Macroinvertebrate and Zooplankton Communities in the Impounded Wetlands of the Great Salt Lake May-November 2010

Prepared for the

Utah Department of Environmental Quality

Division of Water Quality

Prepared by

Dr. Lawrence J. Gray

Senior Ecologist (ESA)

10 January 2011

Table of Contents

	Page
Summary	2
Introduction	3
Sampling Methods	3
Discussion: Macroinvertebrates	
Species Present	5
Composition of Communities	5
Seasonal Trends	6
Biomass	7
Discussion: Zooplankton	
Species Present	8
Rotifers	8
Copepods	9
Cladocerans	9
Zooplankton Metrics	10
Literature Cited	12
Taxonomic References: Macroinvertebrates	14
Taxonomic References: Zooplankton	15
Table Legends	16
Figure Legends	16
Appendix Legends	18

Summary

Twenty-one impounded wetlands in 7 complexes of the Great Salt Lake were sampled for macroinvertebrates and zooplankton from May to November, 2010. Macroinvertebrate communities showed seasonal changes that were directly related to changes in the aquatic vegetation. When submerged aquatic vegetation was sparse, a “base” community of chironomids, pulmonate snails, *Corisella* corixids, and oligochaetes was dominant. As the SAV developed during summer, a “PMI” community of mayflies, damselflies, *Hesperocorixa*, and planorbid snails became more common and dominated in wetlands with the most SAV. *Hyalella*-dominated communities occurred at sites that had increased development of filamentous algae and duckweed by mid-summer. Fall communities reflected both previous SAV development and the extent and timing of decreases in SAV in summer and early fall. Benthic biomass was relatively low at most sites, although a few sites had very high biomass in May just prior to emergence of chironomids. Biomass composition showed seasonal changes with chironomids dominating in May. By fall, biomass was more evenly distributed among all of the major taxa. Zooplankton was sampled extensively for the first time in these wetlands. Most rotifer genera were widely distributed, but *Lecane* was found only in wetlands with extensive SAV. *Eucyclops* was the only abundant and widespread copepod. Ten species of cladocerans were collected. *Simocephalus* and *Scapheloberis* were restricted to wetlands with extensive SAV growth, whereas *Moina* was common in turbid wetlands with little SAV. Potential zooplankton metrics are discussed.

Introduction

Seven wetland complexes adjoining the Great Salt Lake were sampled for macroinvertebrates and zooplankton in May, July, and November 2010 as part of water quality monitoring by the Utah Division of Water Quality. These complexes included 12 impounded wetlands previously sampled for macroinvertebrates in prior years (ISSR, Public Shooting Grounds, Farmington Bay WMA, and Newstate Duck Club; see Gray 2009, 2010), and 9 impounded wetlands in 3 complexes (Ambassador Duck Club, Harrison Duck Club, and the Bear River Migratory Bird Refuge) that were sampled for the first time using current methodology. The primary goal of the macroinvertebrate sampling was to describe the seasonal changes in communities found in the "open water" habitats of these wetlands, since previous sampling had been conducted only in November. 2010 was the first year that extensive zooplankton sampling had been conducted in these wetlands. The primary goal was to describe the species composition and seasonal changes in the zooplankton communities of these wetlands.

Sampling Methods

Sampling sites and dates of sampling are listed in Table 1. The list includes 12 sites previously sampled for macroinvertebrates using the current methodology during November 2007 and November 2009.

Macroinvertebrate samples were collected according to the SOP developed by Arne Hultquist. Briefly, samples were taken with a 500 μm-mesh, 12-inch wide D-net in deeper water away from the shoreline ("open water"). Each sample consisted of 5 net sweeps approximately 1 meter in horizontal distance along the bottom (ca. 1.5 m^2 total benthic area per sample). Mud and smaller debris was washed in the net before placing the remaining material in a plastic bag. Formalin was later added to enhance preservation until samples could be processed.

In the lab, samples were washed with tap water on a 500 μm-mesh brass sieve to remove the preservative and finer sediment. The remaining material was placed in a white enamel pan for separating animals from debris. If there were relatively few animals (1-50) of a particular taxon, all animals of that taxon are picked. If a taxon was abundant, a random subsample of 10-50% of the individuals of that taxon was picked with the goal of obtaining at least 30 individuals. Picked animals were placed in 70% alcohol following separation from the debris for counting and identification. Biomass was determined as wet mass after blotting on a paper towel and weighing. Dry mass was determined by multiplying wet mass by a conversion factor previously computed from reference specimens.

Qualitative zooplankton samples were collected by hand with a conical tow net (80 μm mesh) in the open water habitat per UDWQ SOP. Several tows were combined into a composite sample. In the lab, a Hensen-Stempel pipet was used to withdraw a 1-ml subsample which was then placed in a Sedgewick-Rafter cell for counting and identification with a compound microscope. At least 200 individual zooplankters were enumerated per sample. Additional pipet subsamples were taken and scanned for rare taxa. If less than 200 individuals were present, the entire sample was counted.

Identifications were based on keys given below in the Taxonomic References section and on personal reference specimens plus specimens previously collected from the GSL wetlands. For macroinvertebrates, the level of taxonomic resolution followed the Southwest Association of Freshwater Invertebrate Taxonomists guidelines where applicable (SAFIT 2006). For the zooplankton, cladocerans and copepods were identified to species where possible, and rotifers were identified to genus.

Descriptive statistics and test of significance were calculated using the Prostat® program (Polysoftware International 2009). Count and biomass values were transformed using natural logs before statistical analysis, and percentages were transformed using the arcsin-square root function (Elliott 1971, Green 1979).

Macroinvertebrate community metrics included total sample count, total taxa, and Simpson's diversity index. Additional metrics based on relative abundance are discussed below. Zooplankton metrics included overall relative abundance among all taxa and relative abundance within a specific group (e.g., cladocera).

Field observations were recorded of habitat conditions at each site during sampling. These observations included water depth, depth of submerged aquatic vegetation (SAV), and amount of pond surface area covered by SAV, filamentous algae, and duckweed. Area was estimated as quartile cover classes for each of the 3 groups of vegetation. Cover class values were 0 (vegetation type absent), 1 (vegetation type present , up to 25% cover), 2 (up to 50% cover), 3 (up to 75% cover) and 4 (more than 75% cover).

Discussion: Macroinvertebrates

Species Present

The list of macroinvertebrate taxa collected in 2010 is given in Table 2. The most abundant taxa found in previous sampling, such as the genera listed for chironomids, mayflies, damselflies, pulmonate and planorbid snails, and hemipterans, were also the most abundant in 2010. Overall, the 3 complexes sampled for the first time (Ambassador, Harrison, and Bear River MBR) had the same common taxa as the other complexes. Taxa collected for the first time included the dytiscid beetle *Sanfillipodytes* sp. (formerly part of the genus *Deronectes*) and the planorbid snail *Helisoma* sp. Both were uncommon and collected only at one site (*Sanfillipodytes* at Ambassador W2 pond in July, and *Helisoma* at Ambassador W1 pond in July).

Composition of Communities

As noted in previous reports (Gray 2009, 2010), there are two main communities found in the impounded wetlands: a subset of taxa strongly associated with the aquatic vegetation (i.e., SAV, primarily *Stukenia*), and another subset of taxa associated with bare mud substrates (referred to here as the “base” community). The taxa associated with SAV have been referred to in the literature as “phytophilous macroinvertebrates,” or the PMI community (Cyr and Downing 2006, Feldman 2001). The “base” community is essentially a shallow-water version of the profundal benthos of lakes, such as Utah Lake (Barnes and Toole 1981, Shiozawa and Barnes 1977).

In the GSL impounded wetlands, PMI taxa include *Callibaetis* and *Caenis* mayflies, damselflies, libellulid dragonflies (e.g., *Tramea*, *Erythemis*), planorbid snails (e.g., *Gyraulus*), *Haliplus* beetles, and leptocerid caddisflies (e.g., *Ylodes*). In addition, July sampling indicated that the corixid *Hesperocorixa* is also part of the PMI community. *Hesperocorixa* is the only herbivore among the hemipterans (Table 2), and its abundance was strongly correlated with both the amount of SAV present ($Rs = 0.69$, $P < 0.01$, $N = 20$) and the abundance of other PMI taxa ($r = 0.58$, $P < 0.01$). Nearly all of the reproduction of *Hesperocorixa* occurred in ponds with extensive stands of *Stukenia*. The relative abundance of PMI taxa was highly correlated with SAV cover ($Rs = 0.80$, $P < 0.01$) and typically was highest in ponds with relatively little filamentous algae and duckweed (Fig. 1).

The base community taxa include the chironomids *Chironomus*, Tanytarsini, and Tanypodinae; pulmonate snails, and oligochaetes. In addition, the corixid *Corisella* had its greatest densities at sites with little or no SAV. In contrast to *Hesperocorixa*, the abundance and reproduction of *Corisella* was negatively correlated with SAV cover ($Rs = -0.63$, $P < 0.01$). Dominance by the base community decreased with increasing SAV cover (Fig. 1).

Both the PMI and base community taxa typically are present at a site at the same time with the relative dominance of either community depending upon the relative proportions of substrate types present. For example, Pintail Pond in May had some stands of *Stukenia* interspersed with areas of bare mud. Separate sweep samples from each type of substrate showed the distinct delineation of the two communities (Fig. 2).

The amphipod *Hyalella* is widely distributed throughout the GSL wetlands and is found in low densities at most sites. In a few samples, however, it was present in high densities and can be the most abundant macroinvertebrate present. These samples included Ambassador 100, New State 20, and New State Middle Unit in July, and Ambassador W1, Ambassador 100, New State 20, FBWMA Unit 1, and FBWMA Turpin Unit in November. *Hyalella* is capable of multiple broods during the summer when water temperatures increase (Strong 1972), thus populations can increase rapidly. In terms of habitat characteristics, the relative abundance of *Hyalella* increased when filamentous algae and duckweed increased (Fig. 3).

Seasonal Trends

Seasonal changes in macroinvertebrate community composition closely followed changes in the aquatic vegetation present, particularly the development of the *Stukenia* beds during summer and persistence of these beds into November. These trends are illustrated in Figure 4 for sites that were sampled on all three dates in 2010.

The primary trend was an increase in the proportion of PMI community taxa as SAV increased from May to July. If SAV persisted over the winter and increased to full coverage by July, as occurred at Pintail and Widgeon, the PMI community increased relatively quickly and dominated by July. If little or no SAV overwintered, then its subsequent development during the summer was accompanied by a slower increase in the PMI community (e.g., Ambassador W1, FBWMA Unit 2). If the SAV had little development into summer (e.g., New State 47), or development was affected by significant increases in filamentous algae and duckweed (e.g., FBWMA Unit 1), then the benthos was dominated by the base community.

At Pintail, Ambassador W1, and FBWMA Unit 2, the PMI community continued to increase in relative abundance from July to November despite decreases in SAV coverage. This “carryover” effect likely depends upon the timing the decrease in SAV. If decreases in SAV coverage begin in July (e.g., Widgeon), then the PMI community decreases in abundance by November.

If SAV declines do not begin until fall, then the PMI community remains relative abundant due to continued reproduction and, for insects, a cessation of emergence as late summer recruitment becomes the overwintering generation.

As noted above, some sites showed increased abundance of *Hyalella* by July with the development of increased algae and duckweed. At Ambassador 100 and New State 20, *Hyalella* remained abundant into November.

Seasonal trends were evident in community metrics. Total taxa and Simpson's Index were correlated with SAV coverage for all samples in 2010 (Fig. 5), and changes in total taxa closely paralleled changes in SAV cover at individual sites (Fig. 6).

Biomass

For all samples collected in 2010, biomass was relatively low with three-fourths of all samples having less than 3 g (approx. equivalent to 2 g/m^2, Fig. 7). Exceptionally high biomass occurred in May at FBWMA Unit 2 (162 g/sample) and ISSR South B (45 g/sample) due to very high densities of late-instar *Chironomus*. The lowest value occurred at BRMBR 5C in November (<0.1 g/sample); this site had had been dry in late summer and was refilled less than a month before sampling. As in the November 2009 samples (Gray 2010), biomass was highly correlated with total counts ($r = 0.83$, $P < 0.01$, $N = 47$).

The composition of the biomass varied seasonally with chironomids, primarily *Chironomus*, dominating in May (Fig. 8). In addition to the two sites indicated above, other sites likely had high chironomid biomass in May, but this larval biomass was not indicated in the samples due to emergence (e.g., swarms of adult chironomids were abundant at the Bear River complex in May). By July, biomass was dominated by snails and hemipterans. In November, biomass was more evenly distributed among several groups with significant contributions by odonates, mayflies, and amphipods, in addition to snails, hemipterans, and chironomids.

Discussion: Zooplankton

Species Present

Zooplankton species found at the 7 wetlands complexes during 2010 are listed in Table 3. Ten species of Cladocera, 4 species of Copepoda, and 4 genera of Rotifera were found. In a previous study of the zooplankton of the main bodies of Farmington and Gilbert Bays, Wurtsbaugh & Marcarelli (2004, 2006) found *Artemia,* the harpacticoid copepod *Cletocampus albuquerquensis*, and some of the zooplankters found in this study, including the calanoid copepod *Diaptomus (Leptodiaptomus) connexus*, and the cladocerans *Moina* and *Bosmina*.

Rotifers

Rotifers were the dominant zooplankter in only 4 of the 47 samples collected in 2010 (Widgeon, New State 56, and ISSR West A in July; BRMBR 5C in November). Twenty samples had no rotifers, and rotifers were less than 15% of total zooplankters in an additional 21 samples. All of the rotifers collected (Table 3) are common and widespread in a variety of freshwater habitats (Pennak 1978).

Brachionus was the most frequently collected rotifer and was found in all of the wetlands complexes except Harrison. It was the dominant or codominant rotifer in 17 of the 21 samples it occurred in. It was more abundant in the May and July collections than in the November collections. *Brachionus* tended to be the dominant or codominant rotifer in ponds with less than 50% SAV cover.

Asplanchna was the next most frequently collected rotifer and was dominant or codominant in 7 of the 16 samples in which it occurred. It was found in all of the wetlands complexes. Like *Brachionus*, it was more common in May and July than in November. *Asplanchna* typically was dominant or codominant in ponds with more than 50% SAV cover and with relatively high amounts of filamentous algae and duckweed.

Keratella was found in 11 samples from all of the wetlands complexes. It was present only in the May and July samples, primarily in ponds with more than 50% SAV cover.

Lecane found only in 5 samples in July from Widgeon, Harrison-Silverwood, Harrison-Elbow, BRMBR 4C, and BRMBR 5C. These sites represented 5 of the 8 sites in July with full SAV cover (i.e., SAV cover class = 4).

Copepods

Copepods were found in all of the samples collected in 2010. *Eucyclops* was the most common copepod at most sites and was collected at all sites except the ISSR Southwest South pond. Reproduction of *Eucyclops* was continuous throughout the summer and early fall. *Diacyclops* was rare at BRMBR 4C and 5C, Ambassador 100, and New State 47 ponds; it was common only in the July sample from FBWMA Unit 2. Only 2 individuals of *Skistodiaptomus* were collected at the FBWMA Unit 2 pond in July. *Leptodiaptomus connexus* was present only in the ISSR West A and Southwest South ponds in November where it was the dominant zooplankter.

Cladocerans

Cladocerans were present in 41 of the 47 samples collected in 2010 and were present in all ponds except ISSR West A. Cladocerans were common during all 3 sampling periods, although some species showed seasonal peaks in abundance.

Two species of *Daphnia* were collected; *D*. *pulex* (the most common species in May) and *D*. *dentifera* (formerly *D*. *rosea*; the most common species in November). Few *Daphnia* were collected in July. Both species are common in a variety of lentic habitats and widespread in distribution (Pennak 1978). *D*. *dentifera* is also abundant in Utah Lake (Barnes & Toole 1981). *Daphnia* was present in all of the wetlands complexes and was the dominant cladoceran in FBWMA Units 1 and 2, BRMBR 4C, and Widgeon in May and November (Fig. 9). In general, *Dapnia* was most abundant in larger ponds with extensive limnetic habitats free of aquatic vegetation (Fig. 10).

Chydorus sphaericus also was collected at all of the wetlands complexes. It was common in July and November samples but absent in May. It was most common, and occasionally the dominant cladoceran, in the New State, Harrison, and Bear River complexes. *C. sphaericus* has been described as a littoral/benthic species that is most abundant in eutrophic ponds where vegetation is common (CMU 2001). This description correlates with its high relative importance at the New State sites (Fig. 9) and preference for habitats with diverse vegetation (Fig. 10).

Simocephalus vetulus was found in 11 samples, including all 6 samples at the PSG ponds. It was the dominant cladoceran in Pintail and was common to dominant in Widgeon (Fig. 9). It was also common in July in the BRMBR and Ambassador W1 ponds, and rare in the Ambassador 100 (July) and Harrison-Silverwood (Nov.) ponds. *Simocephalus* is characteristic of ponds with extensive SAV growth where it attaches itself to the vegetation to feed (Hutchinson 1967, Pennak 1978). This description fits with its habitat in the GSL wetlands ponds (Fig. 10).

Scapholeberis is another cladoceran associated with SAV, although it is also known to be neustonic (i.e., associated with the surface film; CMU 2001). It was only found in the Harrison ponds where it was the most common cladoceran (Figs. 9, 10).

Moina macrocarpa and *Pleuroxus procurvatus* are species often found in turbid, muddy waters (Thorp & Covich 1991). *Moina* also is known to be tolerant of highly eutrophic conditions (Cole 1994). Both species typically were found together at the FBWMA, New State, and ISSR ponds (Fig. 9). *Moina* was the most common cladoceran in New State 47 pond on all sampling dates. In this pond, it showed the red coloration characteristic of hemoglobin production at low oxygen levels (Thorp & Covich 1991). *Pleuroxus* was uncommon except at ISSR South B in July. Both species showed a preference for ponds with relatively high amounts of filamentous algae (Fig. 10).

The remaining three species of Cladocera were rare. *Ceriodaphnia* was widespread (it occurred in 5 of the 7 wetlands complexes), but it was common only in the July samples from the smaller Ambassador ponds (100, W2, and W5; Fig. 9). *Bosmina (Eubosmina)* sp. was collected only at Ambassador W2 in July, and *Bosmina longirostris* was present only in the FBWMA Unit 2 and Turpin ponds in November (Fig. 9).

Zooplankton Metrics

Relatively few studies have developed metrics for zooplankton communities in wetlands related to water quality monitoring. Two studies of note include the Wisconsin wetlands zooplankton IBI (Lillie et al. 2002) and the Great Lakes Wetland Zooplankton Index (Lougheed & Chow-Fraser 2002).

The Wisconsin zooplankton IBI was based on a study of 74 wetlands sites located in a variety of landscapes, including native prairie, agricultural land, and urban areas. The IBI was a composite score of individual scores from 3 metrics:

1. total taxon richness (primarily for cladocerans and copepods; based on a total collection of 59 taxa),
2. percentage of males in the population or total absence of all individuals of *Daphnia pulex* (percentage of males correlated with increased “stress” on the wetland), and
3. a composite frequency metric for 10 taxa found at reference wetlands. The most important species were cladocerans (including *Simocephalus vetulus,* which had the highest individual score) and a cyclopoid copepod.

The range of composite IBI scores was then broken into descriptive categories on a scale from “excellent” to “very poor.”

The Great Lakes Wetland Zooplankton Index (WZI) was based on canonical correlation analysis to separate species clusters based on water quality parameters. In general, less-impacted wetlands had more aquatic plant-associated species than pollution-tolerant species (e.g. *Moina*). The study also concluded that diversity indices, total species richness, cladoceran size, and overall zooplankton abundance were not useful indicators of water quality.

Both of these studies suggest that zooplankton associated with SAV are good indicators of high-quality wetlands. In the GSL wetlands, the 2010 sampling indicated that some species, particularly the rotifer *Lecane* and the cladocerans *Simocephalus* and *Scapheloberis*, could serve as reliable indicators of extensive SAV growth. At the other extreme, *Moina* and, to a lesser extent, *Pleuroxus*, could be indicators of less-desirable pond conditions (high turbidity, low oxygen levels, low SAV cover, and high filamentous algae/duckweed cover). Either presence/absence or relative abundance of these taxa could be used for metrics in an IBI similar to the Wisconsin wetlands IBI. Further analysis comparing the zooplankton data directly to water quality parameters would be needed to explore these potential metrics.

Literature Cited

Barnes, J. R., and T. W. Toole. 1981. Macroinvertebrate and zooplankton communities of Utah Lake: A review of the literature. Great Basin Naturalist Memoirs, No. 5.

Cole, G. A. 1994. Textbook of Limnology, 4th Ed. Waveland Press, Prospect Heights, IL

Cyr, H., and J. A. Downing. 2006. The abundance of phytophilous invertebrates on different species of submerged macrophytes. Freshwater Biology 20: 365-374

Elliott, J. M. 1971. Some methods for the statistical analysis of samples of benthic invertebrates. Freshwater Biological Association, Scientific Publication No. 25. 148 p.

Feldman, R. S. 2001. Taxonomic and size structures of phytophilous macroinvertebrate communities in *Vallisneria* and *Trapa* beds of the Hudson River, New York. Hydrobiologia 452: 233-245.

Gray, L. J. 2009. Macroinvertebrates in the wetlands of the Great Salt Lake 2007. Completion report for the Utah Division of Water Quality, Dept. of Environmental Quality, Water Quality Management Section. Salt Lake City, UT

Gray, L. J. 2010. Macroinvertebrates in the wetlands of the Great Salt Lake 2009. Completion report for the Utah Division of Water Quality, Dept. of Environmental Quality, Water Quality Management Section. Salt Lake City, UT

Green, R. H. 1979. Sampling design and statistical methods for environmental biologists. John Wiley & Sons, New York. 257 p.

Hutchinson, G.E. 1967. A treatise on limnology, Volume II: Introduction to lake biology and the limnoplankton. Wiley, New York.

Johnson, B. R., D. C. Tarter, and J. J. Hutchens, Jr. 2000. Life history and trophic basis of production of the mayfly *Callibaetis fluctuans* (Walsh) (Ephemeroptera: Baetidae) in a mitigated wetland, West Virginia, USA. Wetlands 20 (2): 397-405.

Lillie, R. A., P. Garrison, S. I. Dodson, R. A. Bautz, and G. LaLiberte. 2002. Refinement and expansion of wetland biological indices for Wisonsin. Final Report to USEPA - Region V, Wetland Grant #CD975115-01-0, Wisconsin Dept. of Natural Resources, Madison, WI.

Lougheed, V. L., and P. Chow-Fraser. 2002. Development and use of a zooplankton index of wetland quality in the Laurentian Great Lakes. Ecological Applications 12: 474-486.

Polysoftware International. 2009. Prostat statistical analysis and data presentation software (Information available at www.polysoftware.com)

Shiozawa, D. K., and J. R. Barnes. 1977. The Microdistribution and Population Trends of Larval *Tanypus stellatus* Coquillett and *Chironomus frommeri* Atchley and Martin (Diptera: Chironomidae) in Utah Lake, Utah. Ecology 58: 610-618

Southwest Association of Freshwater Invertebrate Taxonomists (SAFIT). 2006. List of Freshwater Macroinvertebrate Taxa from California and Adjacent States including Standard Taxonomic Effort Levels (compiled by Austin Brady Richards and D. Christopher Rogers.) Available at www.safit.org.

Strong, D. R. 1972. Life history variation among populations of an amphipod (*Hyalella azteca*). Ecology 53: 1102-1111.

Wurtsbaugh, W., and A. M. Marcarelli. 2004. Phytoplankton and Zooplankton in Farmington Bay and the Great Salt Lake, Utah (2003). Report to Central Davis Sewer Improvement District, Kaysville, UT.

Wurtsbaugh, W., and A. M. Marcarelli. 2006. Eutrophication in Farmington Bay, Great Salt Lake, Utah; 2005 Annual Report. Report to Central Davis Sewer Improvement District, Kaysville, UT.

Taxonomic References: Macroinvertebrates

Beck, D. E. 1954. Ecological and distributional notes on some Utah Hirudinea. Utah Academy Proceedings 31: 73-78.

Burch, J. B. 1982. Freshwater snails (Mollusca: Gastropoda) of North America. U. S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, OH. 294 p.

Chamberlin, R., and E. J. Roscoe. 1948. Check list of recent Utah mollusca. Bulletin, University of Utah Biological Series 39: 1-16.

Edmunds, G. F., Jr., S. L. Jensen, and L. Berner. 1976. The mayflies of North and Central America. University of Minnesota Press, Minneapolis, MN. 330 p.

Epler, J. 1995. Identification manual for the larval Chironomidae (Diptera) of Florida. Bureau of Surface Water Management, Florida Department of Environmental Protection, Tallahassee, Florida.

Klemm, D. J. 1972. Freshwater leeches (Annelida: Hirundinea) of North America. U. S. Environmental Protection Agency Biota of Freshwater Ecosystems Identification Manual No. 8, US-GPO, Washington, D.C. 53 p.

Merritt, R. W., and K. W. Cummins (eds.). 2007. An introduction to the aquatic insects of North America, 4th ed. Kendall/Hunt Publishing Company, Dubuque, Iowa. 1158 p.

Musser, R. J. 1962. Dragonfly nymphs of Utah (Odonata: Anisoptera). Univ. of Utah Biological Series 12(6), 66 p.

Pennak, R. W. 1978. Fresh-water invertebrates of the United States, 2nd ed. John Wiley & Sons, New York. 803 p.

Provonsha, A. V. 1975. The Zygoptera (Odonata) of Utah with notes on their biology. Great Basin Naturalist 35: 379-390.

Provonsha, A. V. 1990. A revision of the genus *Caenis* in North America (Ephemeroptera: Caenidae). Transactions of the American Entomological Society 116 (4): 801-884.

Rogers, D. C. 2005. Identification Manual to the Freshwater Crustacea of the Western United States and Adjacent Areas Encountered During Bioassessment. Technical Report #1, Ecoanalysts, Inc., Moscow, Idaho. 81 p.

Spencer, D. R., and R. L. Denton. 2003. Aquatic Oligochaeta (Annelida: Lumbriculidae, Haplotaxidae, Naididae, Tubificidae) of Utah. Western North American Naturalist 63: 343-352.

Thorp, J. H., and A. P. Covich (eds.). 1991. Ecology and classification of North American freshwater invertebrates. Academic Press, San Diego, CA. 911 p.

Wiggins, G. B. 1995. Larvae of the North American Caddisfly genera (Trichoptera), 2nd edition. University of Toronto Press, Toronto. 457 p.

Taxonomic References: Zooplankton

Aliberti, M. A., et al. 2010. An image-based key to the zooplankton of the Northeast (USA). Center for Freshwater Biology, Department of Biological Sciences.

University of New Hampshire, Durham, NH 03824 USA. Available online at: http://cfb.unh.edu/CFBkey/html/index.html.

Central Michigan University (various authors). 2001. Zooplankton of the Great Lakes.
Available online at: http://www.cst.cmich.edu/users/mcnau1as/zooplankton web

Brooks, J. L. 1957. The systematics of North American Daphnia. Memoirs of the Connecticut Academy of Arts and Sciences 13:1-180.

Edmonson, W.T. (ed.). 1959. Freshwater Biology, 2nd edition. John Wiley and Sons, New York.

Pennak, R. W. 1978. Fresh-water invertebrates of the United States, 2nd edition. John Wiley & Sons, New York. 803 p.

Resources Inventory Committee, Province of British Columbia. 1997.
A Key to Cladocerans (Crustacea) of British Columbia: Families Daphniidae, Sididae, Bosminidae, Holopediidae, Leptodoridae and Polyphemidae. Available online at: http://www.ilmb.gov.bc.ca/risc/pubs/aquatic/crustacea/index.htm.

Thorp, J. H., and A. P. Covich (eds.). 1991. Ecology and classification of North American freshwater invertebrates. Academic Press, San Diego, CA. 911 p.

Table Legends

Table 1. List of impounded wetlands sampled during 2010. The right-hand column indicates those wetlands that were also sampled for macroinvertebrates using the current methodology in November 2007 and November 2009 (see Gray 2009, 2010).

Table 2. List of macroinvertebrate taxa collected during 2010 in the impounded wetlands.

Table 3. List of zooplankton taxa collected during 2010 in the impounded wetlands. Species identifications are tentative.

Figure Legends

Figure 1. Relative abundance of the base community taxa (top) and PMI community taxa in the GSL impounded wetlands relative to SAV cover class. Data from all sampling periods. Bars indicate 1 s.e. (transformed data; see Sampling Methods).

Figure 2. Relative abundance of base and PMI taxa in varying amounts of SAV (*Stukenia*) at Pintail Pond, 26 May 2010. Percentages are means of 2 net sweeps for sparse SAV and 3 sweeps for dense SAV.

Figure 3. Relative abundance of Hyalella in impounded wetlands with varying amounts of cover of filamentous algae and duckweed.

Figure 4. Relative abundance of PMI community taxa (raw percentages) in relation to SAV cover at selected sites. November 2009 data from Gray (2010).

Figure 5. Relationship of total taxa (top) and Simpson's index to SAV cover for all samples during 2010 (N = 47). For total taxa: Spearman correlation coefficient (Rs) = 0.74, $P < 0.01$; for Simpson's Index, Rs = 0.44, $P<0.01$.

Figure Legends (continued)

Figure 6. Seasonal changes in total macroinvertebrate taxa and SAV cover at selected sites. Top: Pintail and Widgeon ponds (Public Shooting Grounds); Middle: Ambassaddor W1 pond and Bear River 4C pond; Bottom: the three ponds in the Harrison Duck Club. (0) indicates no SAV present.

Figure 7. Frequency distribution of total sample biomass (as grams dry mass) for all benthic samples collected in 2010 (N = 47).

Figure 8. Relative contribution of major taxa to macroinvertebrate biomass at all sites in the GSL wetlands during the three sampling periods in 2010 (N = 7 for May, N = 20 for July and November).

Figure 9. Relative importance values of Cladocera species in the GSL wetlands complexes. Relative importance calculated as the sum of relative frequency (number of samples each species was found at each complex divided by total number of samples from each complex) and relative abundance (mean percentage of all cladocerans from all samples from each complex).

Figure 10. Habitats of Cladocera species in the GSL wetlands. Median cover classes of vegetation types correspond to weighted relative abundance of each species at all of the wetlands ponds where each species occurred.

Appendix Legends

Appendix A. Counts of Macroinvertebrates by taxon, site and date; and Community Metrics by site and date during 2010.

Appendix B. Biomass of Macroinvertebrates by major taxon, site and date during 2010. Biomass given as dry mass per composite sample.

Appendix C. Percent composition of the zooplankton by major taxon, site, and date during 2010. Percentages are counts for that taxon out of total counts of zooplankton individuals from all taxa at that site and date.

Appendix D. Percent composition of rotifers by genus, site, and date during 2010. Percentages are counts for each genus out of total counts of all rotifers at that site and date.

Appendix E. Percent composition of copepods by species, site, and date during 2010. Relative abundance indicated as D (dominant, or greater than 50% of copepods present), C (common, at least 10% of copepods present), or R (rare, less than 10% of copepods present).

Appendix F. Percentage composition of cladocerans by species, site, and date during 2010. Percentages are counts for each species out of total counts of all cladocerans at that site and date.

Appendix G. Water depth in the area of benthic sampling, SAV (submerged aquatic vegetation) height above the bottom, and cover classes of aquatic vegetation (SAV, filamentous algae, and duckweed) by site and date. See Sampling Methods for an explanation of cover classes.

Table 1	**Impounded Wetlands sampled in 2010**				
STORET	**Site**	**Sampling Dates**			Previous Sampling
4985430	Kennecott ISSR - South B pond		20-Jul	15-Nov	(07,09)
4985440	Kennecott ISSR - West A Pond		20-Jul	15-Nov	(07,09)
4985410	Kennecott ISSR - Southwest Pond South			15-Nov	(09)
4985280	Harrison Duck Club - Elbow Pond		21-Jul	17-Nov	
4985270	Harrison Duck Club - Silverwood Pond		21-Jul	17-Nov	
4985260	Harrison Duck Club - South Point Pond		21-Jul	17-Nov	
4985320	Ambassador Duck Club W1	24-May	21-Jul	15-Nov	
4985330	Ambassador Duck Club 100		21-Jul	15-Nov	
4985340	Ambassador Duck Club W2		21-Jul	15-Nov	
4985350	Ambassador Duck Club W5		21-Jul		
4985870	New State Duck Club pond 47	24-May	20-Jul	17-Nov	(07,09)
4985880	New State Duck Club pond 20		20-Jul	17-Nov	(07,09)
4985890	New State Duck Club pond.5-6		20-Jul	17-Nov	(07,09)
4985860	New State Duck Club Middle Unit		20-Jul	17-Nov	(07,09)
4985520	Farmington Bay Wildlife Management Area Unit 1	24-May	20-Jul	16-Nov	(07,09)
4985500	Farmington Bay Wildlife Management Area Unit 2	24-May	20-Jul	16-Nov	(07,09)
4985515	Farmington Bay Wildlife Management Area Turpin Unit - 7th Culvert		20-Jul	16-Nov	(07,09)
4985655	Bear River Migratory Bird Refuge 4C	26-May	19-Jul	16-Nov	
4985650	Bear River Migratory Bird Refuge 5C		19-Jul	16-Nov	
4985630	Public Shooting Grounds Pintail Pond outflow	26-May	19-Jul	16-Nov	(07,09)
4985620	Public Shooting Grounds Widgeon Pond outflow	26-May	19-Jul	16-Nov	(07,09)

Table 2

1. Aquatic Insects: Order	Family	Genus	Species	Taxon Code	Feeding Group
Ephemeroptera	Baetidae	*Callibaetis*	sp.	273	GC
	Caenidae	*Caenis*	*amica*	286	GC
Trichoptera	Leptoceridae	*Ylodes*	sp.	432	SH
	Leptoceridae	*Oecetis*	sp.	431	PR
Odonata	Coenagrionidae	*Ischnura/ Enallagma*	spp.	350	PR
	Aeshnidae	*Aeshna*	sp.	345	PR
	Libellulidae	*Erythemis*	sp.	356	PR
	Libellulidae	*Tramea*	sp.	356	PR
Hemiptera	Corixidae	*Corisella*	sp.	330	PR
	Corixidae	*Trichocorixa*	sp.	330	PR
	Corixidae	*Hesperocorixa*	sp.	330	PH
	Notonectidae	*Notonecta*	sp.	335	PR
Diptera	Ephydridae	Ephydridae	sp.	235	GC
	Chironomidae	*Chironomus*	sp.	84	GC
	Chironomidae	tribe Tanytarsini	sp.	84	GC
	Chironomidae	subfamily Tanypodinae	sp.	89	PR
	Chironomidae	subfamily Orthocladiinae	sp.	86	GC
	Ceratopogonidae		sp.	179	PR
Coleoptera	Dytiscidae	*Oreodytes*	sp.	27	PR
	Dytiscidae	*Sanfilippodytes*	sp.	san	PR
	Dytiscidae	*Laccophilus*	sp.	23	PR
	Hydrophilidae	*Enochrus*	sp.	eno	CG
	Hydrophilidae	*Tropisternus*	sp.	69	CG
	Haliplidae	*Haliplus*	sp.	52	SH

Table 2 (continued)

Other Groups	Family	Genus	Species	Taxon Code	Feeding Group
2. Acarina: Trombidiformes			sp.	7	PR
3. Crustacea: Amphipoda	Hyalellidae	*Hyalella*	*azteca*	489	GC
4. Mollusca: Gastropoda	Lymnaeidae	*Stagnicola*	sp.	503	SC
4. Mollusca: Gastropoda	Physidae	*Physella*	sp.	504	SC
4. Mollusca: Gastropoda	Planorbidae	*Gyraulus*	sp.	505	SC
4. Mollusca: Gastropoda	Planorbidae	*Helisoma*	sp.	505	SC
5. Annelida (Hirundinea)	Glossiphoniidae	*Helobdella*	*stagnalis*	3	PR
5. Annelida (Hirundinea)	Glossiphoniidae	*Glossophonia*	*complanata*	3	PR
5. Annelida (Hirundinea)	Erpobdellidae		sp.	1	PR
5. Annelida (Oligochaeta)	Naididae		sp.	5	GC

Feeding Groups:

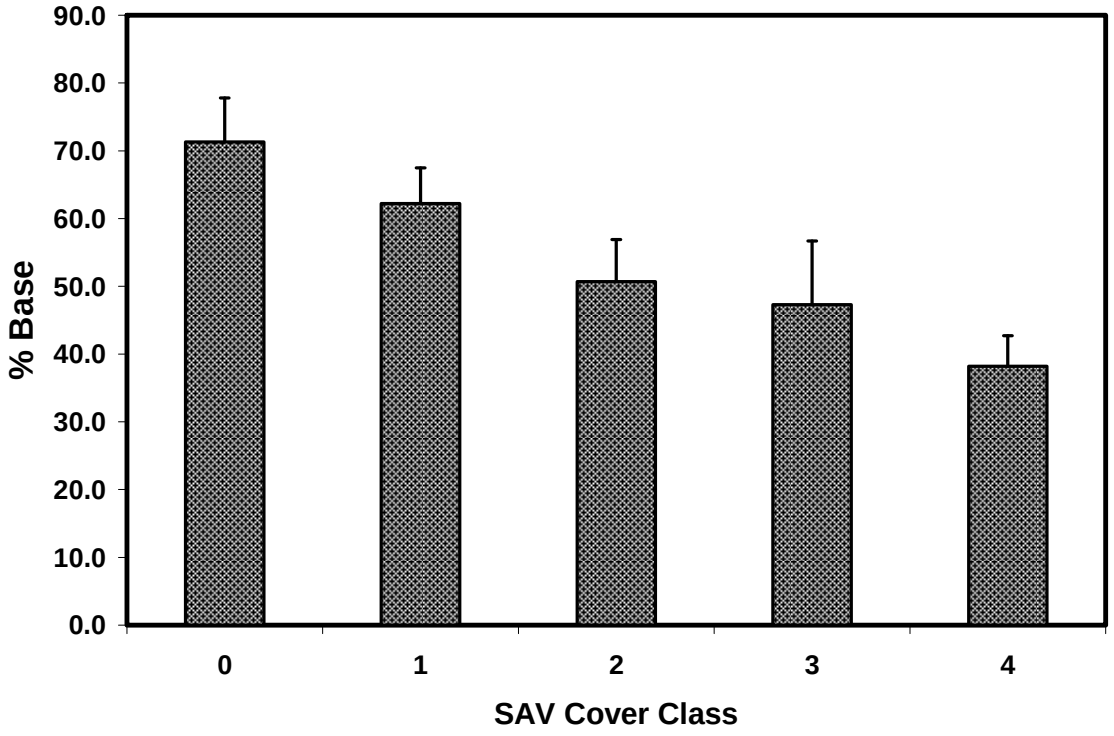
SH = shredder

PR = predator **SC = scraper**

PH = piercer-herbivore **GC = gatherer-collector**

Table 3	**Zooplankton**	
Taxon	**Family**	**Genus/Species**
Cladocera	Daphniidae	*Daphnia dentifera* (Sars)
	Daphniidae	*Daphnia pulex* (Leydig)
	Daphniidae	*Simocephalus vetulus* (O.F.M.)
	Daphniidae	*Scapholeberis* sp.
	Daphniidae	*Ceriodaphnia* sp.
	Chydoridae	*Pleuroxus procurvatus* Birge
	Chydoridae	*Chydorus sphaericus* (O.F.M.)
	Moinidae	*Moina macrocarpa* Straus
	Bosminidae	*Bosmina (Eubosmina)* sp.
	Bosminidae	*Bosmina longirostris* (O.F.M.)
Copepoda	Cyclopidae	*Diacyclops thomasi* (Forbes)
	Cyclopidae	*Eucyclops agilis* (Koch)
	Diaptomidae	*Skistodiaptomus oregonensis* (Lilljeborg)
	Diaptomidae	*Leptodiaptomus connexus* Light
Rotifera	Brachionidae	*Brachionus* sp.
	Brachionidae	*Keratella* sp.
	Asplanchnidae	*Asplanchna* sp.
	Lecanidae	*Lecane* sp.

Figure 1


90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
% Base
0
1
2
3
4
SAV Cover Class

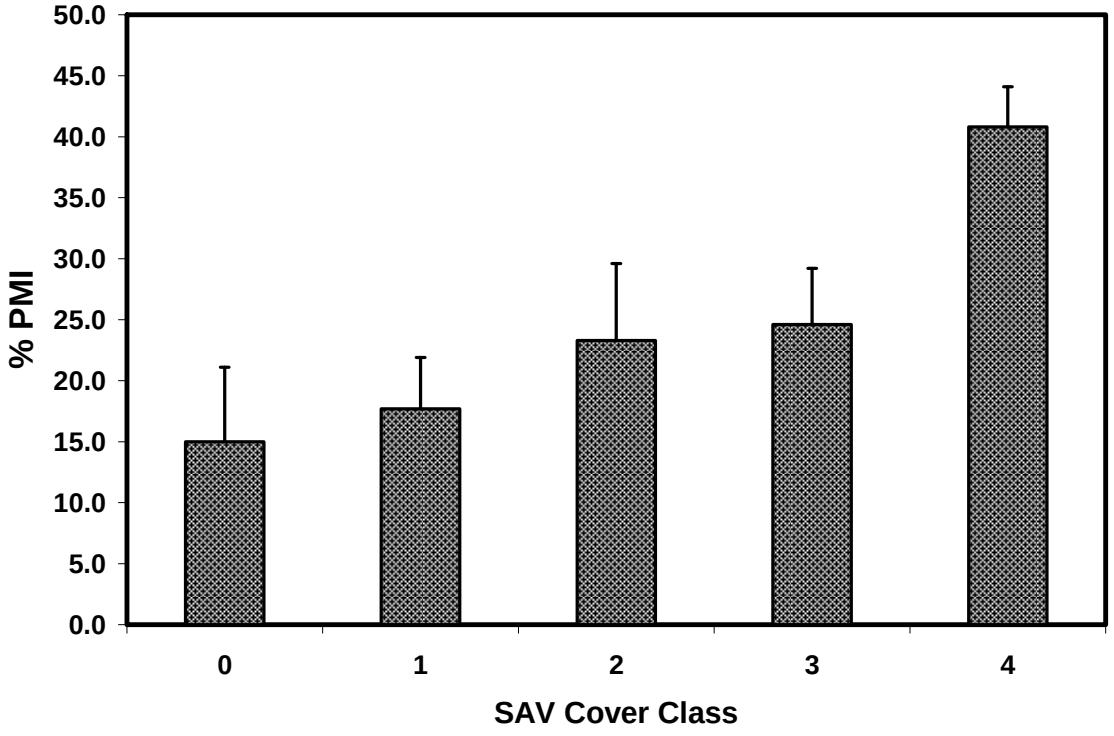

50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
% PMI
0
1
2
3
4
SAV Cover Class

Figure 2

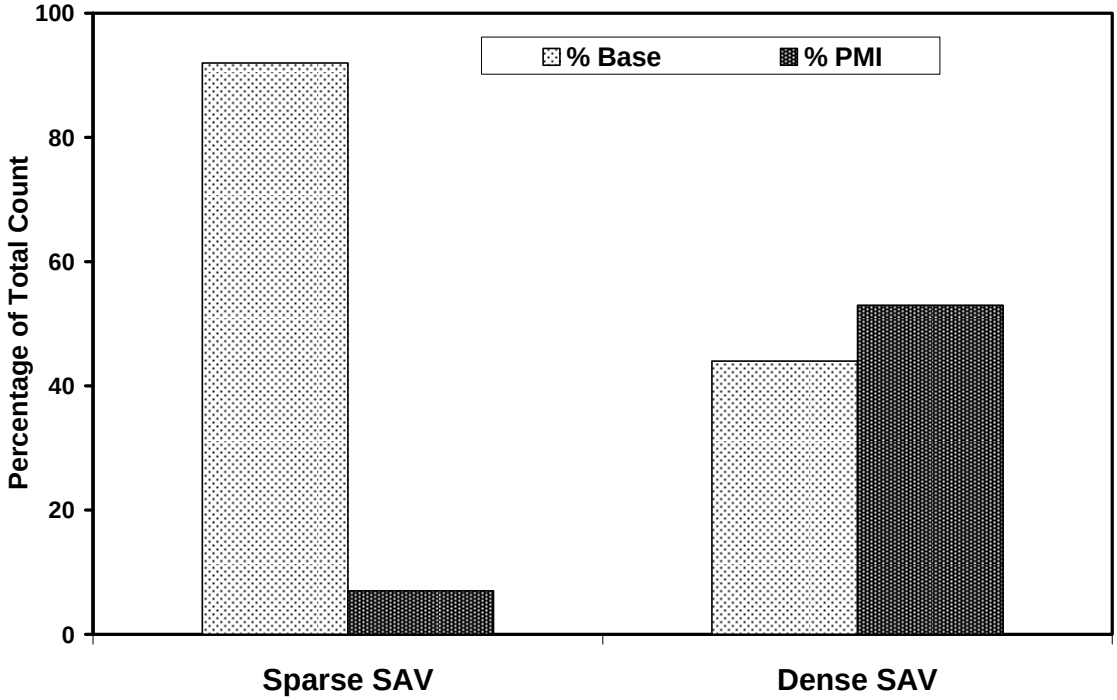

100
80
60
40
20
0
Percentage of Total Count
% Base
% PMI
Sparse SAV
Dense SAV

Figure 3

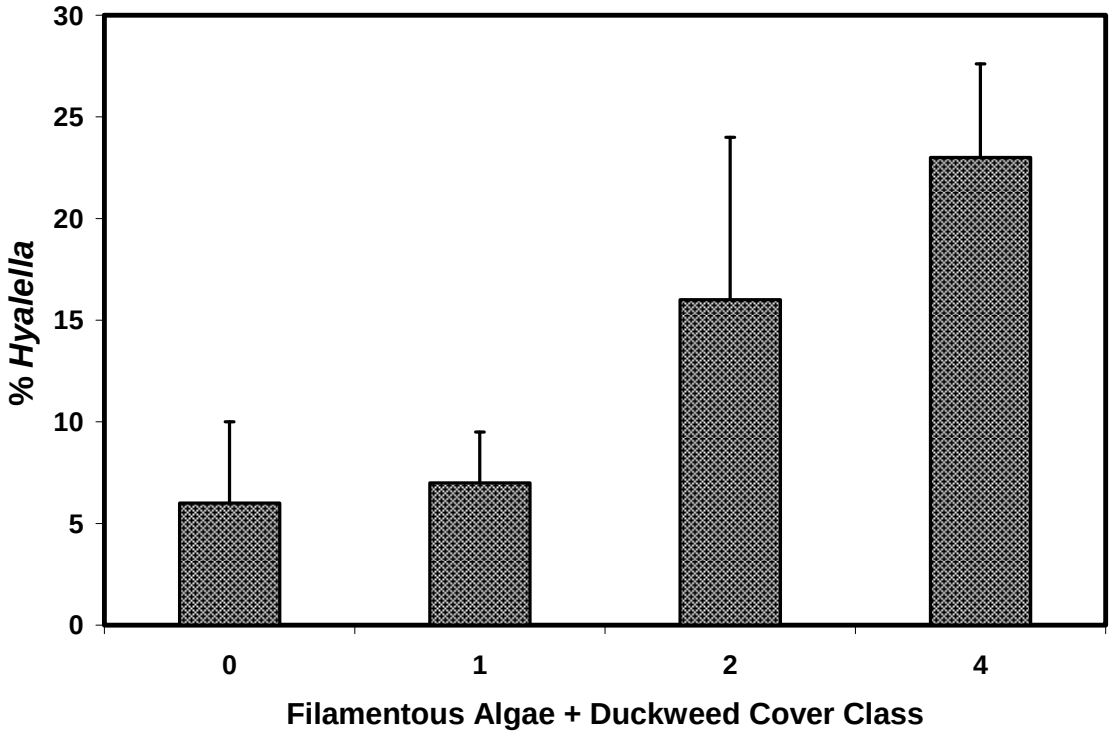
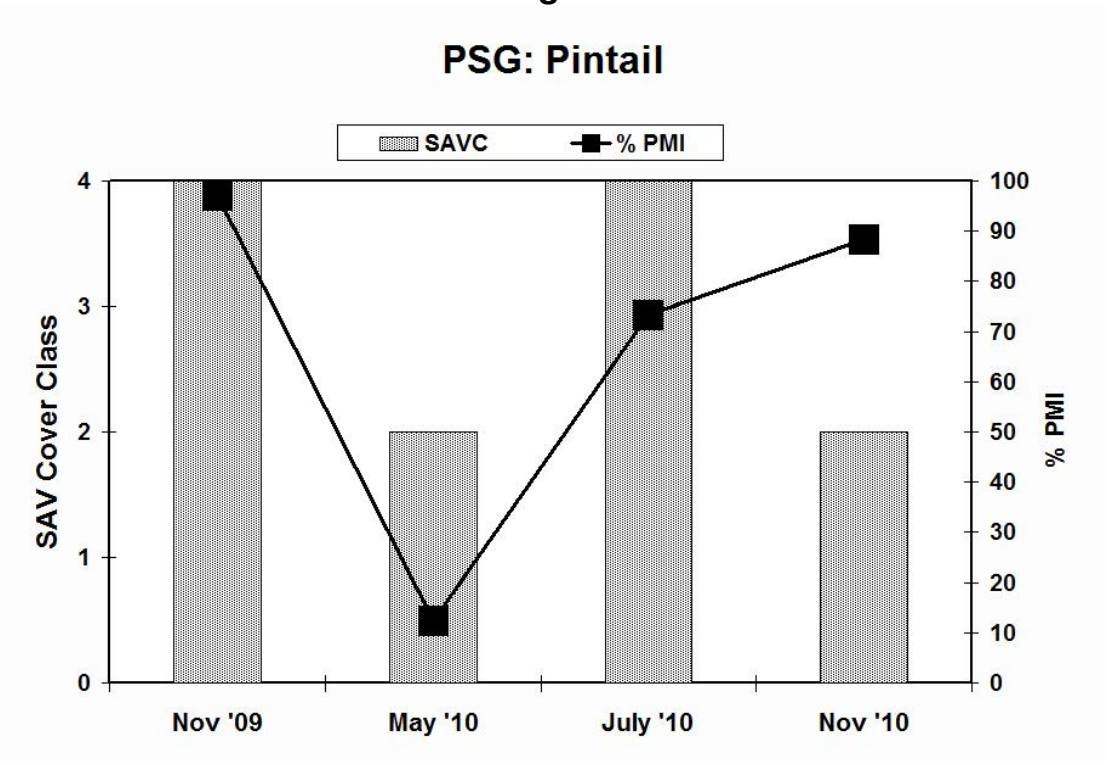

30
25
20
15
10
5
0
% Hyalella
0
1
2
4
Filamentous Algae + Duckweed Cover Class

Figure 4


PSG: Pintail
SAVC
% PMI
SAV Cover Class
% PMI
0
1
2
3
4
0
10
20
30
40
50
60
70
80
90
100
Nov '09
May '10
July '10
Nov '10

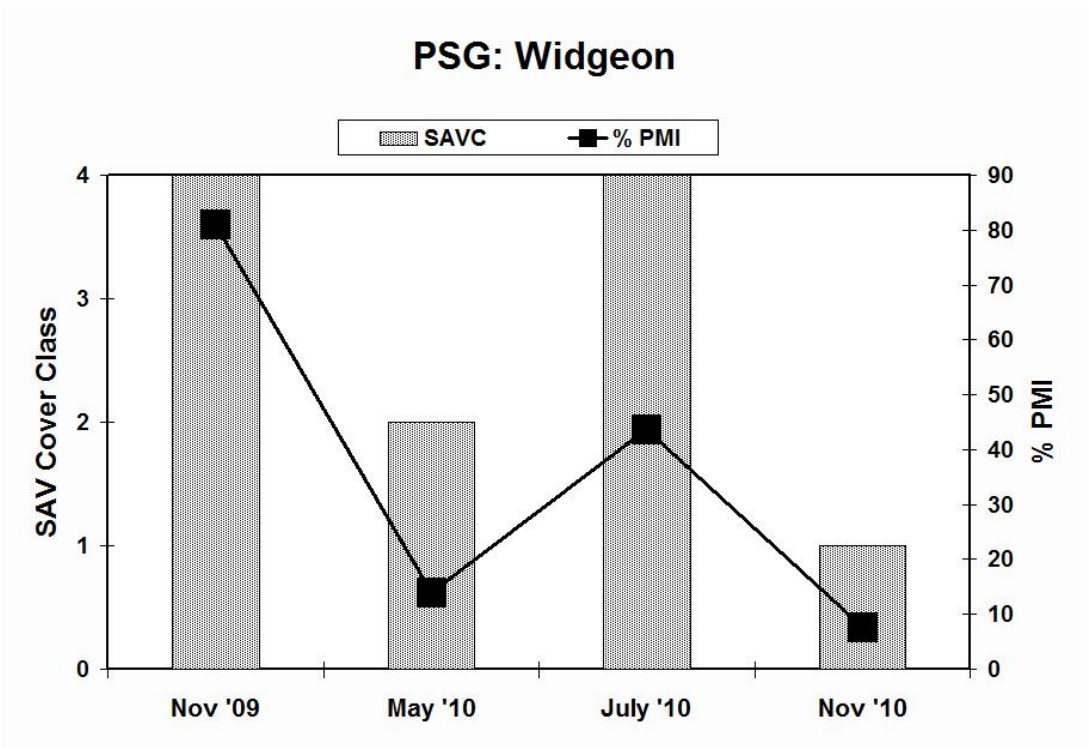
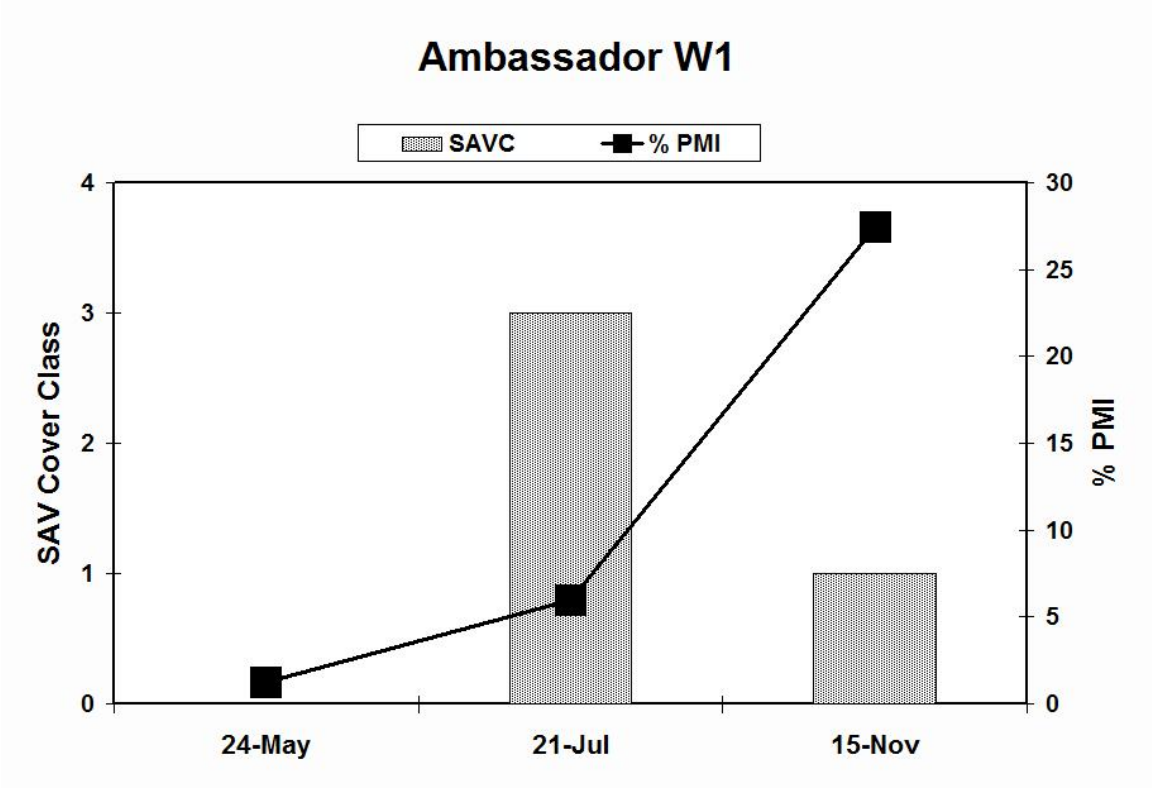

PSG: Widgeon
SAVC
% PMI
SAV Cover Class
% PMI
0
1
2
3
4
0
10
20
30
40
50
60
70
80
90
Nov '09
May '10
July '10
Nov '10

Fig. 4 (continued)



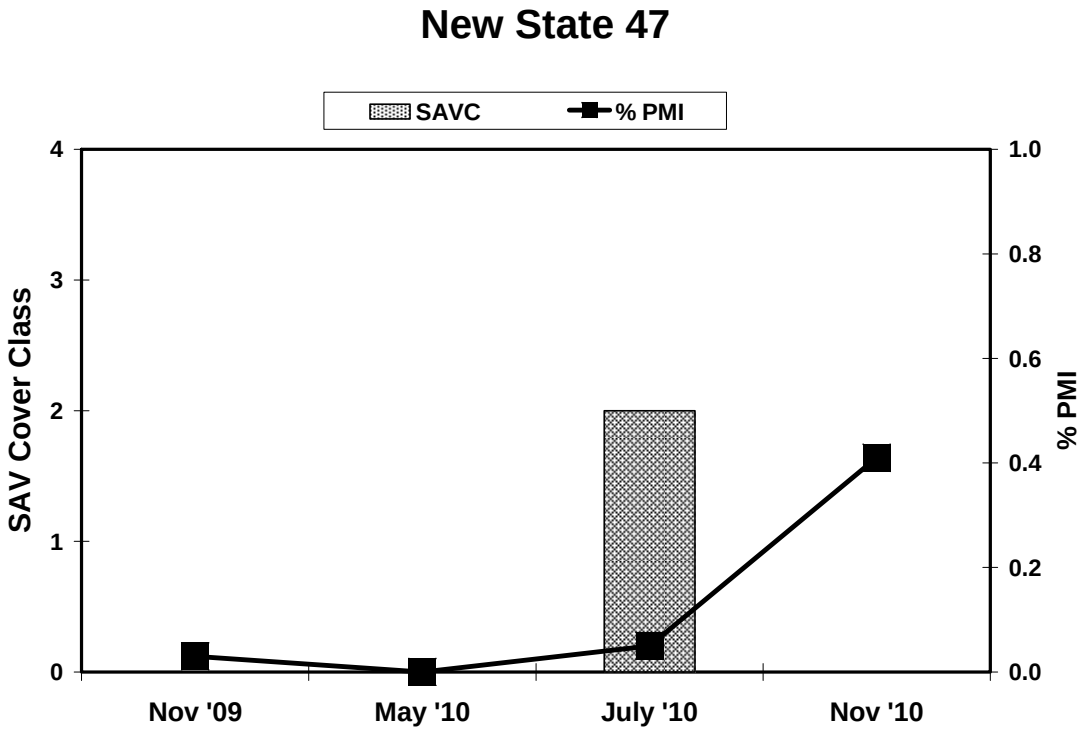


Fig. 4 (continued)

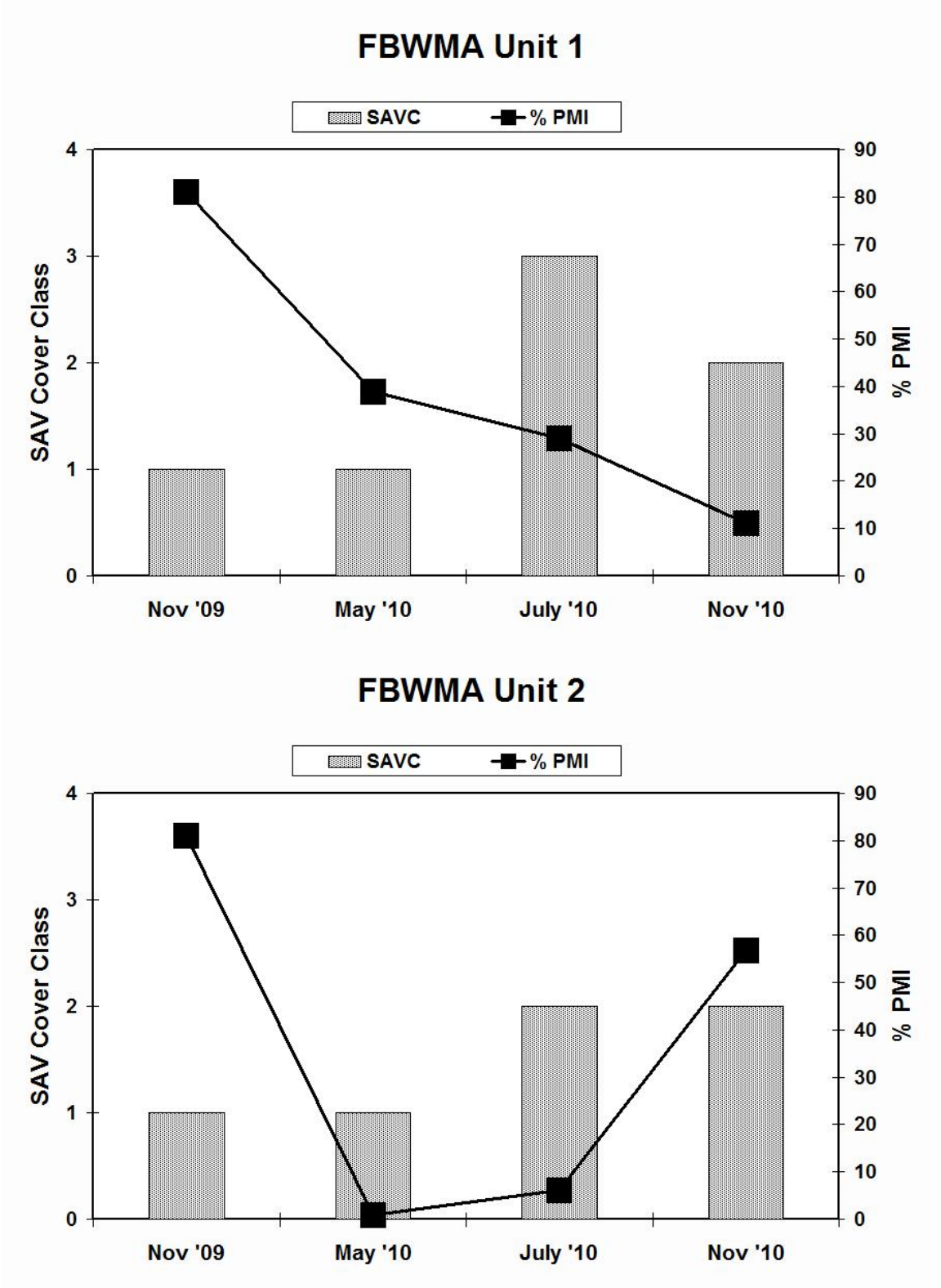
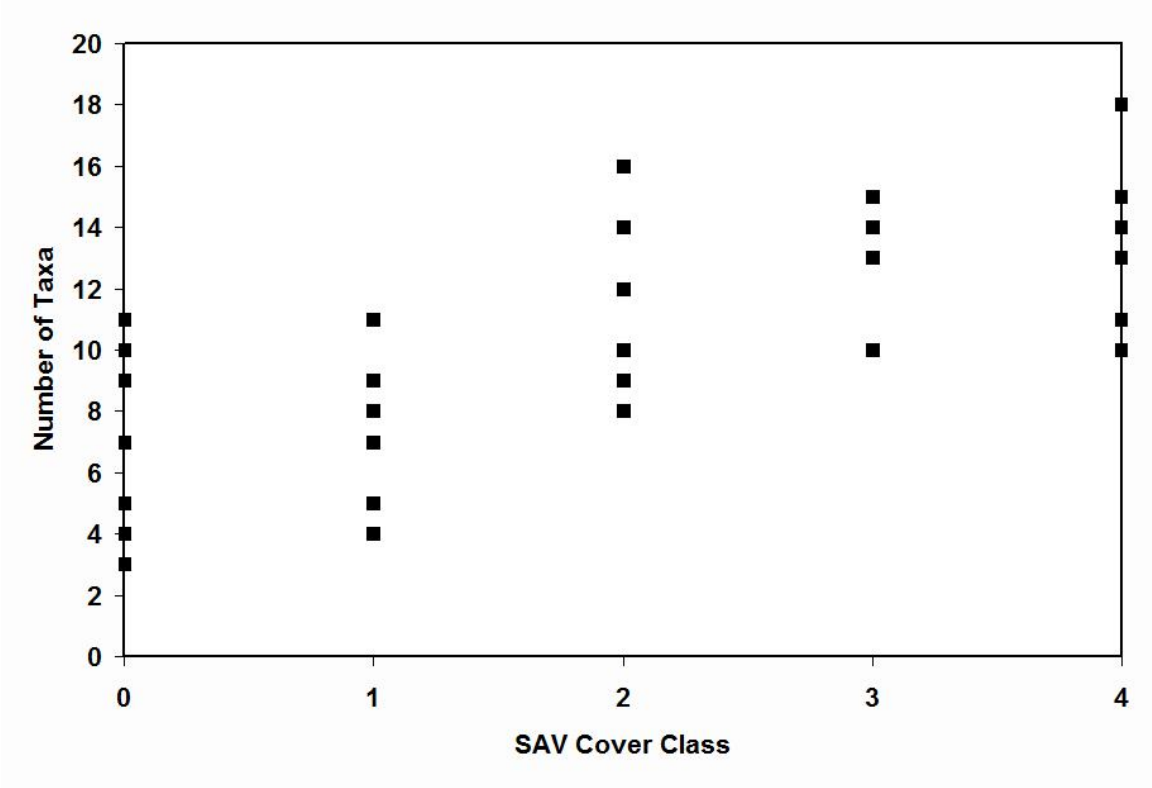


Figure 5


Number of Taxa
0
2
4
6
8
10
12
14
16
18
20
0
1
2
3
4
SAV Cover Class

Simpson's Index
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
0
1
2
3
4
SAV Cover Class

Figure 6

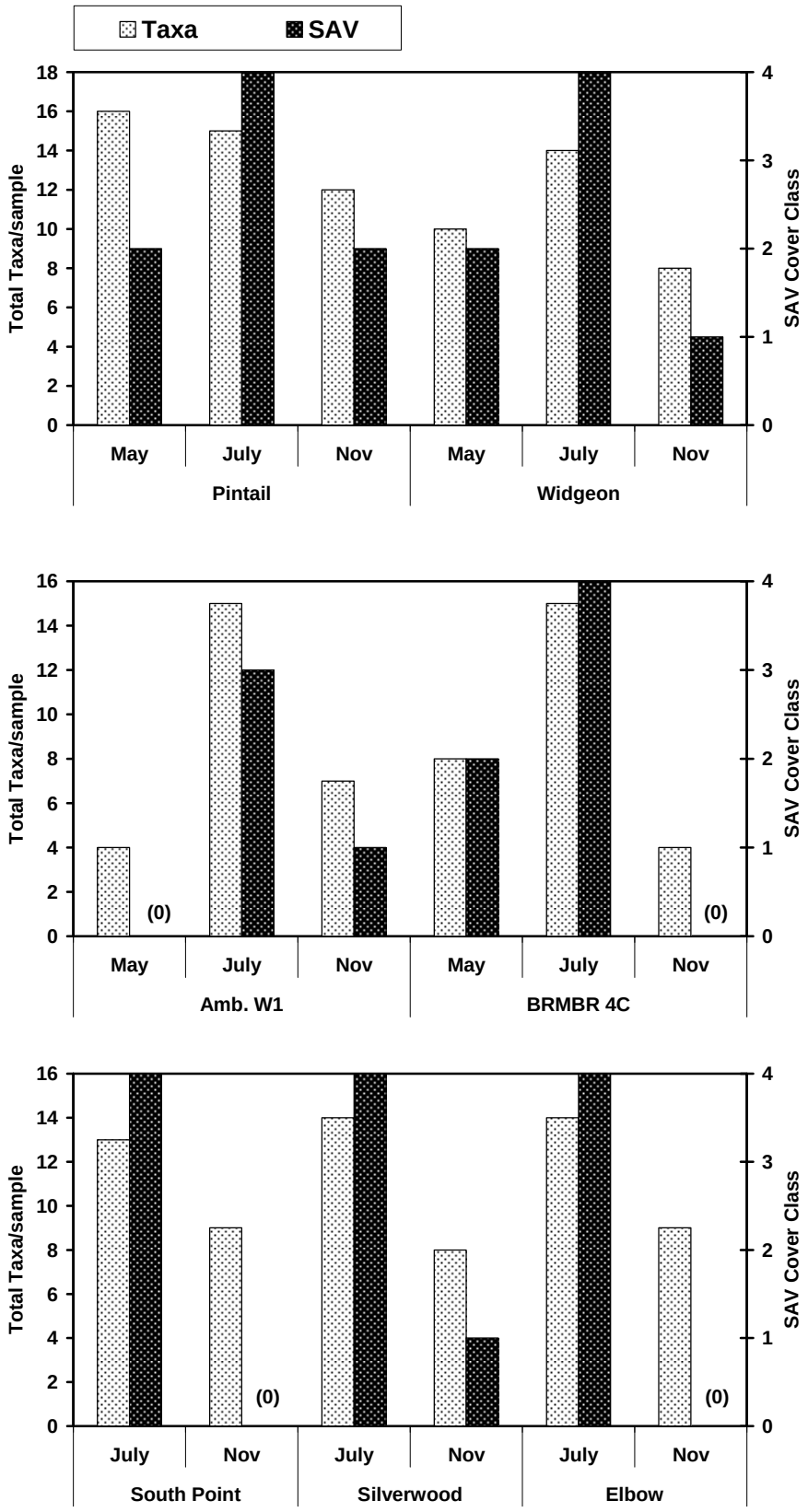

Taxa
SAV
Total Taxa/sample
SAV Cover Class
0
2
4
6
8
10
12
14
16
18
1
3
May
July
Nov
Pintail
Widgeon
(0)
Amb. W1
BRMBR 4C
South Point
Silverwood
Elbow

Figure 7

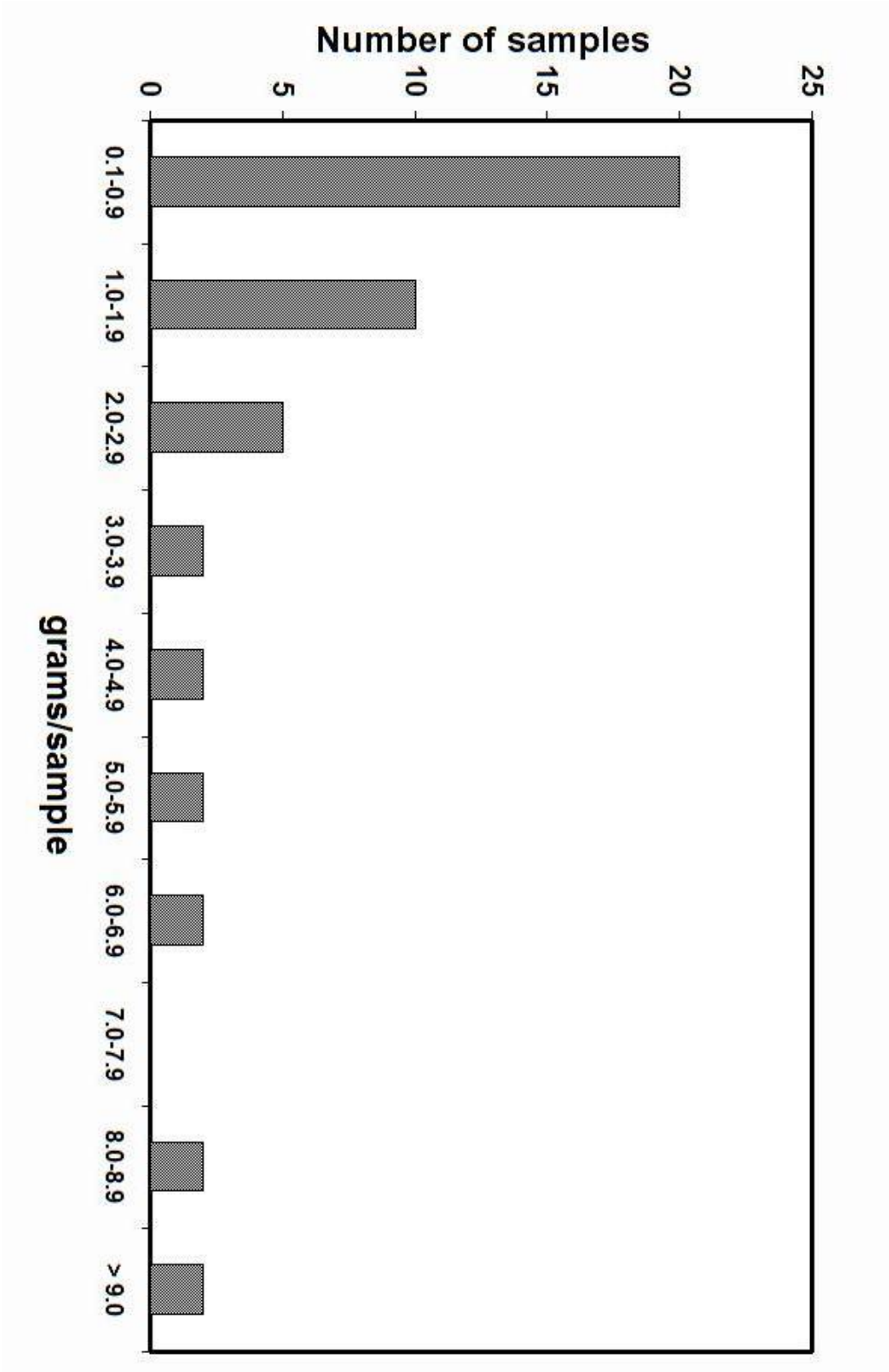
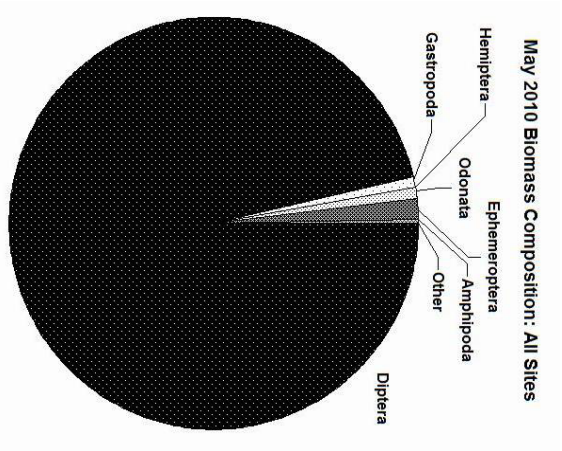
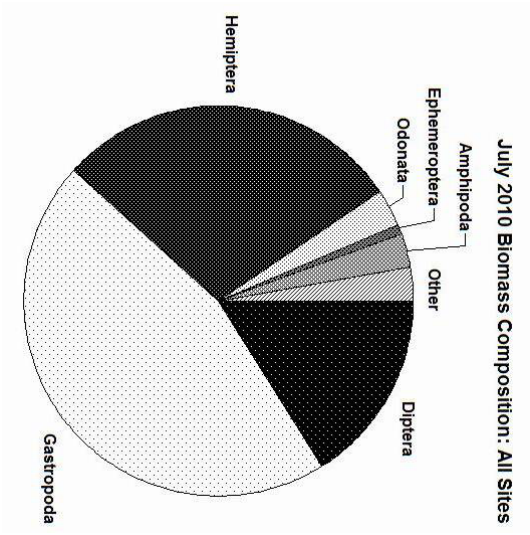

Number of samples
25
20
15
10
5
0
0.1-0.9
1.0-1.9
2.0-2.9
3.0-3.9
4.0-4.9
5.0-5.9
6.0-6.9
7.0-7.9
8.0-8.9
> 9.0
grams/sample

Figure 8


May 2010 Biomass Composition: All Sites
Hemiptera
Ephemeroptera
Odonata
Amphipoda
Gastropoda
Other
Diptera


July 2010 Biomass Composition: All Sites
Amphipoda
Ephemeroptera
Odonata
Other
Diptera
Hemiptera
Gastropoda

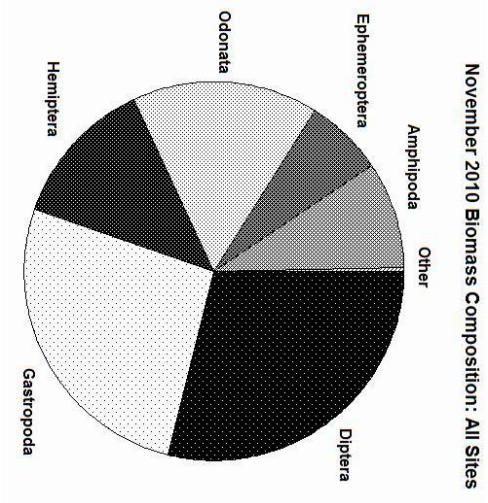

November 2010 Biomass Composition: All Sites
Ephemeroptera
Amphipoda
Other
Odonata
Diptera
Hemiptera
Gastropoda

Figure 9

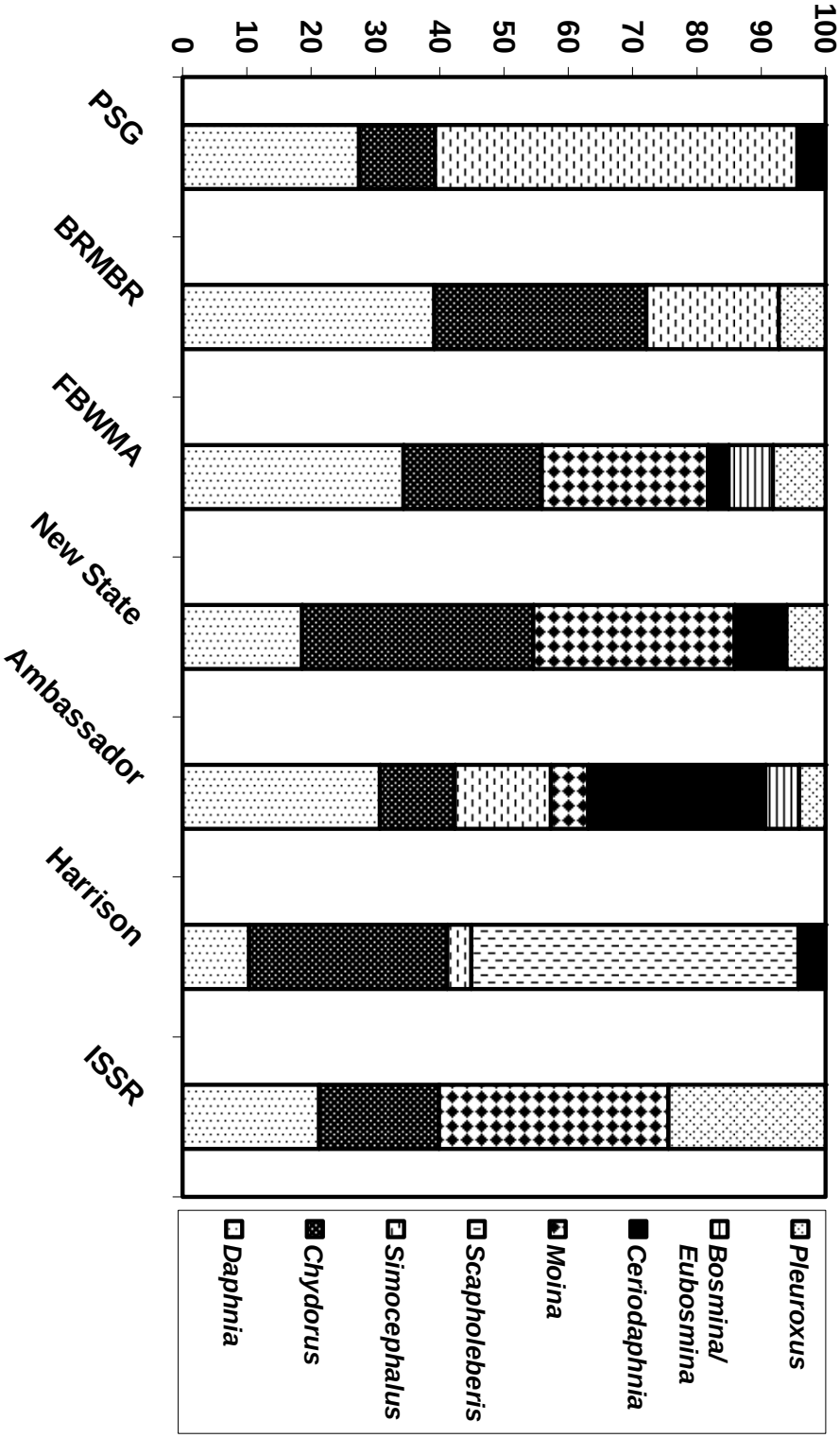
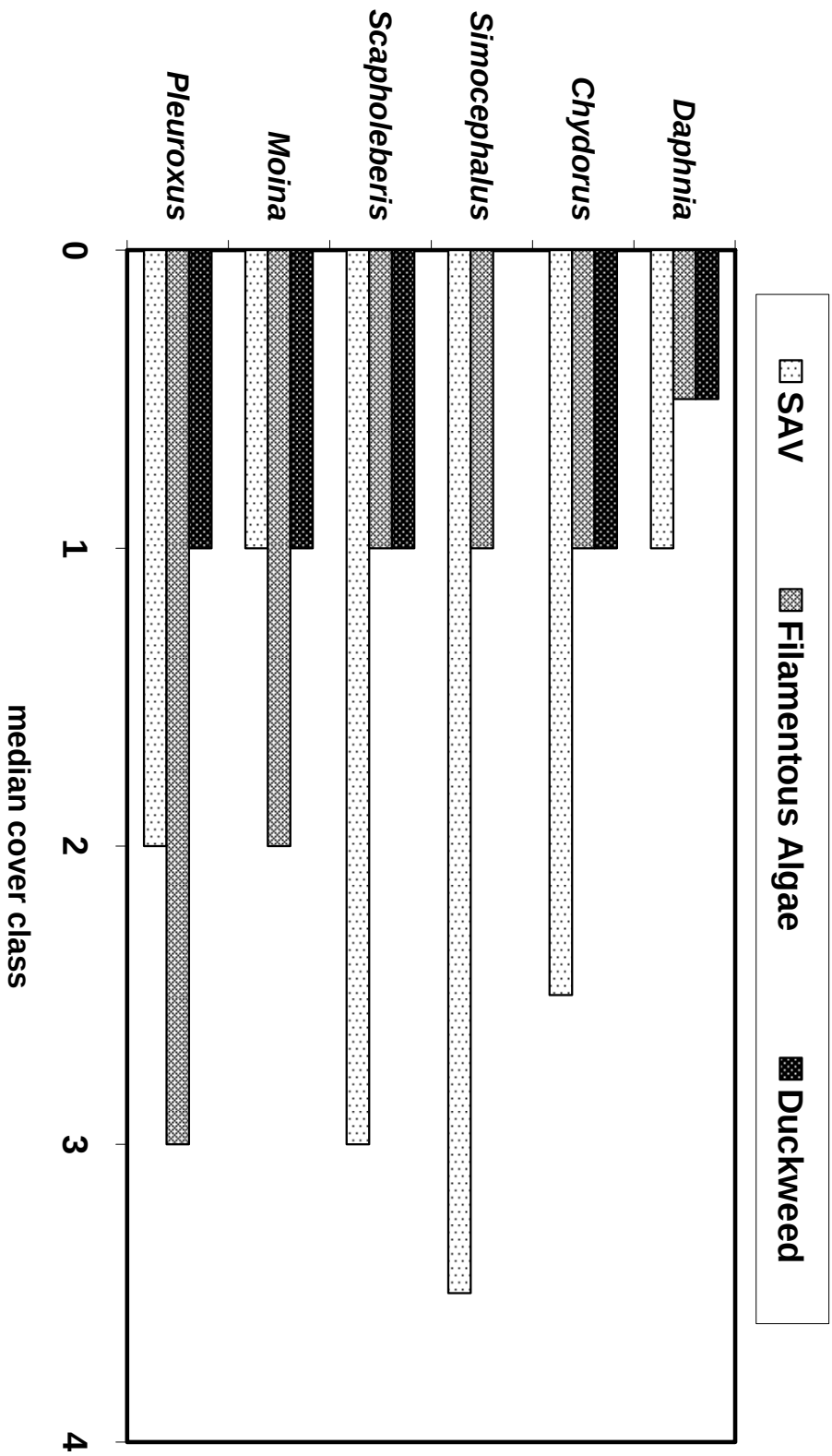

100
90
80
70
60
50
40
30
20
10
0
PSG
BRMBR
FBWMA
New State
Ambassador
Harrison
ISSR
Pleuroxus
Bosmina/ Eubosmina
Ceriodaphnia
Moina
Scapholeberis
Simocephalus
Chydorus
Daphnia

Figure 10


SAV
Filamentous Algae
Duckweed
Daphnia
Chydorus
Simocephalus
Scapholeberis
Moina
Pleuroxus
0
1
2
3
4
median cover class