRB
Arthropoda	Insecta	Pterygota	Diptera	Brachycera	Ephydridae			Ephydra	Ephydra	BRB, FB
Arthropoda	Insecta	Pterygota	Diptera	Brachycera	Ephydridae				Ephydridae	BRB, FB
Arthropoda	Insecta	Pterygota	Diptera	Brachycera	Muscidae				Muscidae	BRB, FB
Arthropoda	Insecta	Pterygota	Diptera	Brachycera	Stratiomyidae			Stratiomys	Stratiomys	FB
Arthropoda	Insecta	Pterygota	Diptera	Brachycera	Stratiomyidae				Stratiomyidae	FB
Arthropoda	Insecta	Pterygota	Ephemeroptera	Pisciforma	Baetidae			Callibaetis	Callibaetis	BRB, FB
Arthropoda	Insecta	Pterygota	Ephemeroptera	Furcatergalia	Caenidae			Caenis	Caenis	BRB, FB
Arthropoda	Insecta	Pterygota	Ephemeroptera	Furcatergalia	Leptohyphidae			Tricorythodes	Tricorythodes	BRB
Arthropoda	Insecta	Pterygota	Hemiptera	Heteroptera	Belostomatidae				Belostomatidae	FB
Arthropoda	Insecta	Pterygota	Hemiptera	Heteroptera	Corixidae	Corixinae	Corixini	Corisella	Corisella	BRB, FB
Arthropoda	Insecta	Pterygota	Hemiptera	Heteroptera	Corixidae	Corixinae	Corixini	Hesperocorixa	Hesperocorixa	BRB
Arthropoda	Insecta	Pterygota	Hemiptera	Heteroptera	Corixidae	Corixinae	Corixini	Sigara	Sigara	BRB
Arthropoda	Insecta	Pterygota	Hemiptera	Heteroptera	Corixidae	Corixinae	Corixini	Trichocorixa	Trichocorixa	BRB, FB
Arthropoda	Insecta	Pterygota	Hemiptera	Heteroptera	Corixidae				Corixidae	BRB, FB
Arthropoda	Insecta	Pterygota	Hemiptera	Heteroptera	Notonectidae	Notonectinae	Notonectini	Notonecta	Notonecta	BRB, FB
Arthropoda	Insecta	Pterygota	Lepidoptera		Crambidae	Nymphulinae	Argyractini	Petrophila	Petrophila	BRB
Arthropoda	Insecta	Pterygota	Odonata	Zygoptera	Coenagrionidae			Enallagma	Enallagma	BRB
Arthropoda	Insecta	Pterygota	Odonata	Zygoptera	Coenagrionidae			Ischnura	Ischnura	BRB
Arthropoda	Insecta	Pterygota	Odonata	Zygoptera	Coenagrionidae				Coenagrionidae	BRB, FB
Arthropoda	Insecta	Pterygota	Odonata	Anisoptera	Libellulidae				Libellulidae	BRB
Arthropoda	Insecta	Pterygota	Trichoptera		Leptoceridae	Leptocerinae	Oecetini	Oecetis	Oecetis	BRB
Arthropoda	Insecta	Pterygota	Trichoptera		Leptoceridae	Leptocerinae	Triaenodini	Triaenodes	Triaenodes	BRB
Arthropoda	Insecta	Pterygota	Trichoptera		Leptoceridae				Leptoceridae	BRB, FB
Arthropoda	Malacostraca	Eumalacostraca	Amphipoda	Gammaridea	Gammaridae			Gammarus	Gammarus	BRB
Arthropoda	Malacostraca	Eumalacostraca	Amphipoda	Gammaridea	Hyalellidae			Hyalella	Hyalella	BRB, FB
Mollusca	Gastropoda		Basommatophora		Lymnaeidae	Lymnaeinae		Lymnaea	Lymnaea	BRB
Mollusca	Gastropoda		Basommatophora		Physidae	Physinae		Physa	Physa	BRB, FB
Mollusca	Gastropoda		Basommatophora		Planorbidae			Gyraulus	Gyraulus	BRB, FB
Mollusca	Gastropoda		Basommatophora		Planorbidae				Planorbidae	BRB, FB
Nemata									Nemata	BRB

Appendix 10. Biomasses (g dry wt./m^2) of different benthic invertebrate taxa in Bear River Bay (BRB) and Farmington Bay (FB) at the different stations and substations during the five sampling events in 2017 and 2018. Data are the means for two replicates at each substation.

Bay	Station	Substation	Month	Amphipoda	Basommatophora	Clitellata	Coleoptera	Diptera	Ephemeroptera	Hemiptera	Hirudinida	Lepidoptera	Nematoda	Odonata	Trichoptera	Trombidiformes	Totals
BRB	1	a	July	0.0367	0.1878	0.0048	0.0000	0.3129	0.3294	0.0010	0.0017	0.0921	0.0009	0.0805	0.0038	0.0050	1.0565
BRB	1	a	June	0.0548	0.4743	0.1469	0.0664	4.4713	0.0713	0.0000	0.0000	0.2308	0.0000	1.6448	0.0117	0.0000	7.1723
BRB	1	a	May	0.0000	0.0596	0.0000	0.0000	1.3482	0.0302	0.0000	0.0000	0.0000	0.0000	0.0763	0.0000	0.0000	1.5142
BRB	1	a	October	0.0026	0.1052	0.0286	0.0000	0.1616	0.0407	0.0001	0.0000	0.0000	0.0000	0.3300	0.0020	0.0029	0.6737
BRB	1	a	September	0.0000	0.1540	0.1357	0.0000	1.4646	0.2931	0.1482	0.0000	0.0563	0.0020	0.5284	0.0016	0.0045	2.7884
BRB	1	b	July	0.0359	0.0374	0.0000	0.1187	0.0889	0.0199	0.0000	0.0000	0.1339	0.0000	0.0443	0.0000	0.0059	0.4849
BRB	1	b	June	0.1422	0.3318	0.0452	0.0000	17.0303	0.0942	0.1771	0.0000	0.0000	0.0000	1.0546	0.0000	0.0441	18.9196
BRB	1	b	May	0.0082	0.0000	0.0000	0.0000	0.9394	0.0050	0.0001	0.0000	0.0000	0.0000	0.0108	0.0000	0.0008	0.9643
BRB	1	b	October	0.0106	0.0427	0.0020	0.0000	1.4365	0.0539	0.0063	0.0000	0.0028	0.0000	0.0000	0.0000	0.0016	1.5564
BRB	1	b	September	0.0000	0.0095	0.0000	0.0000	8.6469	0.0016	0.0057	0.0000	0.0057	0.0000	0.0000	0.0021	0.0002	8.6717
BRB	1	c	July	0.1705	2.4856	0.0000	0.2208	0.3278	0.1307	0.0001	0.0000	0.0446	0.0000	0.0130	0.0000	0.0006	3.3937
BRB	1	c	June	0.1012	0.3718	0.0000	0.1779	3.5370	0.0084	0.9748	0.0000	0.0000	0.0000	0.0271	0.2343	0.0060	5.4384
BRB	1	c	May	0.0002	0.0000	0.0000	0.0000	2.7467	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	2.7478
BRB	1	c	October	0.0000	0.0104	0.0000	0.0816	0.0410	0.0000	0.0106	0.0000	0.0000	0.0000	0.0043	0.0000	0.0000	0.1478
BRB	1	c	September	0.0000	0.0008	0.0000	0.0000	0.3609	0.0006	0.0025	0.0000	0.1576	0.0000	0.0000	0.0000	0.0110	0.5333
BRB	2	a	July	0.0000	0.1635	0.0003	0.0055	0.0677	0.0701	0.0288	0.0000	0.0261	0.0000	0.1423	0.0000	0.0037	0.5081
BRB	2	a	May	0.0000	0.0000	0.0000	0.0000	5.3033	0.0032	0.0100	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	5.3165
BRB	2	a	October	0.0000	0.1378	0.0000	0.0148	0.6214	0.3135	0.0037	0.0000	0.0055	0.0000	0.1609	0.0178	0.0010	1.2765
BRB	2	a	September	0.0000	0.1775	0.0039	0.0000	4.7278	0.3262	0.1141	0.0000	0.0000	0.0000	0.3002	0.0245	0.0000	5.6742
BRB	2	b	July	0.0024	0.3552	0.0008	0.0000	0.1209	0.0215	0.0163	0.0000	0.0014	0.0000	0.1067	0.0000	0.0025	0.6277
BRB	2	b	June	0.1362	0.0962	0.0000	0.5376	0.1080	0.0250	0.2803	0.0000	0.0000	0.0000	0.0119	0.1447	0.0000	1.3399
BRB	2	b	May	0.0000	0.0000	0.0000	0.0000	2.9719	0.0096	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.9830
BRB	2	b	October	0.0000	0.0334	0.0000	0.0000	0.7820	0.0216	0.0063	0.0000	0.0000	0.0000	0.0255	0.0025	0.0012	0.8724
BRB	2	b	September	0.0000	0.0069	0.0933	0.0000	3.1210	0.0259	0.0248	0.0000	0.1717	0.0000	0.0072	0.0577	0.0000	3.5086
BRB	2	c	July	0.0006	0.7742	0.0000	0.8958	0.1174	0.1212	0.0832	0.0000	0.0044	0.0000	0.1331	0.0000	0.0029	2.1328
BRB	2	c	May	0.0000	0.0000	0.0000	0.0230	3.4358	0.0020	0.0053	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	3.4662
BRB	2	c	October	0.0000	0.0297	0.0000	0.0000	2.5540	0.0012	0.0318	0.0000	0.0000	0.0000	0.0000	0.0063	0.0003	2.6234
BRB	2	c	September	0.0000	0.8085	0.0000	0.0000	1.1297	0.5253	0.1615	0.0000	0.0701	0.0000	0.6584	0.0044	0.0000	3.3579
BRB	3	a	July	0.2358	1.3525	0.0000	0.0000	3.3013	0.0082	0.0749	0.0000	0.0000	0.0000	0.0487	0.0000	0.0036	5.0250
BRB	3	a	May	0.0000	0.0000	0.0000	0.0000	0.4909	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.4909
BRB	3	a	October	0.0135	0.0420	0.0000	0.0000	2.9813	0.0010	0.0167	0.0000	0.0000	0.0000	0.0043	0.0000	0.0059	3.0648
BRB	3	b	July	0.0013	0.6754	0.0000	0.0000	14.7890	0.0204	0.0442	0.0000	0.0000	0.0000	0.0388	0.0000	0.0082	15.5772
BRB	3	b	June	0.0000	0.0000	0.0000	0.1669	0.5059	0.0035	0.0080	0.0000	0.0919	0.0000	0.0000	0.0013	0.0000	0.7775
BRB	3	b	May	0.0007	0.0000	0.0000	0.0000	1.7790	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.7797
BRB	3	b	October	0.0006	0.3345	0.0000	0.0000	3.3138	0.0362	0.0651	0.0000	0.0000	0.0000	0.0054	0.0000	0.0071	3.7626
BRB	3	c	July	0.0013	2.3361	0.0000	0.0000	4.3888	0.0707	0.2585	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	7.0554
BRB	3	c	June	0.0003	0.0030	0.0000	0.0861	0.0472	0.0000	0.0281	0.0000	0.0473	0.0000	0.0000	0.0000	0.0001	0.2121
BRB	3	c	May	0.0000	0.0000	0.0000	0.0000	0.6884	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6884
BRB	3	c	October	0.0000	0.0057	0.0000	0.0713	0.4989	0.0000	0.1539	0.0000	0.0096	0.0000	0.0000	0.0000	0.0000	0.7394

Bay	Station	Substation	Month	Amphipoda	Basommatophora	Clitellata	Coleoptera	Diptera	Ephemeroptera	Hemiptera	Hirudinida	Lepidoptera	Nematoda	Odonata	Trichoptera	Trombidiformes	Totals
FB	1	a	July	0.0037	0.0039	0.0076	0.0000	1.6242	0.0048	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.6442
FB	1	a	June	0.1308	0.0000	0.0788	0.0000	19.2468	0.0145	0.0082	0.0000	0.0000	0.0000	0.0000	0.0292	0.0000	19.5082
FB	1	a	May	0.0088	0.0000	0.0000	0.0000	6.3283	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	6.3371
FB	1	a	October	0.0002	0.0000	0.0009	0.0083	1.2025	0.0000	0.0023	0.0000	0.0000	0.0000	0.0050	0.0000	0.0005	1.2196
FB	1	a	September	0.0000	0.0185	0.0000	0.0000	6.0018	0.0000	0.0221	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	6.0424
FB	1	b	July	0.0002	0.0000	0.0197	0.0000	9.9669	0.0000	0.0006	0.0000	0.0000	0.0000	0.0078	0.0000	0.0058	10.0010
FB	1	b	June	6.3371	0.0000	0.0000	0.0000	19.7206	0.0000	0.4318	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	26.4895
FB	1	b	May	0.0508	0.0000	0.0000	0.0000	2.6970	0.0000	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.7493
FB	1	b	October	0.0001	0.0029	0.0027	0.0000	0.3409	0.0000	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3474
FB	1	b	September	0.0000	0.0023	0.0000	0.0000	3.6115	0.0000	0.0546	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	3.6684
FB	1	c	July	0.0001	0.0000	0.0000	0.0156	2.6334	0.0000	0.1684	0.0000	0.0000	0.0000	0.0226	0.0000	0.0006	2.8407
FB	1	c	June	0.0854	0.0000	0.0158	0.0000	15.6415	0.0000	0.5247	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	16.2673
FB	1	c	May	0.0135	0.0015	0.0000	0.0027	1.0046	0.0000	0.0099	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0322
FB	1	c	October	0.0002	0.0035	0.0000	0.0000	0.1848	0.0000	0.0134	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2020
FB	1	c	September	0.0000	0.0010	0.0000	0.0000	2.1138	0.0101	0.0673	0.0000	0.0000	0.0000	0.0881	0.0000	0.0000	2.2803
FB	2	a	July	0.0002	0.0000	0.0000	0.0000	1.5798	0.0000	0.0029	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.5829
FB	2	a	June	0.0008	0.0014	0.0000	0.0334	0.2317	0.0000	0.1275	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3948
FB	2	a	May	0.0000	0.0000	0.0000	0.0000	2.1554	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.1555
FB	2	a	October	0.0000	0.0000	0.0000	0.0145	1.5144	0.0000	0.0085	0.0000	0.0000	0.0000	0.0000	0.0000	0.0010	1.5384
FB	2	a	September	0.0063	0.0000	0.0000	0.1246	4.7685	0.0000	0.1252	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	5.0245
FB	2	b	July	0.0456	0.0000	0.0000	0.0000	2.9173	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.9629
FB	2	b	June	0.0000	0.0000	0.0000	0.0000	0.3624	0.0000	0.2330	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.5954
FB	2	b	May	0.0806	0.0000	0.0012	0.0000	0.2259	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3083
FB	2	b	October	0.0051	0.0060	0.0000	0.0000	5.6158	0.0000	0.0224	0.0000	0.0000	0.0000	0.0285	0.0000	0.0000	5.6778
FB	2	b	September	0.0103	0.0005	0.0000	0.0000	7.7018	0.1172	0.0683	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	7.8981
FB	2	c	July	0.0000	0.0000	0.0000	0.0000	1.2552	0.0000	0.0378	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.2931
FB	2	c	June	0.0000	0.0000	0.0089	0.0316	0.0882	0.0000	0.2102	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3389
FB	2	c	May	0.0000	0.0000	0.0000	0.0154	0.2218	0.0000	0.0027	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2399
FB	2	c	October	0.0013	0.0000	0.0000	0.0188	1.8457	0.0000	0.0440	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.9099
FB	2	c	September	0.0050	0.0120	0.0010	0.0062	0.3797	0.0073	0.0884	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.4995
FB	3	a	July	0.0000	0.0000	0.0000	0.0000	0.0344	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0349
FB	3	a	June	0.0000	0.0000	0.0000	0.0000	0.1198	0.0000	0.0146	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1344
FB	3	a	May	0.0106	0.0000	0.0000	0.0088	0.0214	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0409
FB	3	a	October	0.0000	0.0000	0.0000	0.0000	0.0049	0.0000	0.0020	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0069
FB	3	a	September	0.0000	0.0000	0.0000	0.0000	0.0102	0.0014	0.3435	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3551
FB	3	b	July	0.0001	0.0000	0.0000	0.0000	0.0706	0.0000	0.0555	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1262
FB	3	b	June	0.0000	0.0000	0.0000	0.0281	0.4683	0.0000	1.5673	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.0638
FB	3	b	May	0.0000	0.0000	0.0000	0.0000	0.0258	0.0000	0.0026	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0284
FB	3	b	October	0.0000	0.0000	0.0000	0.0012	0.2837	0.0000	0.0624	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3474
FB	3	b	September	0.0000	0.0000	0.0000	0.0132	0.1232	0.0000	0.0658	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2022
FB	3	c	July	0.0000	0.0000	0.0000	0.0176	0.0748	0.0000	0.6578	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.7501
FB	3	c	June	0.0000	0.0000	0.0000	0.0000	0.0307	0.0000	0.1492	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1799
FB	3	c	May	0.0000	0.0000	0.0000	0.0000	0.0138	0.0000	0.0058	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0196
FB	3	c	October	0.0000	0.0004	0.0000	0.0032	0.6058	0.0001	0.0351	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6446
FB	3	c	September	0.0000	0.0000	0.0000	0.2094	0.1206	0.0000	0.0350	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3649

Appendix 11. Lengths and weights of fish captured in gill nets in Bear River and Farmington Bays in June 2018.

Transect	Station	Replicate net	Species	Standard length (mm)	Weight (g)
Bear River Bay					
1	A	1	Common carp	197	231
1	A	1	Common carp	195	200
1	A	1	Common carp	197	187
1	A	2	Common carp	275	620
1	A	2	Common carp	246	245
1	A	2	Common carp	243	390
1	A	2	Common carp	253	445
1	A	2	Common carp	240	385
1	A	2	Common carp	223	326
1	A	2	Utah chub	190	140
1	A	2	Utah chub	190	140
1	A	2	Utah chub	130	47
1	A	2	Utah chub	143	52
1	A	2	Utah chub	139	66
1	A	2	Utah chub	139	52
1	A	2	Utah chub	131	45
1	A	2	Utah chub	118	38
1	A	2	Green sunfish	78	16
2	A	1	Common carp	220	275
2	A	1	Common carp	137	65
2	A	1	Common carp	224	260
2	A	1	Common carp	223	248
2	A	1	Common carp	199	205
2	A	1	Common carp	192	185
2	A	1	Common carp	185	160
2	A	1	Common carp	163	125
2	A	1	Common carp	165	118
2	A	1	Common carp	167	120
2	A	1	Common carp	165	115
2	A	1	Common carp	124	52
2	A	2	Green sunfish	75	19
2	A	2	Common carp	152	110
2	A	2	Common carp	125	56
3	Not sampled				

Transect	Station	Replicate net	Species	Standard length (mm)	Weight (g)
Farmington Bay					
1	A	2	Utah chub	172	99
1	A	2	Utah chub	172	101
1	A	2	Utah chub	169	86
1	A	2	Utah chub	140	59
1	A	2	Utah chub	145	64
1	A	2	Utah chub	131	53
1	A	2	Utah chub	113	37
1	A	2	Utah chub	142	53
1	A	2	Utah chub	122	40
1	A	2	Utah chub	120	37
1	A	2	Utah chub	130	49
1	A	2	Utah chub	126	38
1	A	2	Utah chub	120	43
1	A	2	Utah chub	122	38
1	A	2	Utah chub	130	47
1	A	2	Utah chub	119	40
1	A	2	Utah chub	141	59
1	A	2	Utah chub	103	22
1	A	2	Utah chub	130	46
1	A	2	Utah chub	131	47
1	A	2	Utah chub	121	40
1	A	2	Utah chub	131	48
1	A	2	Utah chub	126	43
1	A	2	Utah chub	130	38
1	A	2	Utah chub	124	38
1	A	2	Utah chub	160	101
1	A	1	Utah chub	130	43
1	A	1	Utah chub	116	36
1	A	1	Utah chub	129	44
1	A	1	Utah chub	123	49
1	A	1	Utah chub	130	41
1	A	1	Utah chub	119	39
1	A	1	Utah chub	120	37
1	A	1	Utah chub	80	10
1	A	1	Utah chub	162	69
1	A	1	Utah chub	149	87
1	A	1	Utah chub	170	94
1	A	1	Utah chub	160	79
1	A	1	Utah chub	160	91
1	A	1	Utah chub	142	57
1	A	1	Utah chub	150	68
1	A	1	Utah chub	181	106
1	A	1	Utah chub	139	63
1	A	1	Utah chub	150	71
1	A	1	Utah chub	150	65
1	A	1	Utah chub	138	43
1	A	1	Utah chub	142	49
1	A	1	Utah chub	153	57
1	A	1	Utah chub	141	60
1	A	1	Utah chub	152	78
1	A	1	Utah chub	111	35
1	A	1	Utah chub	156	80
1	A	1	Common carp	119	43
1	A	1	Common carp	151	120
1	A	1	Utah chub	128	48
1	A	1	Utah chub	141	79
1	A	1	Utah chub	137	51
1	A	1	Utah chub	156	73
1	A	1	Utah chub	132	44
1	A	1	Utah chub	120	42
1	A	1	Utah chub	130	44
1	A	1	Utah chub	132	45
1	A	1	Utah chub	134	49
1	A	1	Utah chub	125	40
1	A	1	Utah chub	135	50
1	A	1	Utah chub	115	36
1	A	1	Utah chub	126	44
1	A	1	Utah chub	122	41
1	A	1	Utah chub	132	48
1	A	1	Utah chub	128	50
1	A	1	Utah chub	126	44
1	A	1	Utah chub	127	43
1	A	1	Utah chub	131	48
1	A	1	Utah chub	120	35
2	A	1	-	0	0
2	A	2	-	0	0
3	A	1	-	0	0
3	A	2	-	0	0

Appendix 12. Diets of birds from Bear River and Farmington Bays. In most cases, diets are % by weight or volume. Data were derived from Barber and Cavitt (no date), Gaffney (2009), Roberts (2013) and Osmundson (1990).

Area	Species	Sample size (N)	Artemia adults	Diptera (chironomids & other gnats)	Brine fly larvae, pupae & adults	Hemiptera (corixids & others)	Misc. Invert.	Minnows	Carp	Suckers	Seeds & Plants
Bear River Bay											
	American Avocet (Recurvirostra americana)	95		79.5		11.0	7.3				2.1
	American White Pelican (P. erythrorhynchus)	-					0.0	66.0	20.0	4.0	
	Cinnamon Teal (Anas cyanoptera)	2					0.0				100.0
	Great Blue Heron (Ardea herodias)	6					1.7	25.8	16.7	33.0	22.5
	Northern Pintail (Anas acuta)	6					0.0				100.0
Farmington Bay											
	Cinnamon Teal (Anas cyanoptera)	4		71.0			0.0				29.0
	Eared Grebe	39	14.1	36.3	11.5	23.8	0.8	0.0	0.0	0.0	15.0
	Gadwall (Anas strepera)			92.0			0.0				8.0
	Green-winged Teal (Anas carolinensis)	4		77.0			0.0				23.0
	Northern Pintail (Anas acuta)	1					0.0				100.0
Farmington Bay/Bear River Bay											
	American Avocet (Recurvirostra americana)	-		41.2	6.1	28.2	6.1				15.0
	Black-necked Stilt (Himantopus mexicanus)	-		26.7	8.8	47.2	11.0				4.0
Gilbert Bay or unspecified bay of GSL											
	California gull (Larus californicus)										
	Common Goldeneye (Bucephala clangula)										
	Northern Shoveler (Anas clypeata)			Data available but not relevant to Farmington and Bear River Bay study							
	Red-necked Phalarope (phalaropus lobatus)										
	Wilson's Phalarope (Phalaropus tricolor)										
Species with no data for Great Salt Lake											
	American Coot (Fulica americana)										
	American Widgeon (Anas americana)										
	Baird's Sandpiper (Calidris bairdii)										
	Black Tern (Chlidonia niger)										
	Black-bellied Plover (Pluvialis squaterola)										
	Black-crowned Night-Heron (N. nycticorax)										
	Blue-winged Teal (Anas discors)										
	Bufflehead (Bucephala albeola)										
	Calark's Gree (Aechmophorus clarkii)										
	Canada Goose (Branta canadensis)										
	Canvasback (Aythya valisineria)										
	Caspian Tern (Hydroprogne caspia)										
	Eared Grebe (Podiceps nigricollis)										
	Forster's Tern (Sterna forsteri)										
	Franklin's Gull (Leucophaeus pipixcan)										
	Greater Yellowlegs (Tringa melanoleuca)			No data for Great Salt Lake, but available from other water bodies							
	Killdeer (Charadrius vociferus)										
	Least Sandpiper (Calidris minutilla)										
	Lesser Scaup (Aythya affinis)										
	Lesser Yellowlegs (Tringa flavipes)										
	Long-billed Curlew (Numenius americanus)										
	Long-billed Dowitcher (L. scolopaceus)										
	Marbled Godwit (limiosa fedoa)										
	Pied-billed Grebe (Podiymbus podiceps										
	Red-billed Gull (Larus delawarensis)										
	Redhead (Anthya americana)										
	Ruddy Duck (Oxyura jamaicensis)										
	Sanderling (Calidris alba)										
	Sandhill Crane (Grus canadensis)										
	Snowy Egret (Egretta thula)										
	Snoy Plover (Charadrius nivosus)										
	Spotted Sandpiper (Actitis macularius)										
	Western Grebe (A. occidentalis)										
	Western Sandpiper (Calidris mauri)										
	White-faced Ibis (Plegadis chihi)										
	Willet (Tringa semipalmata)										