DRAFT REPORT
Macroinvertebrate and Zooplankton Communities of the Willard Spur Wetlands: Summary Results of 2011-2013 Sampling

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30 September 2015

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1. Summary

This report summarizes the results of all three years of sampling of the macroinvertebrate and zooplankton communities present in the Willard Spur wetlands as part of the development of water quality standards pursuant to the operation of the newly-constructed Perry/Willard Regional Wastewater Treatment Plant. Composition, seasonal trends, and annual trends in the macroinvertebrate community are given in the first section; the second section describes the composition, seasonal changes, and annual changes in the zooplankton community. Suggestions for future study of the macroinvertebrate and zooplankton communities are given in the final section.

As noted in previous reports, the common macroinvertebrate taxa present in the Willard Spur are widely-distributed taxa found in other impounded wetlands along the Great Salt Lake. The relative contribution of the major taxa is also similar with differences largely due to greater sampling effort and the effects of low water levels in 2012 and 2013 in the Willard Spur.

The abundance of macroinvertebrates, measured by counts of individuals and biomass, varied between seasons and between years. Greatest abundance was observed in Summer 2012 (from large numbers of snails) and Spring 2013 (large numbers of chironomids). Abundance was least in Fall 2013 as a result of extensive drying over much of the Willard Spur.

A comparison of macroinvertebrate community metrics (percent PMI and Simpson's Index) between years and between the Willard Spur and other impounded wetlands also reflected changes in flows in the Spur. Both metrics in the Willard Spur followed seasonal trends in growth and senescence of submerged aquatic vegetation with values declining rapidly with decreased flows and drying.

A more detailed examination of peripheral sites sampled in July 2012 revealed the impact of low water levels as a controlling factor for macroinvertebrates. In general, a water depth of 20 cm appears to represent a critical depth in terms of significant change in macroinvertebrate community composition and diversity.

A rough approximation of the role of macroinvertebrate excretion and egestion on nitrogen levels in the water column of the Willard Spur is presented. Overall,

macroinvertebrates have little effect on nitrogen levels, even when biomass is high and water levels are low.

The common zooplankton species found in the Willard Spur during the study period are also common species that have been collected in other GSL wetlands. As with the macroinvertebrate community, the zooplankton community reflected changes in SAV abundance and the effects of water levels on vegetation and water chemistry.

Macroinvertebrate and zooplankton communities in the Willard Spur are affected by similar environmental factors, including the amount of spring runoff, abundance and longevity of aquatic vegetation, and effects of low water levels. Both communities are influenced by the influx of individuals from surrounding aquatic habitats as well as the export of individuals from the Willard Spur to other habitats. These inter-habitat exchanges contribute to the resiliency of these communities after major disturbance, such as drought.

2. Methods

Sampling intensity, both in terms of the number of sites sampled and frequency of sampling, varied among the years. In 2011, samples were collected at 43 sites, including several in the upper Spur near inflows from the Willard Bay tailrace, the old treatment plant channel, and an irrigation channel; 12 sites in mid-channel along the length of the Spur, peripheral sites near the shoreline both north and south of each mid-channel sites (designated “A” and “B”), and a site near the inflow from the Harold Crane drainage ditch (see maps in CH2MHill 2011, 2012). Samples were collected in early March and then from June through October at monthly intervals; however, most samples were collected in August and October. Due in part to logistical difficulties, most sites were sampled only in 2-3 of the 5 months, and only one site (WS-1) was sampled during the entire sampling period. Peripheral sites were sampled only in August. In 2012, 28 sites were sampled, including the mid-channel sites samples in 2011 (WS-1 to WS-12), peripheral sites north and south of the mid-channel sites between the mid-channel sites and the shoreline (designated “C” and “D”), Willard Bay tailrace sites, and the site near the inflow from the Harold Crane drainage ditch. Samples were collected starting in late April and continued monthly until late November. Seven of the eleven

mid-channel sites were sampled in at least four of the seven months. Some sites could not be sampled in certain months due to declining water levels. Peripheral sites were sampled only in July. Only four sites were sampled in 2013, including three mid-channel sites and one tailrace site. Sampling began in late March and continued monthly through November. The mid-channel sites could not be sampled in August and September due to low water levels.

Because of logistical difficulties, low water levels, and perhaps other reasons, only four sites were sampled during the same month (at least within two weeks) in all three years (WS-3 in October, WS-6 in June and October, and WS-8 in June). This amounted to 12 site-month combinations out of a total of 203 sampled during the three years, or only 6% of the sampling effort. This number is emphasized because the lack of data for the same sites in the same months for all years restricts the degree and types of analyses that can be used to examine overall trends. As indicated below, the lack of directly comparable samples meant combining sample data, either by season at the same site or by month at several sites, in order to have sufficient sample size to conduct analyses. Statistical methods followed procedures in Elliott (1971), Green (1979), McCune & Grace (2002), and Peck (2010).

Macroinvertebrate and zooplankton samples were collected from the Willard Spur by Utah Division of Water Quality personnel. Macroinvertebrates were collected with a D-net sampler (0.5-mm mesh) according to the DWQ SOP. Zooplankton were collected with a tow net (0.25-mm mesh) according to DWQ SOP. Samples were preserved in the field in ethanol. Processing of samples followed DWQ SOPs. Data collected for macroinvertebrates included counts of individuals by taxon, biomass, and derived community metrics (Simpson's Index and %PMI; Gray 2011, 2012, 2015). Zooplankton data included counts of individual taxa that were used to determine percentage composition of the community.

Occasional references are made to the results of other DWQ studies at impounded wetlands along the Great Salt Lake in previous years (e.g., Gray 2009-2011). Macroinvertebrate and zooplankton samples from those studies were collected and processed using the same DWQ SOPs as the Willard Spur samples.

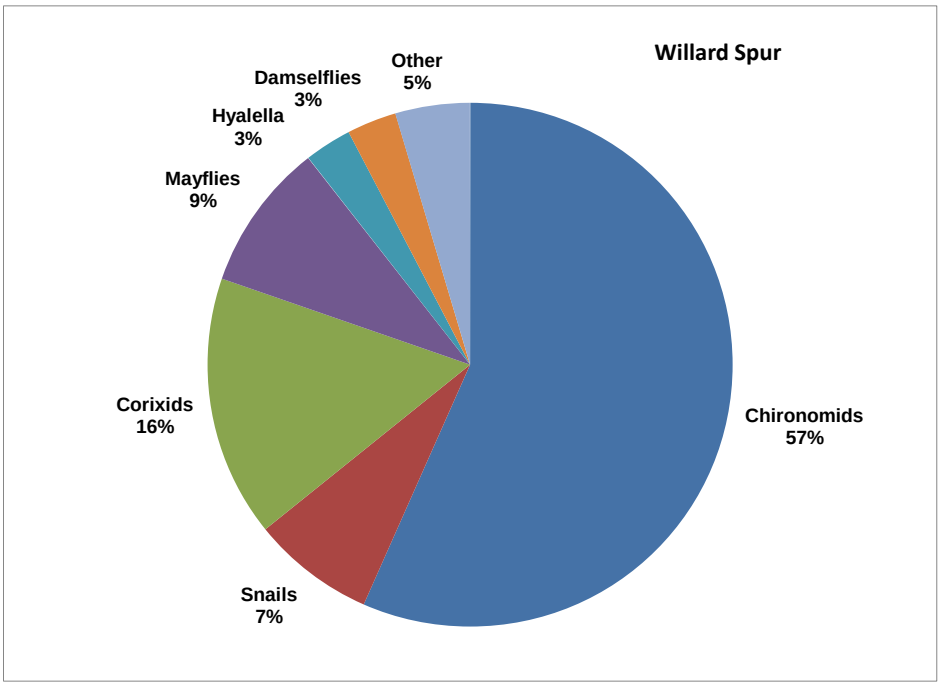
3. Macroinvertebrates

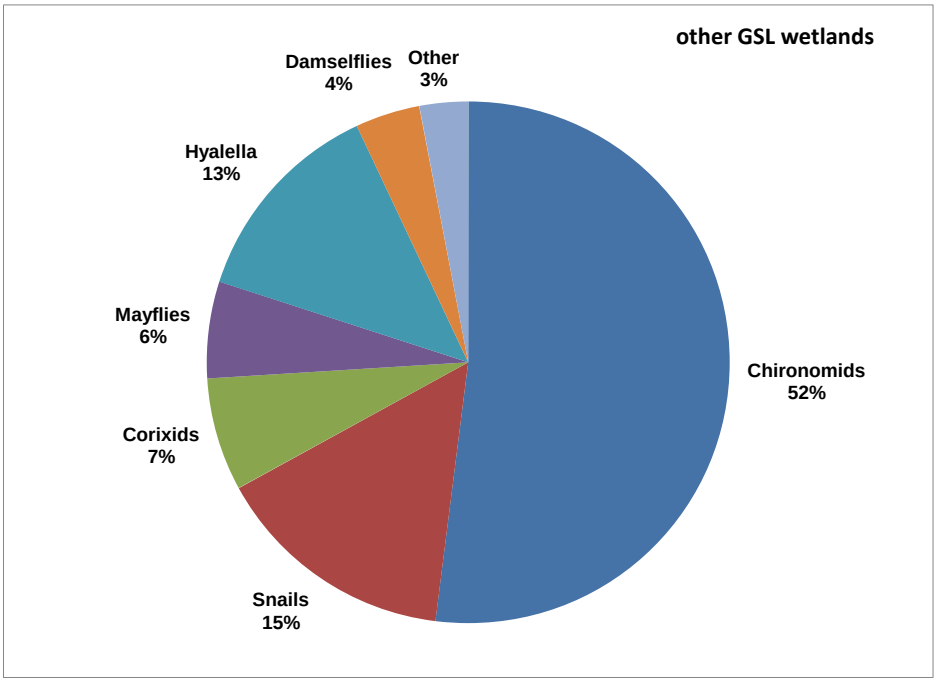
3.1 Community Composition

A list of all macroinvertebrate taxa collected in the Willard Spur during the three years of sampling is given in Table 3.1. As noted in previous reports, the communities in the Willard Spur are very similar to communities found in other impounded wetlands along the Great Salt Lake. In Figure 3.1, the composition of the communities in the Willard Spur is compared to that of other impounded wetlands. Overall, there is a high degree of similarity with only minor differences in the relative abundance of some taxa. Differences evident for some taxa (e.g., corixids, snails, and amphipods) are due to the more extensive sampling throughout the summer months and the low-water conditions in the Willard Spur during 2012 and 2013.

Differences in the macroinvertebrate communities between years within the Willard Spur have been discussed in prior reports (Gray 2013, 2015). Briefly, the macroinvertebrate taxa present in the Spur were the same in all years, but shifts in the relative abundance of the various taxa did occur between years. The more rapid decline in the aquatic vegetation and increasingly stagnant conditions as water levels dropped during late summer 2012 and early summer 2013 resulted in a greater dominance by detritivores and taxa tolerant of low oxygen, such as chironomids and corixids, relative to taxa associated with the aquatic vegetation, such as damselflies and mayflies. The earlier drying in 2013 also interfered with reproductive cycles, particularly for snails.

Figure 3.1. Composition of macroinvertebrate communities. Top graph shows the Willard Spur composition for all main channel site samples from 2011-2013. Bottom graph shows the composition in other GSL impounded wetlands (samples collected in May, July, and November in 2010 and 2011 from the Ambassador, New State, and Harrison Duck Clubs; and Public Shooting Grounds, Farmington Bay WMA, and Bear River NWR; 60 samples total).





3.2 Comparison of Macroinvertebrate Abundance between Years and Seasons

Overall abundance of macroinvertebrates varied greatly between the three years of sampling. As noted previously (Gray 2012), numbers of macroinvertebrates seemed particularly low in 2011 relatively to other impounded wetlands; later, abundance in 2011 appeared low relative to overall abundance in 2012 and 2013. These conclusions were based on annual averages of combined sample counts for all main channel sites sampled each year.

In order to examine the differences in abundance between years within the Willard Spur in more detail, counts per sample and biomass per sample data were compared annually and each year by season for the middle sites (WS-3, WS-6, and WS-8), i.e., the sites that had at least some macroinvertebrate data for all three years in each season. Seasons were defined as Spring: March-May, Summer: June-August, and Fall: September-November. This approach allowed for a more congruent comparison of abundance between years and seasons while still providing sufficient samples sizes.

Figures 3.2.1 and 3.2.2 show the trend line in abundance by season for the entire sampling period and statistical analysis of sample counts by season, respectively. During Spring, there was significant increase in counts in 2013 compare to previous years, primarily due to increased numbers of chironomids (*Chironomus* and *Tanypus*) from the overwintering generations. In the report on the 2011 sampling (Gray, 2012), several reasons for the low Spring numbers in 2011 were given, including greater surface area from higher flows, cold water temperatures, and lack of detritus due to the flushing action of runoff. Of these reasons, the flushing action from runoff appears to be the most likely. Chironomid numbers were also low in Spring 2012 when runoff also caused the Spur to overflow into Bear River Bay as in 2011, as well as low numbers in the overwintering generations from Fall 2011. The large numbers of chironomids in 2013 could be the result of the lack of significant flushing from low runoff in Spring 2013 (CH2M Hill 2015), in addition to much larger overwintering populations from Fall 2012. High densities of chironomids in May have been found previously in other GSL impounded wetlands when large amounts of detritus remained from the previous Fall (personal observation).

There was no difference between sample counts during Summer between years despite the more rapid decline in aquatic vegetation (SAV) in 2012 and 2013. The main difference between years during Summer was the large number of snails caused by an abundance of periphyton on senescing SAV (Hoven et al. 2013). Snails did not reach 2012 population levels in Summer 2013 due to the more rapid decline in SAV and subsequent drying during what normally would have been the peak reproductive period in July and early August (see Gray 2012 for a discussion snail life cycles).

Fall counts showed the effects of drying in 2012 and 2013 but with differing effects each year. In 2012, water levels declined but most areas still had some surface water present. Although the lower water levels resulted in greater oxygen stress and higher salinities (Gray 2013), total counts were similar in Fall 2011 and 2012. In 2013, the lower Spur main channel sites went completely dry in August and September, and few macroinvertebrates were present when flows returned.

Biomass followed similar seasonal trends as the sample counts. The main exception was the high biomass of snails in Summer 2012 (Fig. 3.2.3).

In summary, Spring abundance showed a significant difference between years in both counts and biomass due to high chironomid numbers in 2013. Summer abundance was not significantly different between years for sample counts, but biomass was significantly higher in Summer 2012. Fall abundance was significantly lower for both counts and biomass in 2013 due to drying.

On an annual basis, i.e., combining samples from all seasons, there was no significant difference between years in sample counts (ANOVA, $P = 0.10$). For biomass, 2011 had significantly lower biomass than the other two years ($P = 0.02$).

Figure 3.2.1. Abundance of macroinvertebrates in the Willard Spur by season during the three years of sampling. Plotted values are means of ln-transformed data from the middle Spur sites (WS-3, WS-6, and WS-8). Note: Due to the small number of samples in Spring 2011, samples from WS-1 and WS-2 were also included.

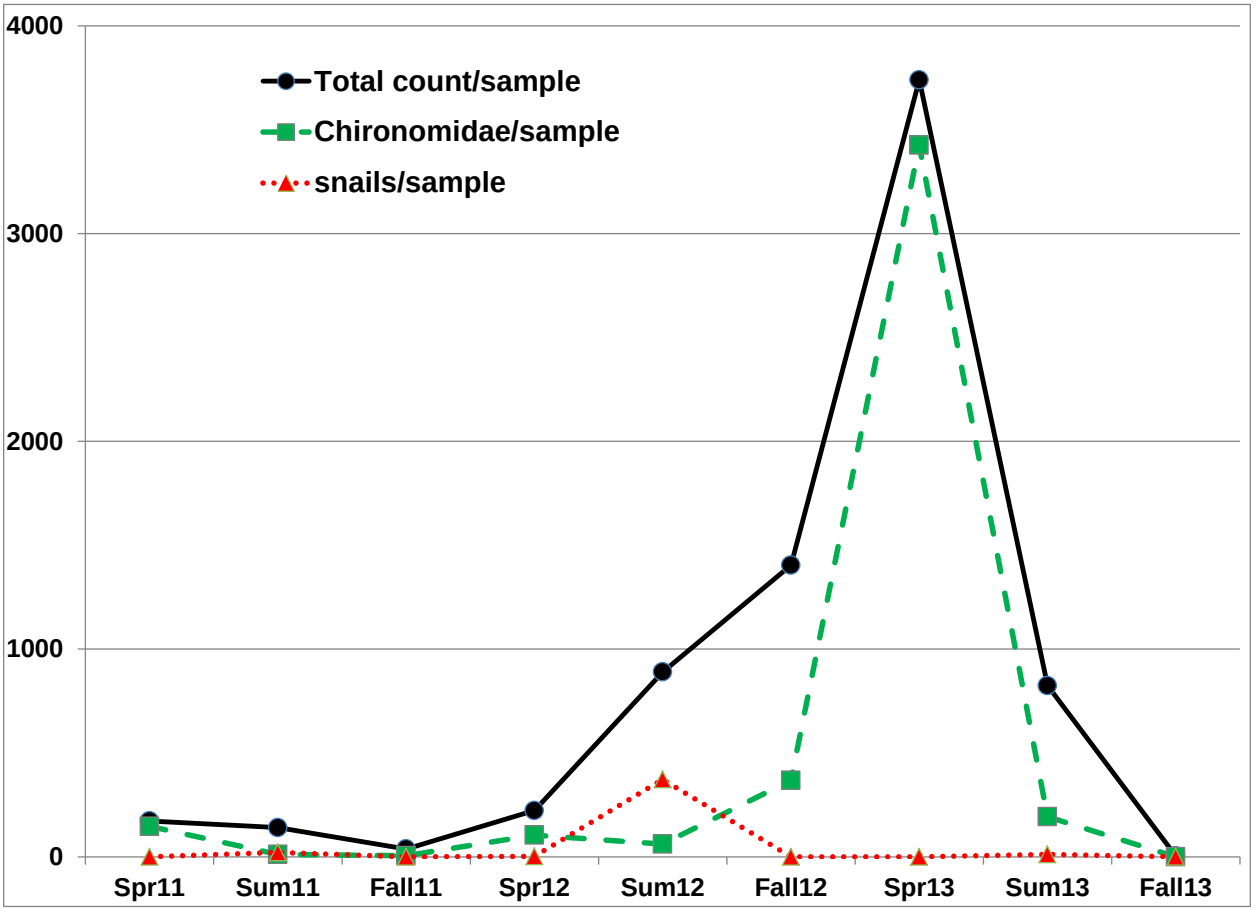


Figure 3.2.2. Sample counts of macroinvertebrates in the Willard Spur by year and season during the three years of sampling. Plotted values are means of ln-transformed data from the middle Spur sites (WS-3, WS-6, and WS-8). Note: Due to the small number of samples in Spring 2011, samples from WS-1 and WS-2 were also included. Error bars show 95% confidence limits.

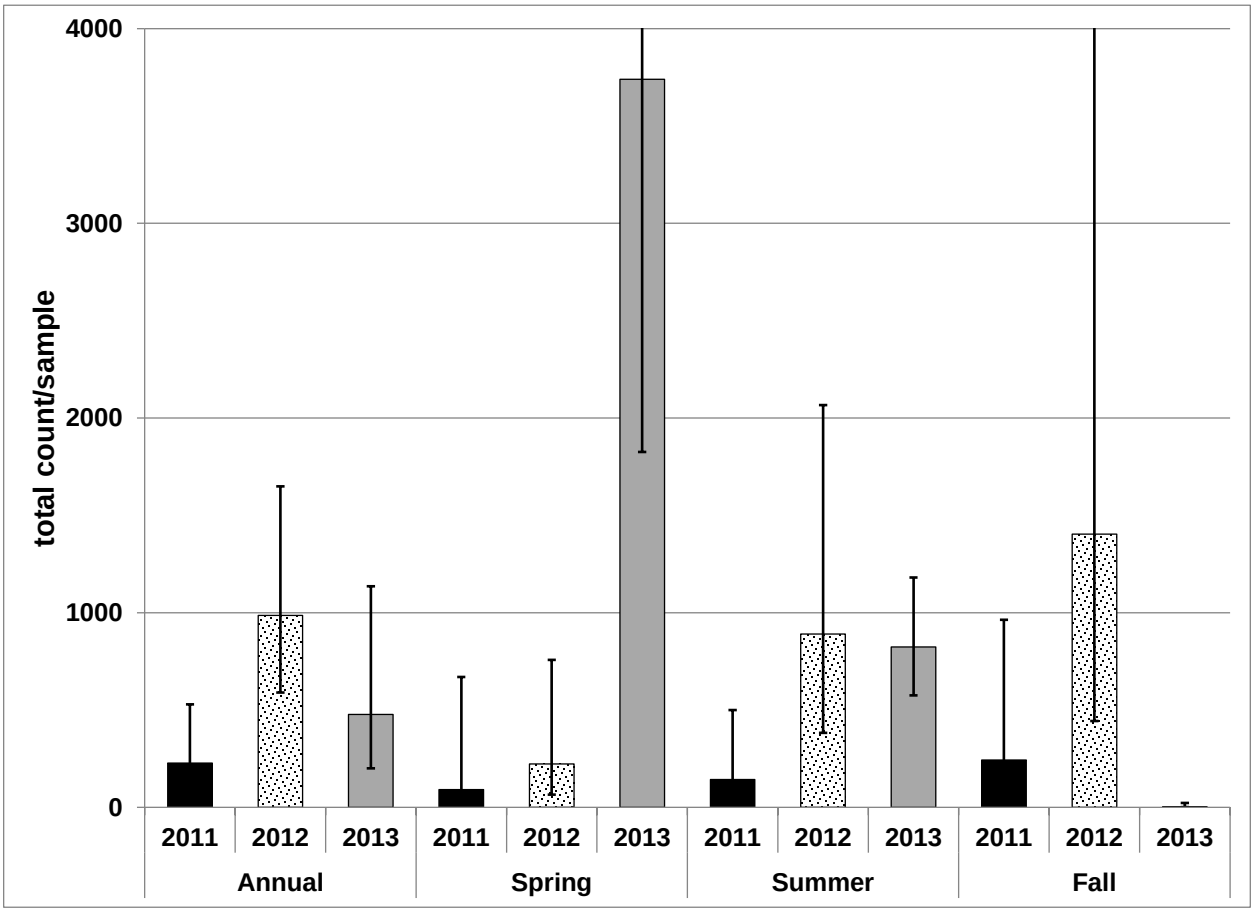
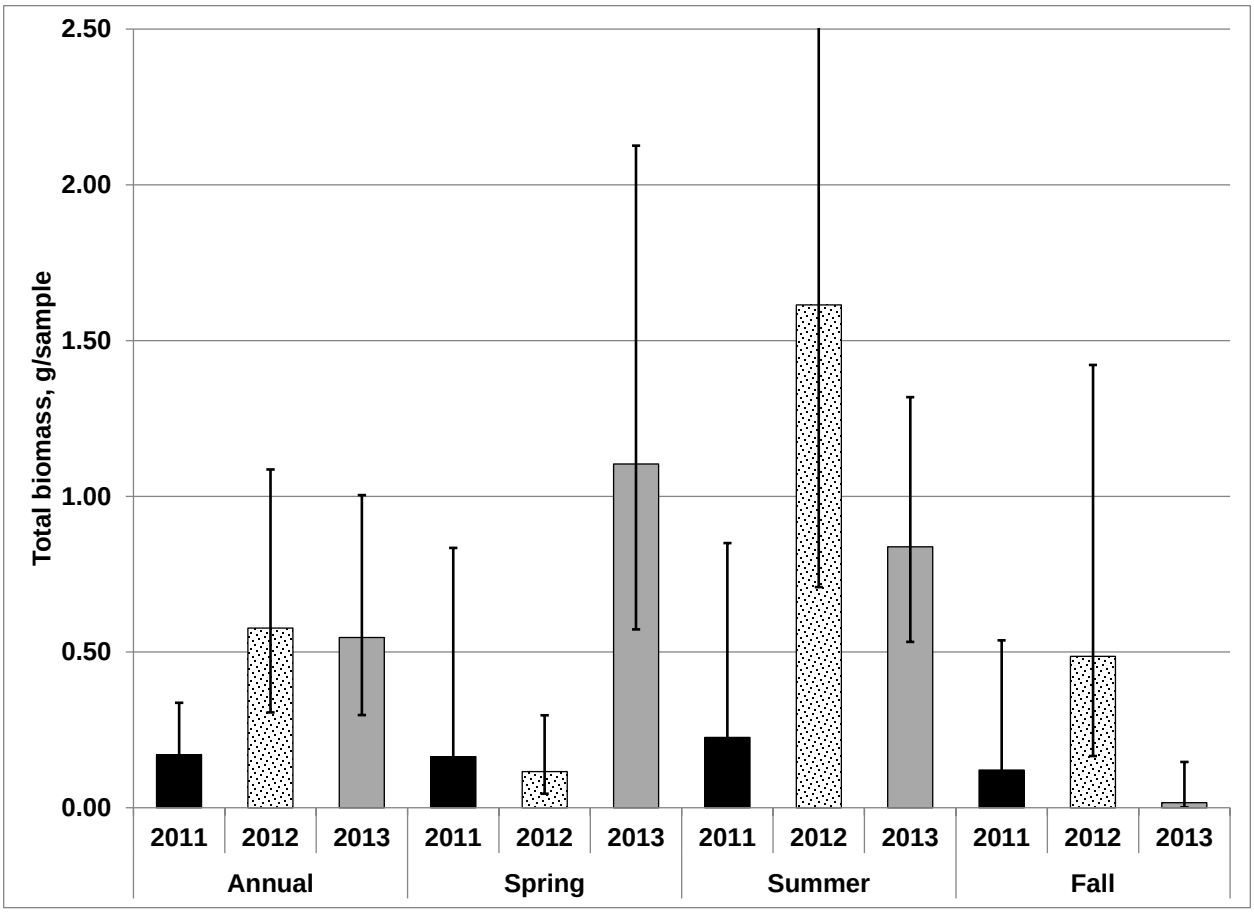


Figure 3.2.3. Sample biomass (grams dry mass) of macroinvertebrates in the Willard Spur by year and season during the three years of sampling. Plotted values from the same sites noted in Fig. 3.2.2. Error bars show 95% confidence limits.



3.3 Macroinvertebrate Community Metrics

Background on the two macroinvertebrate community metrics, percent PMI (phytophilous macroinvertebrates) and Simpson's Index, that have been used as indicators of community changes in the GSL wetlands and the Willard Spur was discussed in Gray (2012), and trends in the annual sampling periods in the Willard Spur were also discussed in Gray (2013, 2015). The focus here is to relate the seasonal trends in each year of sampling in the Willard Spur to the general trends observed in other GSL wetlands.

The annual trends in the percent PMI metric in the Willard Spur reflected the extensive growth of SAV in 2011 which persisted into Fall (Fig. 3.3.1). Values were lower in Summer 2011 in the Spur compared to the general trend in similar GSL wetlands, but this may have been due to the unusually high runoff the preceding spring. By Fall 2011, percent PMI in the Willard Spur was the same as other wetlands where the SAV persisted through Fall. Both low-runoff years were similar to 2011 through July, but the loss of SAV as water levels declined in late summer resulted in no PMI taxa being present even after flows returned in the Fall.

A similar pattern was seen in the Simpson's Index (Fig. 3.3.2). The Willard Spur communities were similar to other GSL wetlands through mid-summer. By Fall, diversity had declined and only a few taxa (mainly chironomids and corixids) were present when flows returned.

Figure 3.3.1. Comparison of seasonal changes in mean percent PMI metric in the Willard Spur relative to GSL wetlands. Willard Spur data from all main channel sites sampled each year. Data from the other wetlands collected from sites mentioned in Fig. 3.1 and additional sites. "GSL IW-high SAV" refers to other impounded wetlands where the SAV was extensive and persisted through the summer. "GSL IW-low SAV" refers to sites where either the SAV senesced in early summer or was sparse.

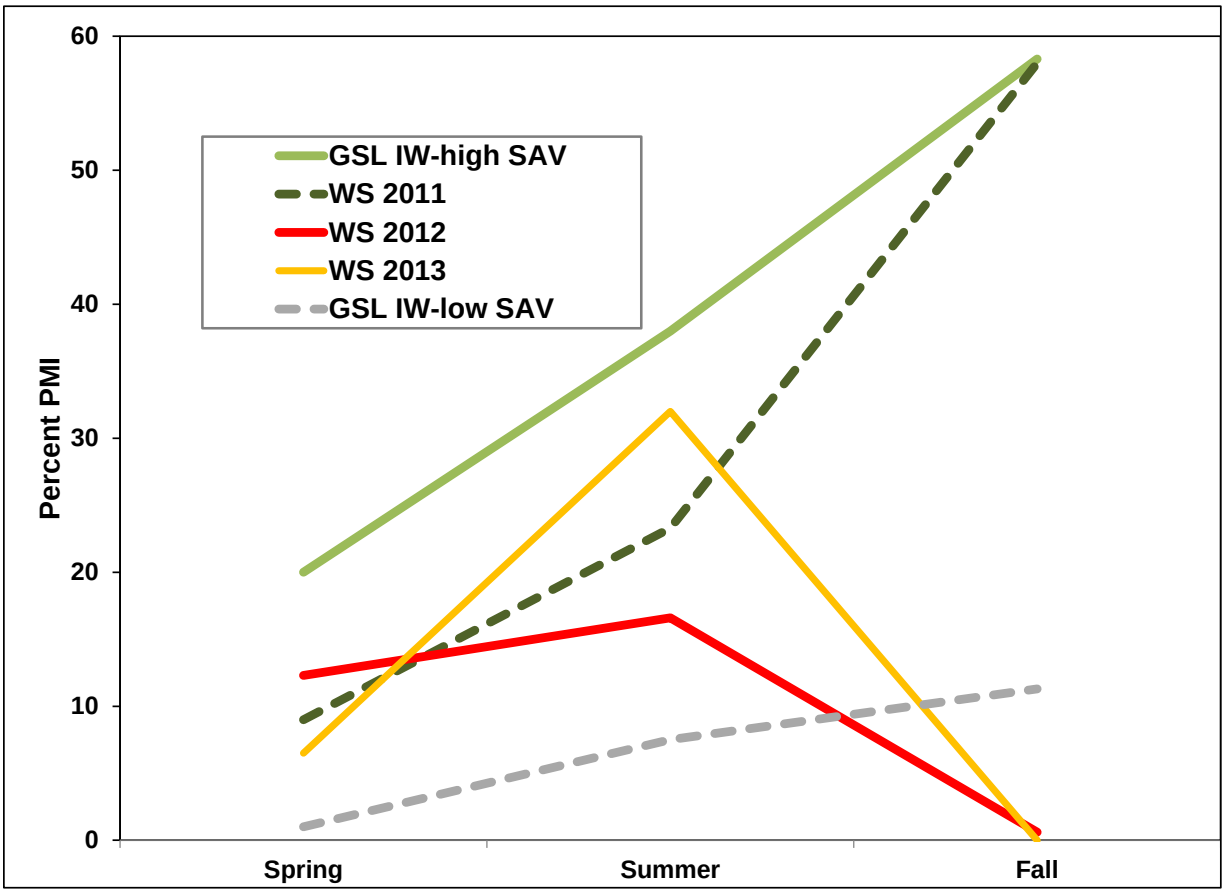
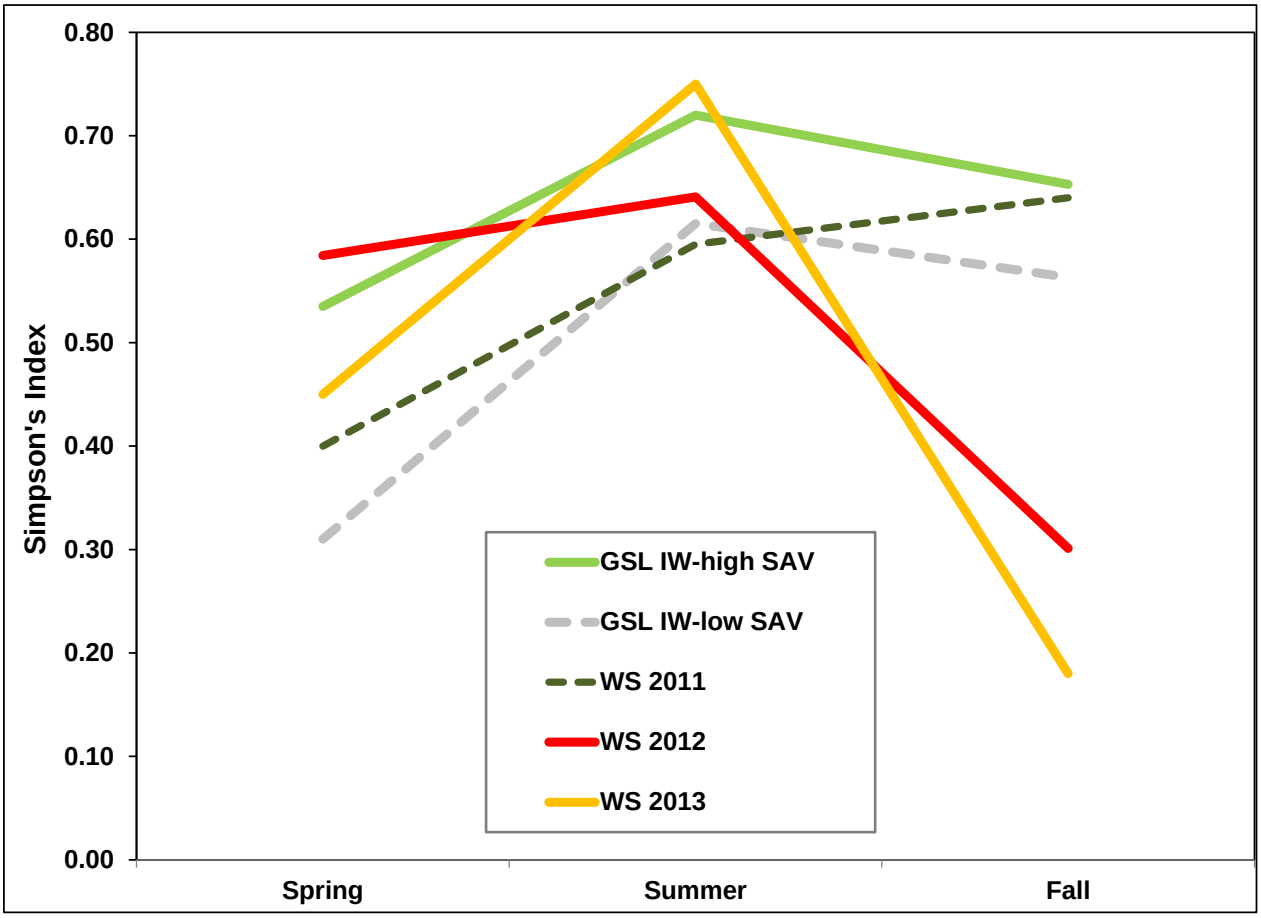


Figure 3.3.2. Comparison of seasonal changes in mean Simpson's Index metric in the Willard Spur relative to GSL wetlands. Data sources and legend are the same as in Fig. 3.3.1.



3.4 Peripheral Sites and Effects of Low Water Levels

In addition to the mid-channel sites in the Willard Spur, additional sites were sampled as discussed above in Section 2. The macroinvertebrate communities at these sites have been discussed in the previous annual reports (Gray 2012, 2013, 2015).

One set of samples, collected at sites located roughly half-way between the mid-channel sites and the shoreline (the “C” and “D” sites in Fig. 3-6 in CH2M Hill 2012), are discussed here to further illustrate the influence of water depth on macroinvertebrate communities.

In August 2011, the macroinvertebrate communities at the perimeter sites showed changes in taxonomic composition that corresponded with habitat changes (shallow water levels, decreased SAV cover, and higher salinity) relative to the mid-channel sites (Gray 2012). The perimeter sites in July 2010 had similar changes in habitat and macroinvertebrate community composition that reflected reduced water levels.

Figure 3.4.1. shows a comparison of the taxonomic composition between the center and perimeter sites using NMS analysis based on sample counts of individual taxa. Axis 1 was most influenced by the relative abundance of PMI taxa (mayflies, odonates, caddisflies, and chrysomelid beetles) and *Hyalella* amphipods, while Axis 2 was most influenced by the relative abundance of hemipterans (mainly corixids) and snails. The blue line in the graph separates two main groups of sites; sites above the blue line were all shallow (20 cm or less) and dominated by corixids, whereas sites below the blue line were deeper and showed greater relative abundance of snails and *Hyalella* amphipods (Fig. 3.4.2). These results, along with the August 2011 results, indicate that a water depth of ca. 20 cm may represent a critical depth in terms of significant changes in community composition and diversity, and that these changes occur not just at sites that are typically shallow (e.g., near-shore), but at deeper, mid-channel sites when water levels decline.

Figure 3.4.1. Comparison of taxonomic composition between the Center (M), North (C), and South (D) transect sites in July 2012. Plot of NMS scores for the first two axes using sample counts of macroinvertebrate taxa. The 2 points labelled "3M" represent replicate samples at that site.

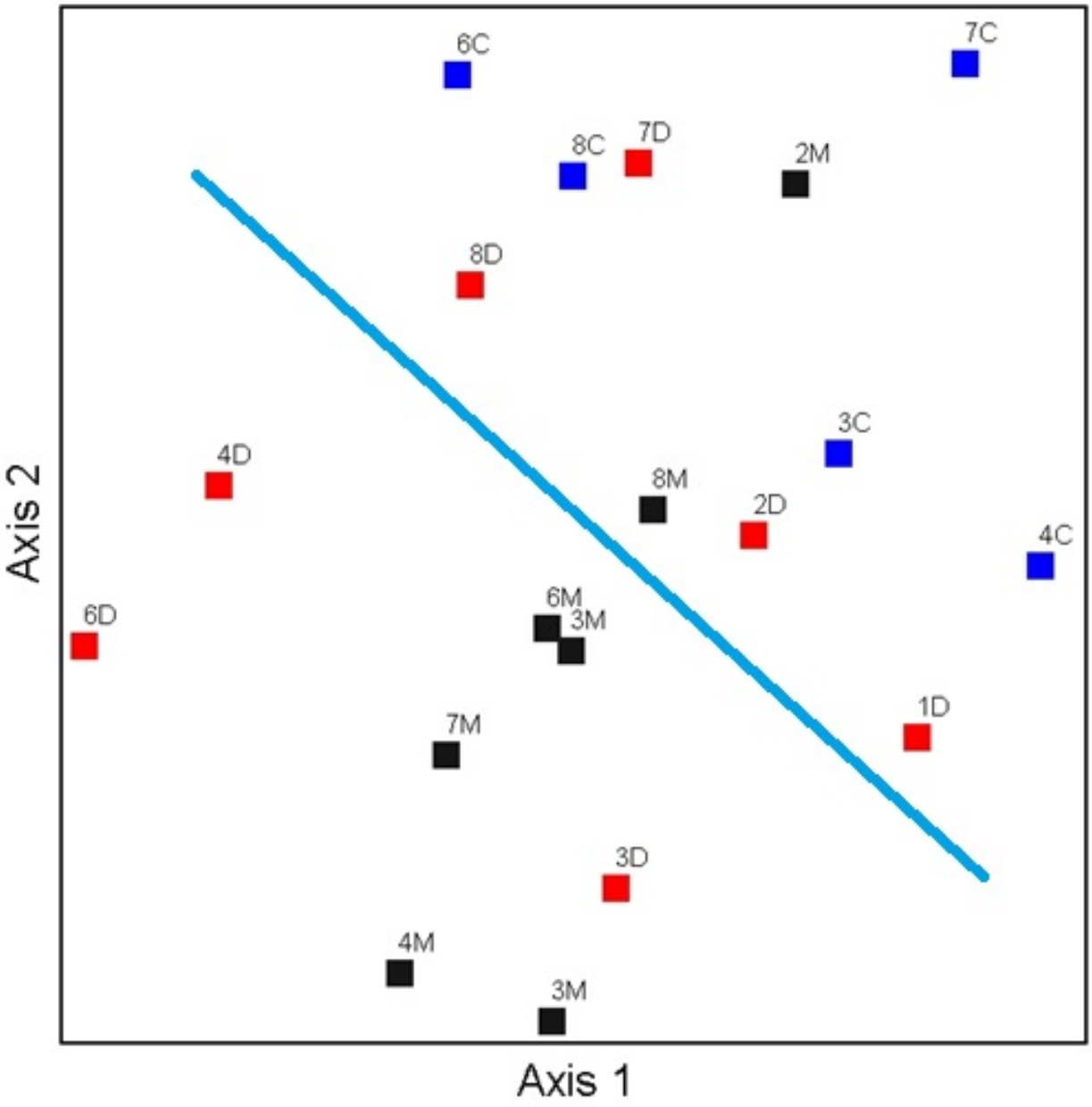
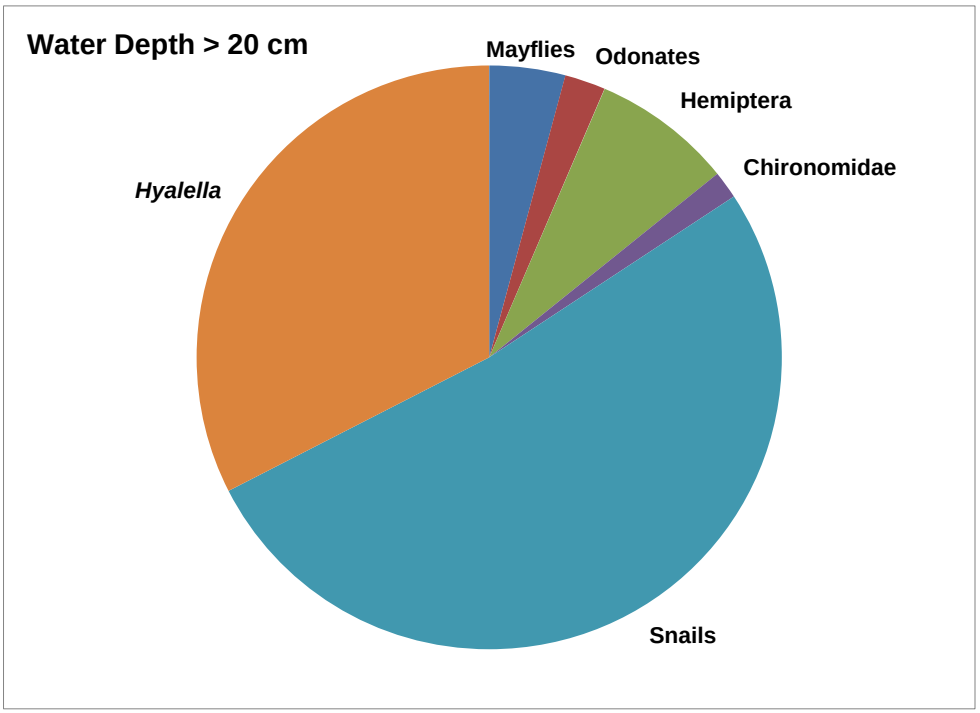
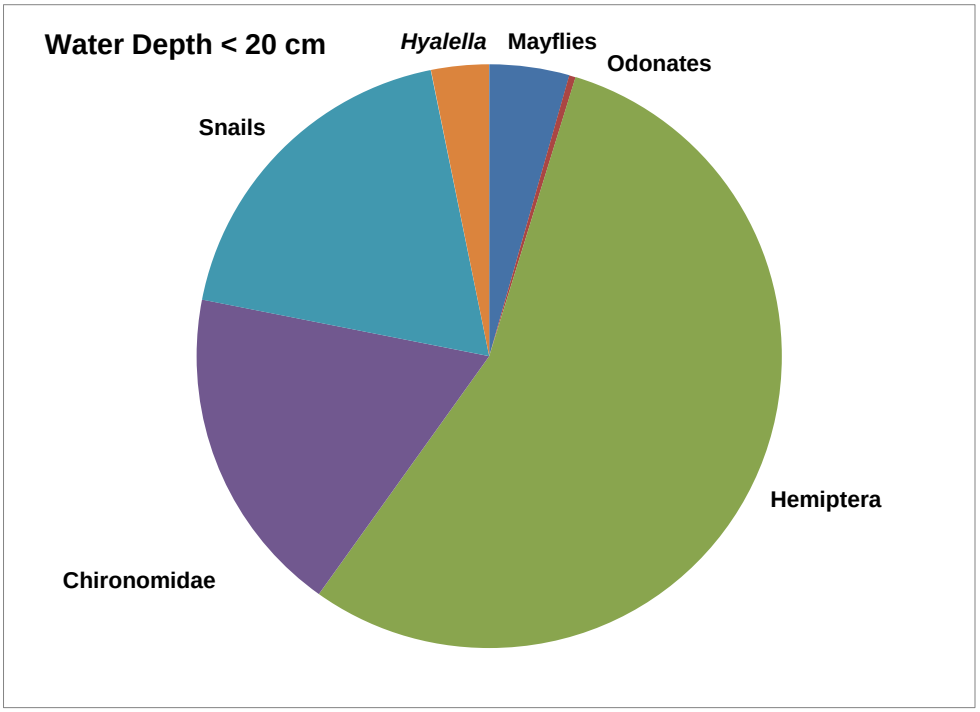


Figure 3.4.2. Taxonomic composition of the two groups of sites indicated in Fig. 3.4.1.





3.5 Summary of Factors affecting Macroinvertebrates in the Willard Spur

As noted in the discussion above and in previous reports, two main habitat factors affecting macroinvertebrate communities in the Willard Spur are the abundance and longevity of SAV growth, and the extent and seasonal timing of low water levels and drying. Both factors lead to reduced diversity and abundance of macroinvertebrates as a result of the loss of habitat structure and concurrent changes in water quality, such as higher water temperature, higher salinity, and reduced oxygen (the influence of these water quality factors on individual taxa was discussed in Gray 2011).

Spring runoff flushing of residual detritus also is likely an important factor. At this point, however, its importance is only a hypothesis as no data has been collected on amounts of detritus present in the Spur during the Fall and Spring seasons. In addition, no data has been collected on the direct loss of macroinvertebrates due to drift out of the Spur into Bear River Bay.

Another potentially important factor is the dynamic exchange of macroinvertebrates with surrounding wetlands. The Willard Spur is not an isolated habitat where macroinvertebrate communities are derived solely from indigenous populations. Recruitment from aerial adults of aquatic insects occurs from a larger area, the extent of which depends on the taxon. Strong fliers, such as adult odonates and hemipterans, potentially can reach the Spur from other GSL wetlands many miles away. Weak fliers, such as mayflies and chironomids, could come from surrounding wetlands, such as the Bear River refuge and Harold Crane WMA. Macroinvertebrates without an aerial stage could reach the Spur through drift in outflows from the surrounding wetlands and Willard Bay. Many taxa are known to be passively transported by waterfowl, shorebirds, and aquatic mammals. For example, snails can be dispersed by ducks (van Leeuwen and van der Velde 2012), late-instar chironomid larvae can survive in shorebirds guts for several hours and be dispersed to new habitats (Green and Sanchez 2006), and ducks can carry amphipods attached to their feathers (Swanson 1984). Although the contribution of macroinvertebrates from other wetlands has not been quantified for the Willard Spur, this mechanism is likely important, especially in the recovery of communities either after drying or salinization resulting from inflows from the Bear River Bay.

3.6 Role of Macroinvertebrates in Nitrogen Cycling in the Willard Spur

Macroinvertebrates exchange nutrients with the surrounding environment as a result of ingestion (feeding), egestion, excretion, and storage in tissues. In some systems, such as desert streams, macroinvertebrates can have a relatively significant role in nitrogen dynamics (Grimm 1988). Ascertaining the role of macroinvertebrates in Willard Spur nutrient dynamics would require studies far beyond that completed thus far. For example, needed information would include the nutrient composition of the various invertebrate taxa, secondary production rates, rates of nutrient ingestion, egestion, and excretion at typical water temperatures, and exchanges between the Willard Spur and surrounding wetlands in the biomass of aerial adults and individuals in the aquatic drift.

A very rough idea of the role of macroinvertebrates in the nitrogen dynamics of the Willard Spur is presented here. Using measurements of total nitrogen in the water, macroinvertebrate biomass data from samples collected in August 2012, and literature values for egestion + excretion (Grimm 1988 and references therein), an approximation of the contribution of macroinvertebrates to the total nitrogen in the water column over a short period of time can be calculated. The intent is to provide a general “order of magnitude” view of the potential impact of macroinvertebrates as a guide for future considerations of nutrient loads in the Willard Spur.

The samples from several mid-channel sites (WS-2, WS-3, WS-4, and WS-6) in August 2012 were selected because benthic samples showed the highest biomass of macroinvertebrates found in the Willard Spur during the three years of study, primarily due to large numbers of snails. Total nitrogen concentrations in the water were relatively high (1.5 – 2.9 mg/L TN); however, the total amount of nitrogen present in the water column on a unit area basis was less than at these sites in June and July when the water was deeper. For example, August TN amounts averaged 372 mg TN in the water column per square meter of bottom (average water depth of 17 cm), compared to 493 mg TN/m^2 (average water depth of 31 cm) in July. Thus, the impact of egestion + excretion by macroinvertebrates on total nitrogen amounts in the water potentially would be greatest in August.

Egestion + excretion rates were calculated using Grimm’s (1988) values as she included data for *Physa* snails and other common aquatic insects (e.g., chironomids,

baetid mayflies) that were abundant in the Willard Spur samples selected. In addition, her values came from laboratory measurements at a water temperature (25^0C) that was within the range of measured water temperatures present at the four sites in August 2012 (water temperature range: 22-32^0C, mean temperature = 26^0C).

Of the 4 sites, site WS-2 reflected the case where macroinvertebrates would have the greatest impact on total nitrogen amounts. Macroinvertebrate biomass at this site was 8.6 g dry mass/m^2 of which 97% was snail *(Physa*) biomass and the remainder chironomids and corixids. The TN concentration was 2.93 mg/L; with a depth of only 6 cm, the amount of nitrogen in the water column was 176 mg/m^2. Total egestion + excretion, weighted for the different taxa, is estimated to be ≈ 21 mg TN/m^2/day, or about 12% of the total nitrogen in the water column on a daily basis.

If TN and biomass at all four sites are averaged, macroinvertebrates would contribute ≈ 2% of the TN in the water column. The actual impact likely would be much less as the above calculations assume that all the nitrogen in egestion (feces) would immediately enter the water column. Given that the macroinvertebrate biomass present at these sites falls in the upper 4% of sample biomass values during the three years of sampling, the contribution of macroinvertebrates to the total nitrogen in the water column would be a fraction of 1% most of the time.

4. Zooplankton

The zooplankton communities in the Willard Spur have been discussed in detail in previous reports in terms of species composition, seasonal trends, and responses to changes in habitat. The emphasis here will be to reiterate the similarities and differences in species composition in the Willard Spur with that found in other GSL impounded wetlands, discuss in more detail the composition of the community in different regions within the Willard Spur, and to summarize the environmental factors influencing zooplankton communities. Emphasis is placed on the Cladocera as this taxon had the highest species diversity and species-specific responses to habitat and water quality conditions.

4.1 Community Composition: Comparison of the Species in the Willard Spur with other GSL Impounded Wetlands

A list of taxa, distributions, and peak abundance for zooplankters collected in the Willard Spur is given in Table 4.1. All of the species listed have been collected in other GSL wetlands, thus there are no zooplankters that are found only in the Willard Spur.

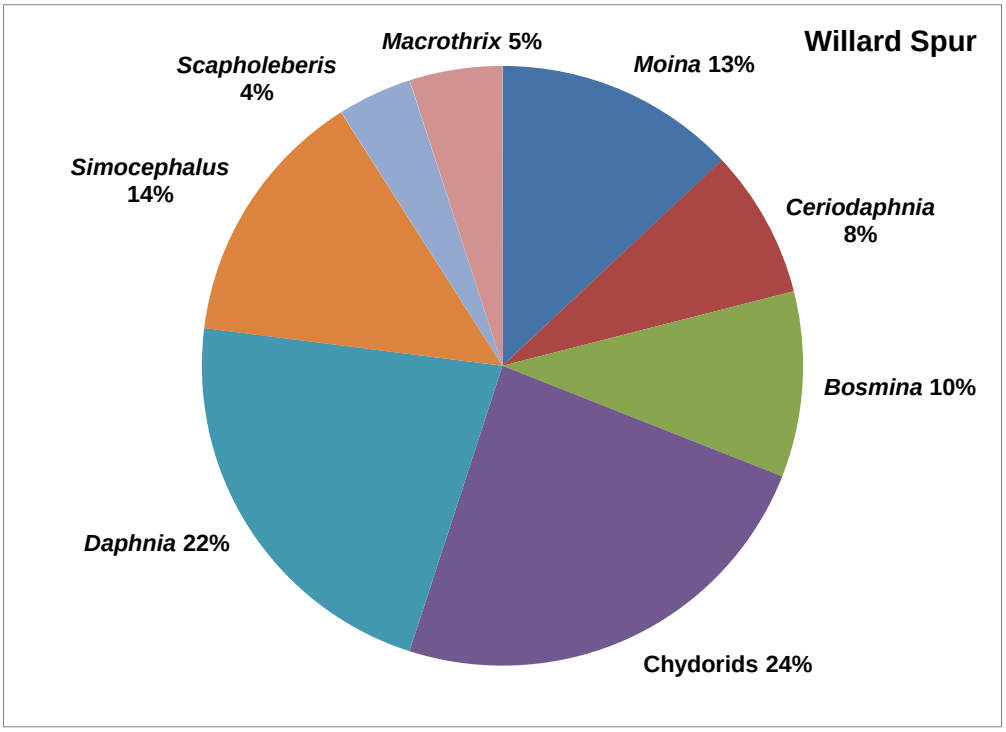
Figure 4.1 shows the overall composition of the Cladocera species present in the Willard Spur compared to that found in other GSL impounded wetlands. Both were similar in the relative proportion of species associated with the SAV (*Scaphaloberis* and *Simocephalus*) as well as common species found in a variety of habitats, such as *Ceriodaphnia*. The greater relative proportions of *Macrothrix*, *Bosmina*, and various chydorids (*Alona*, *Pleuroxus*), in addition to the lower proportion of *Daphnia* in the Willard Spur, reflect the low water levels present in 2012 and 2013.

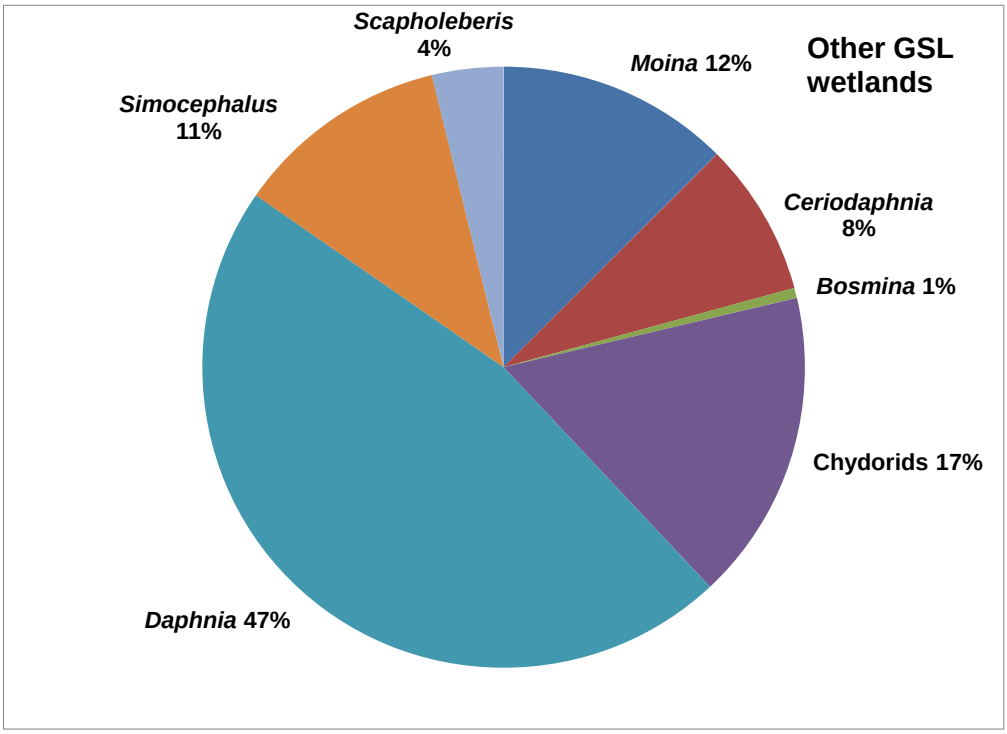
However, it should be noted that interpretation of this data is problematic due to the technique used in sampling. Field sampling of zooplankton involved tossing a plankton net into the water and dragging it back, resulting in a sample that collected individuals only in the upper 15-25 cm of the water column. At shallow water sites, this technique would collect most, if not all, of the water column, including species that are mainly benthic (e.g., *Alona* and *Macrothrix*). At deep water sites, the technique is biased

against collecting benthic species and species that may exhibit diel vertical migration, but it would be biased in favor of species associated with the SAV at the surface, such as *Scaphaloberis* and *Simocephalus* and open-water species, such as *Daphnia*.

The differences between the Willard Spur and other wetlands reflect this sampling bias. More samples were taken in shallow water conditions in the Willard Spur than at the other wetlands. In addition, more samples were taken throughout the warm months in the Willard Spur.

Figure 4.1. Overall composition of the Cladocera zooplankton by species in the Willard Spur main channel sites, 2011-2013, and other GSL impounded wetlands (data from 67 samples collected in 2010-2011; sites same as in Fig. 3.1)





4.2 Cladoceran composition within habitats: August 2011 and July 2012

The species and relative abundances of cladocera present at the mid-channel and peripheral sites sampled in August 2011 and July 2012 were analyzed to determine if these zooplankters, like the macroinvertebrates, displayed any differences based on either location or habitat characteristics, particularly water depth. Figure 4.2.1 shows an NMS plot comparing cladoceran species composition between the mid-channel (center) and peripheral sites in August 2011. The arrow indicates a general gradient of increasing amounts of algae and periphyton. Group 1 sites (left of the arrow) had relatively deep water and extensive SAV cover. This gradient was reflected in a shift in zooplankton community composition from dominance by *Alona* and *Chydorus* (e.g., Site 2) to dominance by *Ceriodaphnia* (e.g., Site 10M). Group 2 included the lower Spur sites that had shallow water depths, high water temperatures, and high amounts of algae and periphyton. The dominant cladocerans at these sites were *Moina* and *Alona*. Thus, as with the macroinvertebrates, shallow water depth appeared to be a factor in the species of Cladocera present.

In July 2012, there was little difference in cladoceran species composition at the mid-channel and peripheral sites (Fig. 4.2.2). Transects from WS-3 to WS-7 showed similar communities with dominance by *Simocephalus* and chydorids. Site WS-2 was the exception due to high numbers of *Moina* entering the Willard Spur from the Willard Bay tailrace (Gray 2013).

Figure 4.2.1. NMS plot based on cladoceran species composition between the Center (M), North Edge (A), and South Edge (B) sites in August 2011. Group 1 sites to the left of the arrow had relatively deep water and high SAV cover. Group 2 included the lower Spur sites with shallow water depths. (The 2 points labelled "10M" represent replicate samples at that site.)

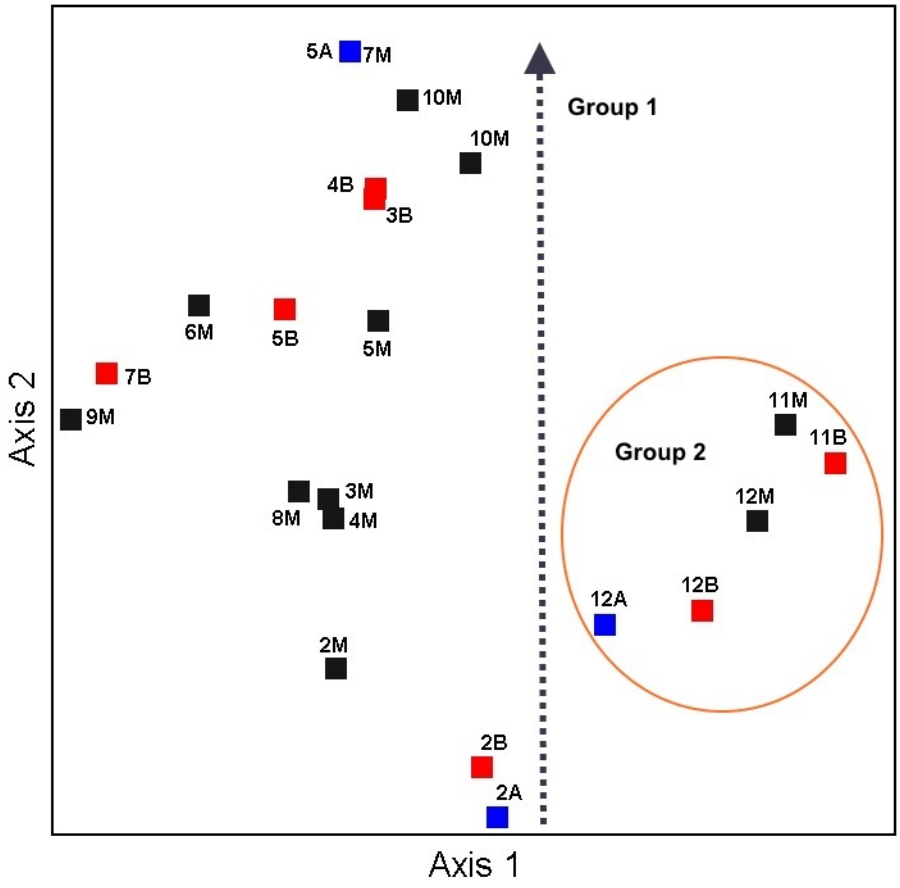
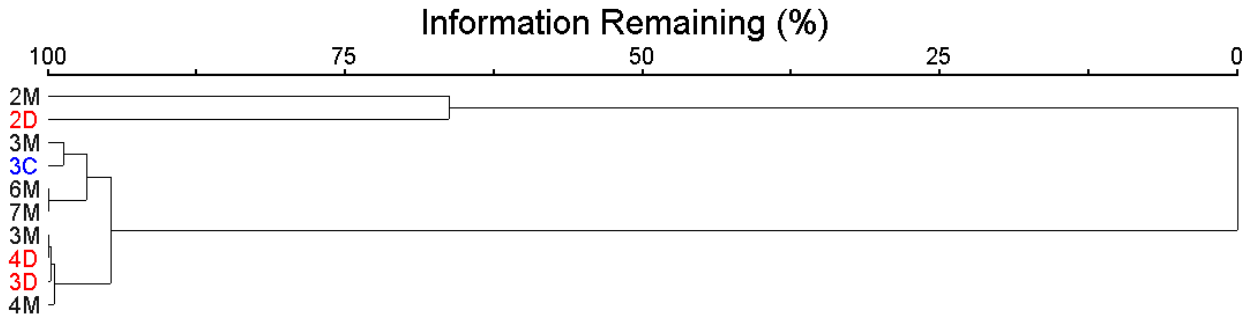


Figure 4.2.2. Dendrogram of cladoceran zooplankton community composition at transect sites in July 2012. Transect sites were channel center (M), north between the center and shoreline (C), and south between the center and shoreline (D).



4.3 Summary of Factors affecting Zooplankton in the Willard Spur

The environmental factors affecting zooplankton populations in the Willard Spur are very similar to those affecting the macroinvertebrate communities, including the extent of spring runoff, recruitment of individuals from other habitats outside of the Spur, the abundance and longevity of SAV growth, and low water levels.

Spring runoff would affect zooplankton to a greater extent than macroinvertebrates. High flows would carry individuals out of the Spur into Bear River Bay. This export has been observed in Farmington Bay where Spring samples contained large numbers of freshwater species derived from the Farmington Bay WMA wetlands (Gray, unpublished). High runoff would also import individuals carried in outflows from the Bear River refuge wetlands, Willard Bay reservoir, and Harold Crane wetlands. The extent of these transfers in and out of the Spur are unknown at this point, except for the limited data indicating the occasional importance of individuals carried into the upper Spur from Willard Bay as noted above.

The importance of SAV cover to certain species has been noted above. However, it is not fully known how this affects other species due to sampling bias. It is known that the loss of SAV as water levels decline does create habitats that favor benthic species and species tolerant of lower oxygen concentrations and higher salinity, such as *Moina.*

5. Recommendations for Future Study

If the goal in the future is to monitor the potential impact of the treatment plant on invertebrate communities of the Willard Spur, then a more focused sampling regime is needed that emphasizes sampling relatively few sites intensively rather than sampling a large number of sites occasionally. As noted above, one of the difficulties encountered in the analysis over the three-year sampling period was the few samples taken at the same site and month each year. Suggested sites would be primarily in the upper Spur, perhaps no further downstream than WS-6. Multiple samples at each site also would aid in statistical analysis.

Although it might be difficult to coordinate logistically, it also would help analysis if the sampling schedule could be adjusted to reflect changes occurring in the Spur (e.g., rapid decline in water levels, senescence of SAV) rather than follow a rigid time interval. Otherwise, it will be difficult to separate any impacts from the treatment plant from natural disturbances.

For macroinvertebrates, another consideration is the emphasis on quantitative abundance data. The current methodology using sweep nets to collect samples is fine for rapid bioassessment work (hence the use of metrics, such as %PMI), but it is only semi-quantitative and depends on field conditions. Even with the same personnel, the effectiveness of sweep nets varies with water depth and extent of aquatic vegetation; these factors likely played a role in what appeared to be a low abundance of macroinvertebrates in the 2011 samples (average water depths in summer 2011 at main Spur sites were > 70 cm compared to < 30 cm in 2012 and 2013). If quantitative data are deemed necessary, then sampling with a stovepipe-type sampler at least 25-cm in diameter, in which all material is removed from the entire water column, would be recommended.

Sampling methodology also was discussed as an issue with the zooplankton communities. If quantitative abundance is desired, then the zooplankton should be sampled either in a more defined manner when a net is used (e.g., specific tow lengths that cover the entire water column) or sampled with a Juday plankton trap. Sampling sites and timing of samples would follow the suggestions above for the macroinvertebrates.

Another area of study, separate from general monitoring, would be to examine the potential influx of invertebrates from surrounding wetlands, as least those present in the water column. Drift nets could be used where major inflows occur, such as the Bear River NWR ponds and Willard Bay tailrace. Nets could also be used to examine export of individuals during spring runoff into Bear River Bay. In addition, samples could be taken to determine the extent of detritus export during runoff.

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Table 3.1 List of macroinvertebrate taxa collected in benthic samples from the Willard Spur, 2011-2013. Taxon Code refers to the numerical code assigned to that taxon by the Utah State U. Bug Lab (if present). Feeding Group designations: Shredder (SH), Collector-gatherer (GC), Predator (P), and Scraper (Sc). Designations for relative abundance: Common (C, found at most sites and in most samples), Uncommon (U, found at most sites in some samples), Rare (R, found only as occasional individuals at few sites). X = collected that year, 0 = not collected that year. Relative abundance for other impounded wetlands taken from Gray (2009, 2010, and unpublished).

1. Aquatic Insects: Order	Family	Genus	Species	Taxon Code	Feeding Group	2011	2012	2013	Relative Abundance Willard Spur	Relative Abundance Other GSL Wetlands
Ephemeroptera	Baetidae	*Callibaetis*	sp.	273	GC	X	X	X	C	C
	Caenidae	*Caenis*	*amica*	286	GC	X	X	X	C	C
Trichoptera	Leptoceridae	*Ylodes*	sp.	432	SH	X	X	X	U	U
Odonata	Coenagrionidae	*Ischnura* (+ *Enallagma*)	spp.	350	PR	X	X	X	C	C
	Coenagrionidae	*Archilestes*	sp.	354	PR	X	X	0	U	R
	Libellulidae	*Erythemis*	sp.	356	PR	X	X	X	U	U
	Aeshnidae	*Aeshna*	sp.	345	PR	X	X	0	R	R
Hemiptera	Corixidae	*Corisella*	spp.	330	PR	X	X	X	C	C
	Corixidae	*Hesperocorixa*	sp.	330	PR	X	X	X	C	C
	Corixidae	*Sigara*	sp.	330	PR	0	0	X	R	U
	Notonectidae	*Notonecta*	sp.	335	PR	X	X	X	C	C
Diptera	Ephydridae	*Ephydra*	sp.	235	GC	X	X	X	R	R
	Ceratopogonidae	subfamily Ceratopogoninae	sp.	80	PR	X	X	0	R	U
	Stratiomyidae		sp.	225	GC	X	0	0	R	R
	Tabanidae	*Chrysops*	sp.	249	PR	X	0	0	R	U
	Tipulidae	*Prionocera*	sp.	n/a	SH	X	0	0	R	R
	Dolichopodidae		sp.	226	PR	0	X	0	R	R
	Chironomidae	*Chironomus*	sp.	84	GC	X	X	X	C	C
	Chironomidae	tribe Tanytarsini	sp.	84	GC	X	X	X	C	C
	Chironomidae	subfamily Tanypodinae	sp.	89	PR	X	X	X	C	C
	Chironomidae	subfamily Orthocladiinae	sp.	86	GC	X	X	X	C	C
Coleoptera	Dytiscidae	*Agabus*	sp.	16	PR	X	0	0	U	U
	Dytiscidae	*Stictotarsus*	sp.	30	PR	0	X	X	R	R
	Dytiscidae	*Hydroporus*	sp.	n/a	PR	0	X	0	R	R
	Hydrophilidae	*Enochrus*	sp.	n/a	CG	X	X	X	C	C
	Hydrophilidae	*Tropisternus*	sp.	69	CG	X	X	X	U	U
	Hydrophilidae	*Berosus*	sp.	59	PR	X	X	0	U	U
	Chrysomelidae		sp.	n/a	SH	0	X	X	U	U
2. Other Groups										
2. Acarina: Trombidiformes			sp.	7	PR	X	0	0	R	R
3. Crustacea (Amphipoda)	Hyalellidae	*Hyalella*	*azteca*	489	GC	X	X	X	C	C
(Isopoda)	Asellidae	*Caecidotea*	sp.	493	GC	X	0	0	R	R
4. Mollusca: Gastropoda	Physidae	*Physella*	sp.	504	SC	X	X	X	C	C
	Lymnaeidae	*Stagnicola*	sp.	503	SC	X	X	0	R	R
	Planorbidae	*Gyraulus*	sp.	505	SC	X	X	0	C	C
	Ancylidae	*Ferrissima*	sp.	500	SC	0	X	0	R	R
5. Annelida (Oligochaeta)	Naididae		sp.	5	GC	X	X	X	C	C
(Hirundinea)	Glossiphoniidae	*Helobdella*	*stagnalis*	3	PR	X	0	0	R	R
(Hirundinea)	Erpobdellidae		sp.	1	PR	X	0	0	R	R

Table 4.1 List of zooplankton species collected from the Willard Spur, 2011-2013.

Cladocera							
Family	**Species**	**2011 Occurrence**	**2011 Peak**	**2012 Occurrence**	**2012 Peak**	**2013 Occurrence**	**2013 Peak**
Daphniidae	*Daphnia dentifera* (Sars)	widespread; uncommon	July	widespread; common	Apr-May	widespread; common	Apr-May
Daphniidae	*Daphnia pulex* Leydig	widespread; rare	August	(not collected)		(not collected)	
Daphniidae	*Simocephalus vetulus* (O.F.M.)	widespread; common	July	widespread; common	July	widespread; common	June
Daphniidae	*Scapholeberis* sp.	widespread; uncommon	October	widespread; common	June	widespread; common	July
Daphniidae	*Ceriodaphnia quadrangula* (O.F.M.)	widespread; common	August	widespread; common	May	widespread; rare	June
Chydoridae	*Pleuroxus striatus* Schödler	widespread; uncommon	October	widespread; uncommon	June	(not collected)	
Chydoridae	*Pleuroxus aduncus* (Jurine)	(not collected)		widespread; common	June	widespread; common	June-July
Chydoridae	*Pleuroxus procurvatus* Birge	Outfall Confl., WS-1; rare	August	(not collected)		(not collected)	
Chydoridae	*Alona* sp.	widespread; common	August	widespread; rare	July	WS-3 only	June
Chydoridae	*Chydorus sphaericus* (O.F.M.)	widespread; common	August	widespread; common	June	mainly WS-3, common	June
Chydoridae	*Leydigia* sp.	WS-7 to 9; rare	August	(not collected)		WS-6 only; rare	July
Moinidae	*Moina macrocarpa* Straus	WS-10 to 12; common	October	WS-2 to 5; common	July-Oct.	widespread; common	July
Bosminidae	*Bosmina longirostris* (O.F.M.)	widespread; uncommon	October	WS-1; rare	August	widespread; common	Oct
Macrothricidae	*Macrothrix rosea* (Jurine)	(not collected)		WS-4, 5; uncommon	August	widespread; common	July
Copepoda							
Family	**Species**						
Cyclopidae	*Eucyclops agilis* (Koch)	widespread; common	October	widespread; common	Aug.-Sept.	widespread; common	April
Cyclopidae	*Diacyclops thomasi* (Forbes)	widespread; uncommon	October	widespread; common	Sept.	widespread; common	Sept.
Diaptomidae	*Leptodiaptomus connexus* Light	widespread; uncommon	July	widespread; uncommon	Sept.-Nov.	widespread; rare	Nov
Diaptomidae	*Skistodiaptomus oregonensis* (Lilljeborg)	(not collected)		MZ Tailrace; rare	April	MZ Tailrace; rare	April
Rotifera							
Family	**Species**						
Asplanchnidae	*Asplanchna* sp.	widespread; common	August	widespread; common	June-Aug.	widespread; uncommon	Nov
Brachionidae	*Brachionus plicatilis* O.F.M.	widespread; uncommon	August	widespread; uncommon	June	widespread; common	Nov
Brachionidae	*Notholca acuminata* Ehrenberg	widespread; rare	August	(not collected)		(not collected)	