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Technical Memorandum No. 86-68220-09-10

Culm Breakdown of Three Types of Macrophytes in Las Vegas Wash and Associated Macroinvertebrates, Nutrients, and Trace Elements

Larval caddisflies (*Smicridea*) associated with decomposing material in the Wash.



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Abstract

Decomposition of air-dried macrophytes including hardstem bulrush (*Schoenoplectus acutus*), southern cattail (*Typha domingensis*), and common reed (*Phragmites australis*) were studied in Las Vegas Wash (near Las Vegas, Nevada) using the litter bag technique. Samples were analyzed for macroinvertebrate colonization, dry mass, lignin content, nutrients, and trace elements. Fine-mesh litter bags which excluded macroinvertebrates had loss rates that were significantly lower than those in mesh bags of larger size. It appeared, however, that macroinvertebrate functional feeding groups such as shredders were not associated with differences in decomposition. Different species of macrophytes did not appear to attract specific macroinvertebrate communities. There was evidence that the caddisfly, *Smicridea*, physically modified culm material and aided in processing, but data suggested that microbial processing was most important in biological breakdown of material. Regression analysis indicated that sediment and plant species were important determinants in loss of decomposing plant material. Bulrush breakdown was fastest. Absolute mass of important trace elements such as arsenic and selenium increased in plant material up to day 76 of exposure.

Introduction

Emergent macrophytes are often important in wetland environments, providing structure, primary production, and the basis for detrital food webs after senescence. These important functions may be altered when environments are invaded by non-native plants. Replacement of native emergent vegetation by aggressive invasives such as common reed (*Phragmites australis*) is considered a threat to affected wetlands (Marks et al., 1994). Ecosystem changes from reed invasion often include increases in biomass at a site (Findlay et al., 2002) which in theory could impact biota via increased biological oxygen demand. Alteration of plant communities in this way can impact a variety of ecosystem services, such as sediment/nutrient/trace element retention and environments needed for biota, including aquatic invertebrates.

Las Vegas Wash (Wash) is a perennial stream associated with Las Vegas, Nevada. In the 1930's and 1940's, wastewater treatment plants were built for the Las Vegas community which ultimately discharged into the Wash. This additional water resulted in the development of a wetland area which extended nearly the entire length of the Wash and became important habitat for waterfowl and other wildlife. Later, increased population growth in the Las Vegas metropolitan area augmented discharge into the Wash from water treatment facilities and resulted in large amounts of channel erosion. This down-cutting and channelization of the Wash resulted in a falling water table and draining of the previously inundated floodplain. Wetland areas were largely diminished as a result.

Beginning in 2000, attempts were made to promote channel stabilization by decreasing down-cutting, reducing stream erosion, and protecting the channel with native riparian vegetation. As of 2005, eight grade control structures were in place with several more in

the planning stages. While plantings of native wetland plants (e.g., bulrush (*Schoenoplectus* spp.)) have occurred at areas along the Wash, in many cases the exotic invasive haplotype of common reed has emerged as the dominant emergent wetland plant. Some places in the Wash have also been invaded by southern cattails (*Typha domingensis*). While this species is native to the area, it is known as an aggressive invader (Escutia-Lara et al., 2009; e.g., Woo and Zedler, 2002), especially under conditions of high nutrient concentrations as found in the Wash.

Emergent plants are integral elements of nutrient/carbon cycling in wetlands. Plants sequester nutrients and other constituents and provide a carbon source in the form of detritus for biota. Plant litter accumulation and decomposition are important wetland functions, with a balance between these components needed to sustain wetland productivity. There are often important differences in decomposition between plant species, with some plants more recalcitrant than others and these disparities may impact aquatic invertebrates (important in wetland foodwebs) dependent on these carbon sources. Decomposition differences in plants are often related to lignin concentrations found in plant cell walls. Constituents that typify cell wall material include: cellulose, lignin, and hemicellulose. Of these, lignin is especially resistant to microbial degradation because of its complex chemistry of cross-linked polymers. Lignin may also reduce bioavailability of other cell wall constituents to decomposition (e.g., Ágoston-Szabó and Dinka, 2008).

Different plants may also vary in their ability to take up or retain environmental contaminants. Because detritus is an important food source for many organisms, contaminant enrichment may have impacts to food webs. Natural decomposition of plants in waterways associated with wastewater treatment sometimes produces detritus enriched with trace elements that can be at concentrations potentially hazardous to aquatic organisms.

Litter decomposition typically occurs in steps that progress sequentially from leaching, mechanical fragmentation, microbial colonization, and processing by invertebrates (e.g., shredders). Invertebrates vary in importance to the breakdown process in wetland types and in some cases the wetland environment or litter species may not be suitable for invertebrate production. In those cases microbes (mostly fungi) may be responsible for the vast majority of litter weight loss. As decomposition progresses, nutrient concentrations may increase as microbial biomass increases. Microbial (fungal) nitrogen may account for a quarter of nitrogen associated with litter biomass (Findlay et al., 2002). While the importance of these processes has been recognized, little information is available on decomposition of macrophytes in urban wetland systems, and especially lacking are comparisons between exotic invasive plant species and their native counterparts. Information on decomposition and conditions needed to sustain invertebrate decomposers could be important in determining whether undesirable plant species are impacting important functions in the Wash.

The purpose of this study was to compare decomposition rates and macroinvertebrate colonization patterns between the aggressive invaders common reed and cattail, and

native bulrush to determine whether substantial differences in processing characteristics exist between these plants along with trace element and nutrient dynamics. I also examined breakdown processes when macroinvertebrates were excluded with fine mesh. These data could be important in directing management activities concerning the control of cattail and common reed. If the functional attributes are similar, there may be little need for abatement, on the other hand if there are large detrimental impacts associated with decomposing reed or cattail, control may be justified. This study also begins to provide some basic information on carbon cycling in the Wash.

Study Design and Methods

Study area—Several sites were selected in the Wash watershed for use in decomposition studies. These included LW3.85, LW5.5, and LW6.05. These sites correspond to historic macroinvertebrate collection sites (e.g., Nelson, 2007). Long-term water quality collections indicate that nutrient concentrations are elevated within the Wash, with inorganic nitrogen concentrations (sum of ammonia and nitrate nitrogen) averaging around 15 mg/L (Bureau of Reclamation, Lower Colorado Regional Office, 2008). Total nitrogen concentrations found at reference sites in the xeric western United States range in value from 0.22-0.90 mg/L (USEPA, 2000).

Methods--Standing dead culms of bulrush (most of this material was *S. acutus*), common reed, and southern cattail were collected from a variety of locations in December of 2007. A ceramic knife was used in harvesting to avoid contaminating material used in trace element analyses. Culms were air-dried to a constant weight and approximately 20 g placed in mesh bags (20 X 20 cm) made of 1 cm mesh polypropylene material. Culm bags were submerged and attached to rebar posts using plastic covered steel wire at three locations within the Wash. Replicate samples were deployed in spring of 2008 and then collected periodically [in June, September, and in December] so that culm bags were collected that had increasing days of exposure to the Wash. Fine-mesh bags (300- μ m mesh) filled with 20 g of culm material were deployed along with other bags and then collected in June. This mesh size is used to inhibit colonization of culm material by macroinvertebrates and provide an estimate of the importance of microbial vs. macroinvertebrate processing. Nine reed, cattail, and bulrush coarse-mesh bags along with 9 fine-mesh bags (3 of each species) were deployed. Some additional bags were deployed in case of losses from vandalism or bed movement from flooding. Three additional bags for each of the species were retained for measurement of initial condition.

Retrieved culm bags were stored in labeled plastic bags, packed in ice and shipped to the laboratory where each was frozen until processed. Thawed culm bags were washed over a 600 micron sieve and invertebrates picked from the substrate under 10X magnification. Invertebrates were identified to lowest practical taxon using a dissecting scope and numbers tallied. In cases where invertebrates were too numerous to process in a reasonable time, smaller and more abundant organisms (e.g., chironomids) were subsampled using a 3 X 3 cm square grid with 84 squares. Grid squares were randomly selected and organisms picked until at least 200 organisms were processed. All organisms within the final selected square were processed even if the total number

exceeded 200. Total counts for abundant taxa for the sample were extrapolated from the subsample tallies. Less common invertebrates were counted in total.

Invertebrates associated with polypropylene mesh bags that held fine mesh bags were processed with the aim of determining assemblages that were attracted to the structure of the bags but without access to culm material.

In addition to macroinvertebrates from culm bags, kick-net samples were also used to collect samples from the three sites during the periods when culm samples were retrieved. These samples were used to determine whether community structure on culm samples differed from the invertebrate assemblage associated with cobble, rock, and sandy substrates. A 1-minute kick method with a D-frame net (700-800 micron mesh) was used for sampling benthic invertebrates along a ca. 10-meter reach at each sampling site. Invertebrate samples were preserved in 70% propanol and then processed in a manner similar to thawed culm bags.

Biomass of initial culm material was determined after air drying (air drying was incorporated so that microbial communities would not be destroyed) to constant weight. Separate batches of air-dried culms were dried at 60°C for conversion of air-dried mass to oven-dried weight. Oven-dried weights were directly determined for material retrieved after exposure to the Wash environment. Chemical analyses of culms for total nitrogen, arsenic (As), mercury (Hg), selenium (Se), and phosphorus were performed on samples where suitable quantities of material were retained. Initial lignin content was determined to help explain differences in decomposition rates. Nutrients and trace elements from culm material were analyzed by Huffman Laboratories. Samples were typically homogenized in a ceramic mill and then digested in teflon tubes with a mixture of nitric and perchloric acids. Analysis took place by both ICP-AES (phosphorous) and ICP-MS (As, Se, Hg). Nitrogen was analyzed by direct instrumental high temperature combustion with N₂ separated from other gases on a chromatography column. Lignin analyses were done by the West Virginia University Rumen Fermentation Profiling Laboratory, Morgantown, WV, using AOAC (1990) protocols.

Sediment associated with retrieved culm bags from the Wash was retained on a 70 micron sieve during sample processing. Sediment was dried at 60°C and then weighed.

Surface water quality (dissolved oxygen, conductivity, pH, and temperature) and velocity were measured with portable meters at each sample location. Estimates of plant cover, height, and species along with water depth were made at each location along the transects. For culm processing analyses, mean numbers for water quality variables were used which enclosed the specific period of time when processing occurred.

Data analysis— The decomposition rate constant, k , was calculated using the following equation:

$$k = -(\ln(X_i/X_o))/t$$

where X_0 is the original dry weight (60°C), X_t the dry weight of material remaining after time t , and t is the time in days in the wetland.

These k values were used for comparison to other literature values and to contrast decomposition rates between fine mesh and coarse mesh bags. Decomposition rates from fine mesh and coarse mesh bags were compared with paired t -tests using samples retrieved from the same rebar post after the initial deployment.

Stepwise multiple regression (SMR) was used to determine which candidate variables were important in determining culm mass loss from the different samples. Initial independent variables used for the model included: dissolved oxygen, conductivity, date, percent cover, pH, plant height, plant species, sediment mass, velocity, water depth, and water temperature. Macroinvertebrate taxa richness and abundance were also used in the initial model.

Multivariate analysis (CANOCO 4.0), biotic indices of abundance and taxa richness measures, along with functional feeding group status (Merritt and Cummins, 1996) of wetland invertebrates were used in analysis of invertebrate assemblages. Feeding group metrics are considered surrogates of complex processes such as trophic interaction, production, and food source availability (Cummins and Merritt, 1996). Ordination techniques were used to examine patterns in the macroinvertebrate data. Detrended Correspondence Analysis (DCA) was used to determine whether there were differences in community structure between culm-bag invertebrates, those associated with mesh from which bags were constructed, and those collected with kick-nets. Direct ordination with Canonical Correspondence Analysis (CCA) was used to identify physical and chemical variables that were most closely associated with invertebrates found on culm bags. Faunal data were transformed (square root transformation) before analysis. Forward selection of environmental variables and Monte Carlo permutations were used to determine whether variables exerted a significant effect on invertebrate distributions. If environmental variables were strongly correlated, only a single variable was selected for use in CCA to avoid problems with multicollinearity. Environmental variables were normalized if the Shapiro-Wilk Test indicated the necessity for transformation.

Results

Water quality parameters are presented in Table 1 and indicate that adequate concentrations of DO were available, that the Wash has relatively high conductivities and water temperatures, and that velocities varied at locations sampled during the study.

A paired t -test comparing k values for coarse and fine mesh samples after 76 days in the Wash rejected the null hypothesis of no difference ($P=0.0259$, $n=8$), with losses from coarse-mesh bags higher than losses from fine-mesh bags (Figure 1). Comparison of losses indicates that $64.7 \pm 9.7\%$ of decomposition took place in bags that excluded macroinvertebrates, suggesting a maximum value for the portion of breakdown that could be associated with microbial decomposition.

Stepwise multiple regression of data from coarse mesh bags for the entire study identified the amount of sediment in the bag, species of culm material, water temperature, number of days of exposure, and pH as important predictors of % culm loss (Table 2).

Some variables, such as days of exposure, are also coupled with water temperature which would obviously impact culm loss. The amount of sediment negatively affected culm loss in the model, suggesting that burial slows breakdown of material. Sediment found in culm bags averaged 36g/bag, but varied widely from a low of 0.9 g to as much as 225 g per bag. Sediment totally covered some samples, which were never relocated and thus not retrieved. The species of plant material also appeared to be important and a comparison of culm loss by plant type indicates that loss of common reed material was much lower after 76 days of exposure (Figure 2) than was loss of bulrush or cattail material. This was also reflected in day 76 k values (bulrush $k=0.0253 \pm$ (SE) 0.004, cattail $k=0.0252 \pm$ (SE) 0.009, reed $k=0.006 \pm$ (SE) 0.0009). Although k values (calculated only for the initial 76 days of exposure) were similar for bulrush and cattail, cattail material persisted throughout the course of the study while bulrush was gone by the second sampling date. Invertebrate metrics were not significant in the model.

Culm chemistry -- Some of the explanation for differences in processing could be explained by lignin and nutrient analysis for initial material used in the study. Bulrush, which overall decomposed the fastest, had characteristics associated with less recalcitrant materials including significantly lower percent lignin and higher initial values of nutrients (Figures 3- 5). Common reed, while having lignin concentrations similar to cattail, may behave very differently from the other macrophytes because it contains plant structures (leaves and stems) that decompose at different rates.

Losses in mass were, in most cases, faster than N or P enrichment of plant debris (at the time scale used in this study). Although nutrient concentrations tended to increase over time (Figure 4), total nitrogen after 76 days, on a culm weight basis, declined by 58% for bulrush and 66% for cattail. In contrast, common reed experienced an initial increase in nitrogen by day 76 (+46%) but a decline by day 151 (72% decline). Phosphorous content also tended to increase over time (Figure 5).

Elements such as As and Se increased in concentration in all plant material after the first 76 days of exposure to the Wash (Figures 6 and 7). Mercury results (Figure 8) were more variable and these concentrations actually declined in the case of cattail. Despite decreases in biomass, total As and Se increased by 76 days.

Macroinvertebrates—Thirty-two taxa were detected from culm bags and kick-nets collected during the study (Table 3). A net-spinning (collector-filterer) caddisfly (*Smicridea*) was the most common invertebrate detected during the study. Shredders and collectors made up the majority of types of functional feeding groups that were present in the Wash (Figure 9).

Ordination with DCA (Figure 10a and 10b) suggested that there were differences in the macroinvertebrate community based on whether samples were collected with a kick-net or from colonization of culm bags. Most kick-net samples were located in the positive portion of Axis I in the diagram (Figure 10a). Mayflies such as *Camelobaetidius musseri* and *Fallceon quilleri* which are considered to be grazers and scrapers (Baptista et al., 2006, Stagliano and Whiles, 2002; see Figure 11 for *C. musseri* distribution) were especially associated with kick-net samples (e.g., Figure 10b). Shredders, which might be expected to be more common in culm bags, were located towards the middle of the diagram (e.g., *Cricotopus*). These were bags in which culm material was still present and suggests that this midge larva may be associated with detritus in the Wash (however, see discussion below). More characteristic of culm bags in the ordination, however, were taxa that feed as collectors (e.g., *Smicridea*, *Pseudochironomus*, and *Rheotanytarsus*) or those such as *Haetaerina*, *Pentaneura*, and *Hemerodromia* that are predators (see Figure 12 for *Smicridea* distribution). Although classified as a collector, *Smicridea* may have been breaking down culm material by creating small gouged-out depressions that were especially noticeable in reed stems. This may have been to avoid higher flows and for securing its capture net. Reed appeared to be a good substrate for *Smicridea* and in-situ material was also observed to hold large numbers of this collector-filterer (pers. obs.). Macroinvertebrates that were associated with mesh-only also appeared to be separated in ordination space from culm bags with physid snails common on these surfaces (Figure 13). It is unclear why this pattern occurred.

There was no discrimination in the multivariate analysis between community assemblages associated with type of plant culm material, since culm bags containing different types of material were mixed together in ordination space (Figure 10a).

CCA with just culm bags resulted in Figure 14. Eigenvalues were 0.106 for Axis I, 0.065 for Axis II, and 0.043 for Axis III. Species data explained 22.0 % of the variance, while 70.6 percent of species-environment relation was explained in the first two axes. It appeared that culm biomass within the bags was especially important along Axis I, but this may have been mostly associated with seasonal differences in macroinvertebrate communities since biomass was highly negatively correlated with days of exposure ($r = -0.7422$, $p = 0.0000$). Some taxa such as the predator *Hemerodromia* were only detected at the June sampling, while others, including the shredder *Polypedilum* were found on all sampling occasions. Biomass was largely gone by the first sampling date and therefore the continue abundance of *Polypedilum* in December was likely not associated with culm material. It appeared that the shredder *Cricotopus* was associated with biomass in the positive portion of Axis I (Figure 14). This midge larva was detected in all seasons but was more abundant in June than later in September and December. When just June data was examined, however, there was no correlation between *Cricotopus* abundance and culm biomass ($p = 0.2976$, ln transformed data). *Cricotopus* abundance was significantly negatively correlated with retrieval date ($r = -0.5865$, $p = 0.0010$). Again, it appeared that seasonal differences in phenology were responsible for *Cricotopus* association with the positive portion of Axis I.

Axis II appeared to separate assemblages based on surface water conductivity and vegetation height and mostly contained samples collected in September and December. Abundance of macroinvertebrates was negatively associated with conductivity ($r = -0.5767$, $p = 0.0122$) especially when June data were omitted. It appeared that conductivity was often higher at nearshore environments and this may have played a role in discriminating between communities. Height of nearby vegetation was positively associated with macroinvertebrate abundance ($r = 0.4436$, $p = 0.0180$). The presence of macrophytes can sometimes influence adult behavior, which can then increase larval abundance in specific areas (Remsburg and Turner, 2009).

In summary, no patterns in the invertebrate community emerged that were associated with plant species undergoing breakdown.

Discussion

Macroinvertebrates--Processing rates with coarse vs. fine mesh suggested differences related to access by macroinvertebrates. Physical fragmentation may play some role in these observed differences; however, velocity was not significant in predicting culm loss, suggesting that the link between flow and fragmentation is weak. Other evidence that macroinvertebrates were responsible for processing came from ordination which indicated a difference in assemblages associated with sampling technique. No functional feeding groups were clearly associated with processing; however, hydropsychid collector-filterer caddisflies (*Smicridea*) appeared to be responsible for breaking down material by physically modifying the culm substrates on which they resided. Hydropsychid caddisflies have been implicated in the collapse of bridges from biting out depressions in wood pilings (Flint, 1996) and may even create depressions in much harder surfaces such as travertine (Paprocki et al., 2003). Net-spinning caddisflies, may, along with capture of small particles in the Wash also produce such particles as they gouge litter. It is likely that *Smicridea* uses a variety of substrates for attachment and makes facultative use of macrophytes. Decomposing wetland macrophytes often contain high numbers of invertebrate collectors and, along with scrapers, can be the most important invertebrates involved with culm breakdown (Bayo et al., 2005). Both of these functional feeding groups were relatively common in the Wash.

The species of culm material appeared to produce no difference in macroinvertebrate community make-up in the Wash; instead the main difference observed in ordination appeared to be related to seasonal changes or phenology of assemblages. This suggests that there were no large differences in the ability of senescent macrophyte material to support Wash invertebrates. Other studies comparing invertebrate use of reed vs. cattail also found no difference in the ability of these macrophytes to support food webs (Kulesza and Holomuzki, 2006).

Culm processing— Comparison of processing rates where macroinvertebrates were excluded from culm bags suggests that the majority of biologically-mediated breakdown in the Wash was microbial in nature. Other studies of macrophyte decomposition have reported contributions of decomposition related to microbial decomposers as high as 89-99% (Bayo et al., 2005). Data from the present study suggests differences in breakdown

associated with plant type and that common reed is processed more slowly, at least initially, than other emergent plants in the Wash. Other literature (Christenson et al., 2009) has documented similar differences between plant species. Bulrush culm material was, unlike other materials, largely gone by day 151. This faster breakdown was associated with lower lignin and higher baseline nutrient concentrations. Exogenous nitrogen, however, is readily available in the Wash and microorganisms may not be dependent upon nitrogen contained within plant material (e.g., Melillo et al., 1982).

Decomposition rates obtained from this study were relatively high during the initial 76 days with breakdown rate coefficients for bulrush and cattail of $k=0.025/\text{day}$ and reed of $k=0.006/\text{day}$. Average literature values for *Typha domingensis* and *Phragmites australis* indicate k values of 0.0045 and 0.0039/day respectively, while *Schoenoplectus (Scirpus) acutus* values were presented as 0.0055/day in the Appendix provided in Chimney and Pietro (2006). However, decomposition rates in high nutrient environments during summer months when water temperatures are high, may be fairly rapid (bulrush $k=0.037/\text{day}$) (Thullen et al., 2008), and similar conditions in the Wash may explain, in part, the relatively rapid loss of material.

Nutrient/trace element dynamics—While nutrients were concentrated in culm material exposed to the Wash, decreases in biomass resulted in a net loss of nutrients to the environment. There is likely a point earlier in the process, before large declines in biomass occur, where nitrogen mass would be increased in culm material. Sediment in the Wash could result in burial of large amounts of nutrient-containing plant material resulting in nutrient immobilization or, in the case of nitrogen, loss to the atmosphere, which could be an important ecosystem service. Nutrient uptake would occur during plant growth and also during microbial growth on senescent and decomposing material. Nutrient enrichment of detritus has been frequently interpreted as an indication of associated microbial biomass (e.g., Menéndez, 2005). Nutrient export from the system could occur by burial of material along with denitrification and removal by insects when they emerge from the aquatic environment as flying adults. Most longitudinal profiles indicate a biogeochemical steady state (inputs=outputs) of nutrient concentrations (Brookshire et al., 2009) in most streams. Complexities, of course, may be associated with different environments along the Wash, such as backwaters or lentic areas above erosion control structures, which were not sampled during this study.

Much of the available literature on trace elements and plants is related to living tissue (e.g., Outridge and Noller, 1991), making comparison between decomposing material in the Wash with other sites tenuous. Given that caveat, Hg uptake into aquatic plant leaves from unpolluted sites in the tropics varied from 0.03 to 0.075 $\mu\text{g/g}$ (Molisani et al., 2006) suggesting that concentrations in culms exposed to the Wash (Mean=0.03 $\mu\text{g/g}$, maximum=0.10 $\mu\text{g/g}$, $n=27$) were relatively low. There was evidence for sequestration of the trace elements As and Se in culm material. In addition to increased concentrations, there was also an overall increase in mass of these materials for at least the first 76 days of the study. Mass accumulation was moderated by the concomitant decay of the litter as the study progressed. In the Wash macrophyte tissue mean values for As were 4.9 $\mu\text{g/g}$ and ranged from 0.15 to 33.0 $\mu\text{g/g}$ while Se mean values were 2.6 $\mu\text{g/g}$ and ranged from

0.22 to 8.8 $\mu\text{g/g}$. Some of these Se concentrations were higher than those from another study that examined Se concentrations from living macrophyte tissue at sites associated with the Wash (mean values for vegetative tissue ranged from 1-3 $\mu\text{g/g}$) (Pollard et al., 2007). Lakes contaminated with As in Canada resulted in average concentrations of 17.2 $\mu\text{g/g}$ of As in cattail shoots (Dushenko et al., 1995) a value that is 3X higher than the As measured in decomposing macrophyte tissue in the Wash. Hamilton (2004) in a review of Se in the food chain lists levels of concern for Se in diet as ranging from 2-7 $\mu\text{g Se/g}$ dry weight, values which are similar to those found in the Wash culm material. The diet information in Hamilton (2004) is focused mostly on fish and birds, however, more recent information suggests that sublethal effects may occur in invertebrates at concentrations as low as 1 $\mu\text{g Se/g}$ dry weight (deBruyn and Chapman, 2007). The presumed bioconcentration of these elements in culm and invertebrate material could lead to entry into Wash food webs. As a well known example, selenium accumulation in wetlands has been shown to cause death of waterfowl at Kesterson Reservoir National Wildlife Refuge (Ohlendorf, 1989). However, Sobolewski (1999) suggests that specific conditions may be necessary to produce ecotoxicological effects and this may only rarely occur in wetlands. Numerically abundant invertebrates such as *Smicridea* and *Petrophila* could theoretically further bioconcentrate and transfer toxicants to both aquatic and, after adult emergence, terrestrial food chains (e.g., Walters et al., 2008). It is unclear how much Se/As would be easily taken up by invertebrates feeding on decomposing culm material in the Wash. A portion of the trace elements may be inert and Zawislanski et al. (2001) suggested this was the case with a study of decomposing marsh plant species. Large amounts of Se and other trace metals were found to be associated with fine sediment on plant material. This fine sediment was present despite cleaning material before analysis. It is likely that this was also the case in the present study at the Wash.

Macrophyte comparisons—Long-term bulrush processing was very different from that of both common reed and cattail. Bulrush was gone by the second sampling date and this species was initially highest in nutrient concentrations and lowest in recalcitrant lignins. Further, high Se concentrations were associated with bulrush plant material after 76 days.

The initial (after 76 days) loss rate of material for cattail was similar to that of bulrush, but recalcitrant material persisted to the end of the study. As in the case of bulrush and reed, decomposing cattail also tended to concentrate trace elements.

Common reed persisted in the environment. However, reed is somewhat unique in that it contains plant structures that decompose at different rates (Ágoston-Szabó and Dinka, 2008). Leaves decompose much faster than the main body of the plant (Dinka et al., 2004). Findlay et al. (2002) estimated that 13% of aboveground biomass of common reed is leaf blades. In theory, this variety of litter types may be desirable since it has been suggested that a mixture of detrital types (fast and slow processors) are necessary to maximize invertebrate abundance (Bjelke et al., 2005). The stem material may be persistent in the environment and function like woody debris in providing structure for biota. Common reed may also remain as standing litter for longer than cattail (Findlay et al., 2002) resulting in greater persistence in the terrestrial environment and resulting in a constant source of material to the aquatic environment. In the Wash it appears that the

majority of macrophyte biomass is represented by common reed. Reed, however, does appear to be spatially segregated from bulrush, with bulrush sometimes common in deeper, more lentic locations above erosion control structures.

Management implications—All three culm detritus types supported macroinvertebrates and also sequestered elements such as As and Se. Data suggests that there is a high likelihood of burial of culm material, although it should be noted that culm bags may not be totally appropriate mimics of sediment capture by native culm material. Burial could allow for transformation of nutrients and/or trace elements.

Macrophytes in the Wash may remove some potentially harmful elements from the water column. However, at least a portion of these elements are associated with culm/microbial biomass and potentially may then be biologically available to detritivores and other biota. Fine particulate organic matter (FPOM) produced during processing presents a likely pathway to contamination of invertebrate biomass via collector-filterers which are common in the Wash.

Net spinning caddisflies are likely important in processing culm material and also in capturing FPOM in the Wash. Adult emergence may also remove nutrients from the aquatic system. Common reed may decrease the rate of nutrient loss from the system by removing and retaining material while losses associated with bulrush would be much faster.

The combination of numerous coarse particulate organic matter (CPOM) sources, benthic algal communities, relatively complex macroinvertebrate communities, and frequent flooding all would make describing a longitudinal nutrient budget for the Wash difficult.

Further studies—Although there were no differences in invertebrate assemblages observed in culm bags of different plant species, it may be of value to sample standing areas of the differing living vegetation types for macroinvertebrates. There may be differential uses associated with living/standing dead material that change once material senesces and enters the water. If differences are present, it may be evidence that dissimilar plant species have different macroinvertebrate values in the Wash. Experimental testing of the ability of *Smicridea* to influence processing rates would also be of interest in the context of the Wash environment.

Differences in decomposition rate along with nutrients/trace element uptake and invertebrate colonization should be studied with different reed structures. Information from this initial study also indicates that more frequent sampling intervals should be observed for examining decomposition rates, something less than the 76 days that was used in this initial study. It may also be of interest to monitor trace elements in invertebrates. Although Hg concentrations appeared to be low, both As and Se were measured at concentrations that might be considered as marginal for ecosystem health. Macroinvertebrate tissue thresholds for adverse effects in fish could be exceeded in this environment and collection of macroinvertebrates for analyses may be in order.

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Table 1. Water quality parameters associated with culm bags in Las Vegas Wash in 2008. The range of values are presented in parentheses.

Month	Variable					
	Dissolved oxygen (mg/L)	Conductivity (uS/cm)	Water temperature (°C)	pH	Depth (m)	Velocity (m/S)
April	9.1 (7.9-9.9)	2403 (2270-2500)	21.5 (20.3-22.6)	8.1 (7.5-8.3)	0.4 (0.2-0.6)	0.42 (0.08-1.05)
June	7.4 (6.2-8.3)	2303 (2280-2450)	27.9 (26.6-29.4)	8.2 (7.4-8.6)	0.4 (0.2-0.6)	0.27 (0.01-0.84)
September	7.2 (6.0-8.3)	2350 (2150-3230)	28.7 (27.1-30.3)	7.9 (6.9-8.1)	0.4 (0.1-0.7)	0.37 (0.01-1.07)
December	8.2 (7.9-8.6)	2216 (2100-2340)	22.2 (20.5-23.5)	7.9 (7.8-8.0)	0.4 (0.3-0.5)	0.39 (0.07-0.80)

Table 2. Results of stepwise multiple regression for culm loss.

Variable	Coefficient	Std Error	P
Constant	-154.785	77.4182	0.0581
Sediment	-0.13450	0.04035	0.0030
Plant species	-6.43084	2.61697	0.0223
Water temp	3.36574	1.21141	0.0110
Exposure period	0.17811	0.03472	0.0000
pH	17.9512	8.45614	0.0453
R Squared	0.7250		

Table 3. Taxa associated with culm bags and kick-net samples from the Las Vegas Wash during June, September, and December sampling.

Taxon	Functional feeding group	Total number of individuals
EPHEMEROPTERA		
Baetidae		
<i>Camelobaetidius musseri</i>	Grazer	334
<i>Fallceon quilleri</i>	Scraper	409
ODONATA		
Calopterygidae		
<i>Hetaerina</i> sp.	Predator	79
Coenagrionidae		
<i>Argia</i> sp.	Predator	193
Gomphidae		
Libellulidae		
<i>Brechmorhoga</i> sp.	Predator	3
TRICHOPTERA		
Glossosomatidae		
<i>Culoptila</i> sp.	Scraper	6
Hydropsychidae		
<i>Smicridea</i> sp.	Collector-filterer	9525
Hydroptilidae		
<i>Hydroptila</i> sp.	Piercer	34
Leptoceridae		
<i>Nectopsyche</i> sp.	Shredder	3
LEPIDOPTERA		
Pyrilidae		
<i>Petrophila</i> sp.	Scraper	515
DIPTERA		
Chironomidae		
Orthoclaadiinae		
<i>Cricotopus</i> sp.	Shredder	247
<i>Thienemanniella</i> sp.	Collector-gatherer	21
Chironominae		
<i>Chironomus</i> sp.	Shredder	1
<i>Cladotanytarsus</i> sp.	Collector-filterer	1
<i>Dicrotendipes</i> sp.	Collector-gatherer	4
<i>Endotribelos</i> sp.	Collector-gatherer	22
<i>Polypedilum</i> sp.	Shredder	5966
<i>Pseudochironomus</i> sp.	Collector-gatherer	15
<i>Rheotanytarsus</i> sp.	Collector-filterer	6
<i>Xestochironomus</i> sp.	Predator	1
Tanypodinae		
<i>Pentaneura</i> sp.	Predator	113
Empididae		
<i>Hemerodromia</i> sp.	Predator	51
Simuliidae		
<i>Simulium</i> sp.	Collector-filterer	2

Tipulidae		
<i>Limonia</i> sp.	Shredder	3
TURBELLARIA	Predator	3
OLIGOCHAETA		
Lumbriculidae	Collector-gatherer	6
HIRUDINEA		
Glossiphoniidae	Predator	4
<i>Helobdella triserialis</i>	Predator	1
GASTROPODA		
Ancyliidae	Scraper	1
Physidae	Scraper	44
Thiaridae	Scraper	4
BIVALVIA		
Corbiculidae		
<i>Corbicula</i> sp.	Collector-filterer	40

Figure 1. Decomposition coefficients (k values) associated with different sized mesh culm bags after 76 days in Las Vegas Wash.

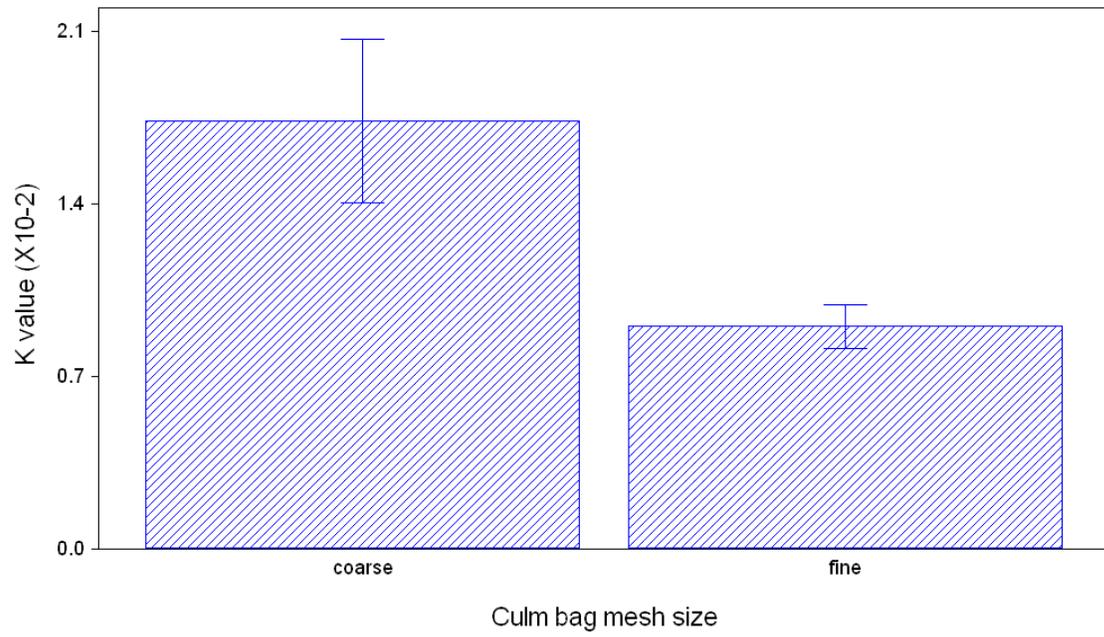


Figure 2. Percent culm loss over time for three species of macrophytes in the Las Vegas Wash.

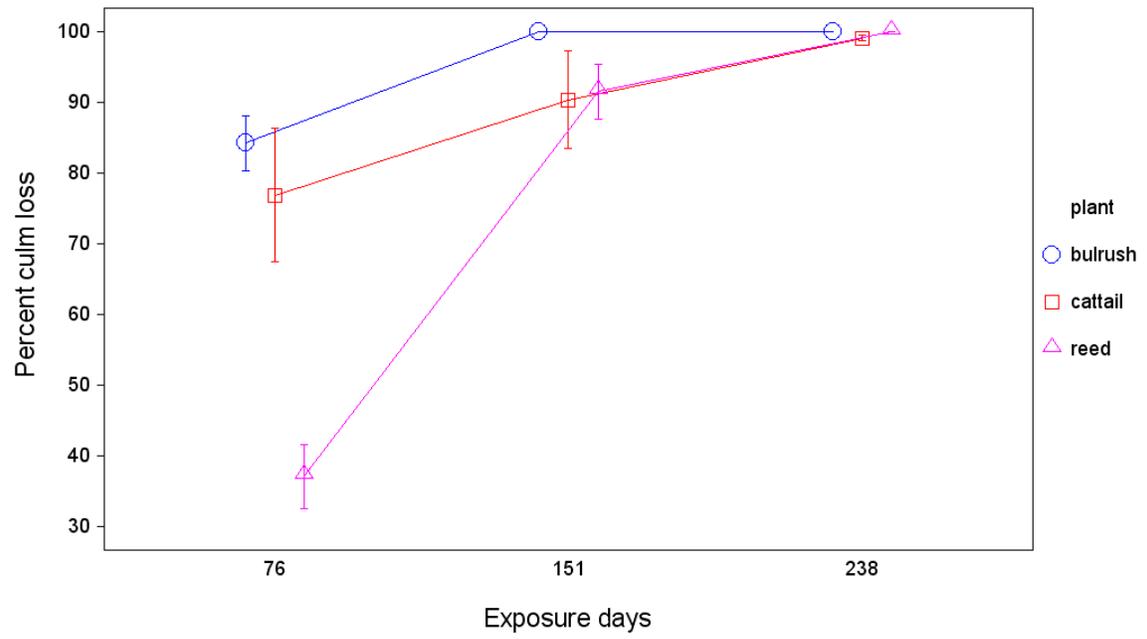


Figure 3. Percent lignin found in initial macrophyte species obtained from Las Vegas Wash. These values are from material prior to placement of culm bags in the water.

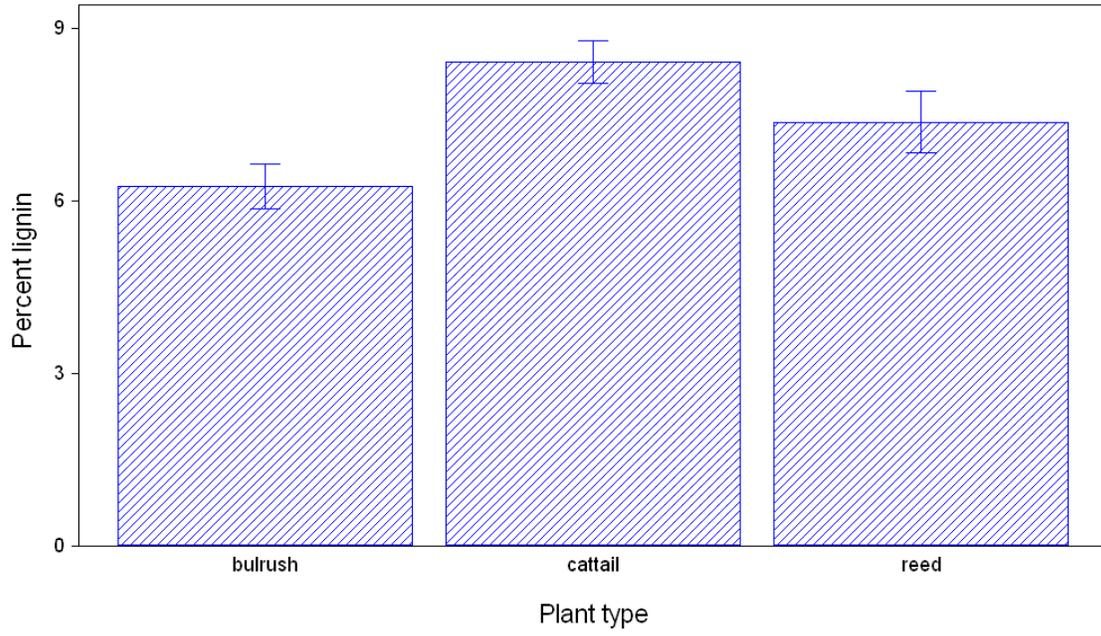


Figure 4. Nitrogen content of plant material before (day 0) and after placement in Las Vegas Wash water (days 76-238).

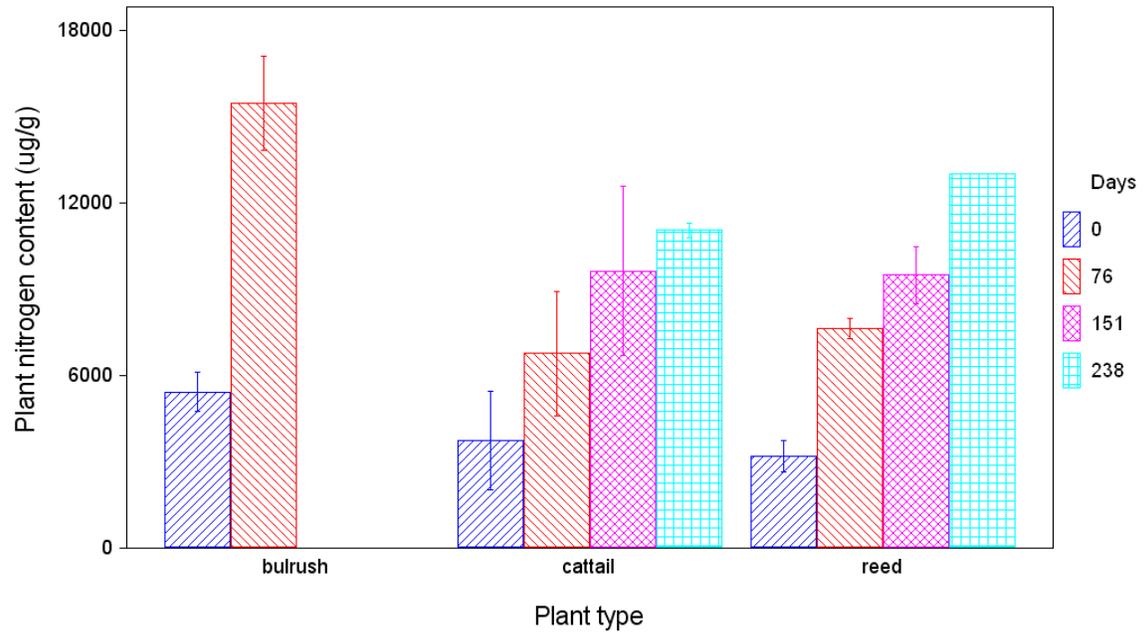


Figure 5. Phosphorous content of plant material before (day 0) and after placement in Las Vegas Wash water (days 76-238).

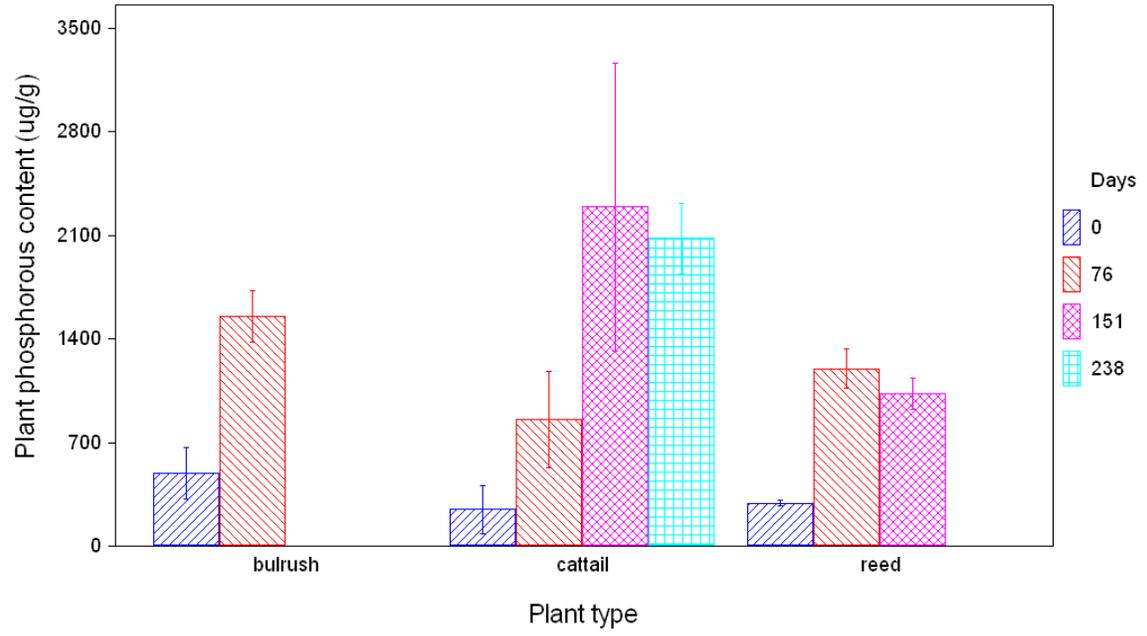


Figure 6. Arsenic content of plant material before (day 0) and after placement in Las Vegas Wash water (days 76-238).

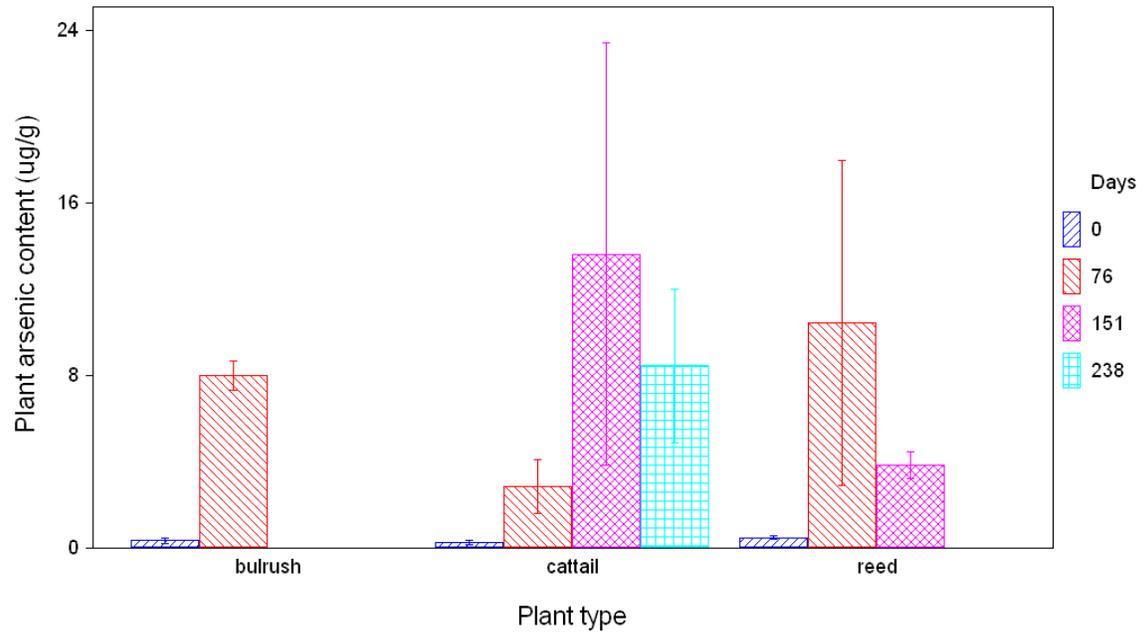


Figure 7. Selenium content of plant material before (day 0) and after placement in Las Vegas Wash water (days 76-238).

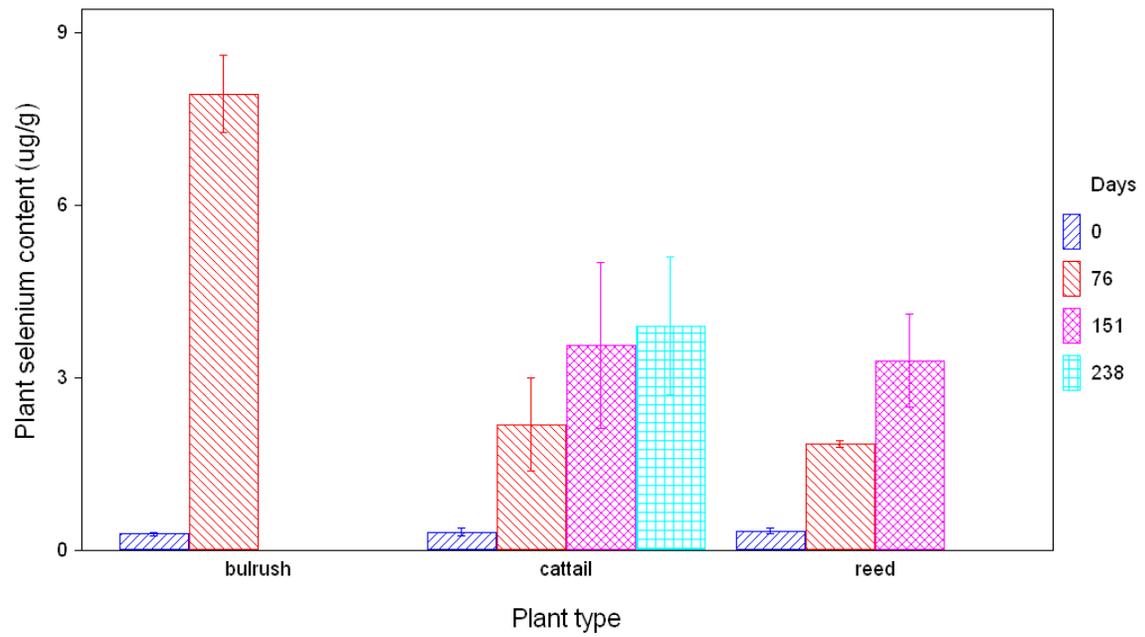


Figure 8. Mercury content of plant material before (day 0) and after placement in Las Vegas Wash water (days 76-238).

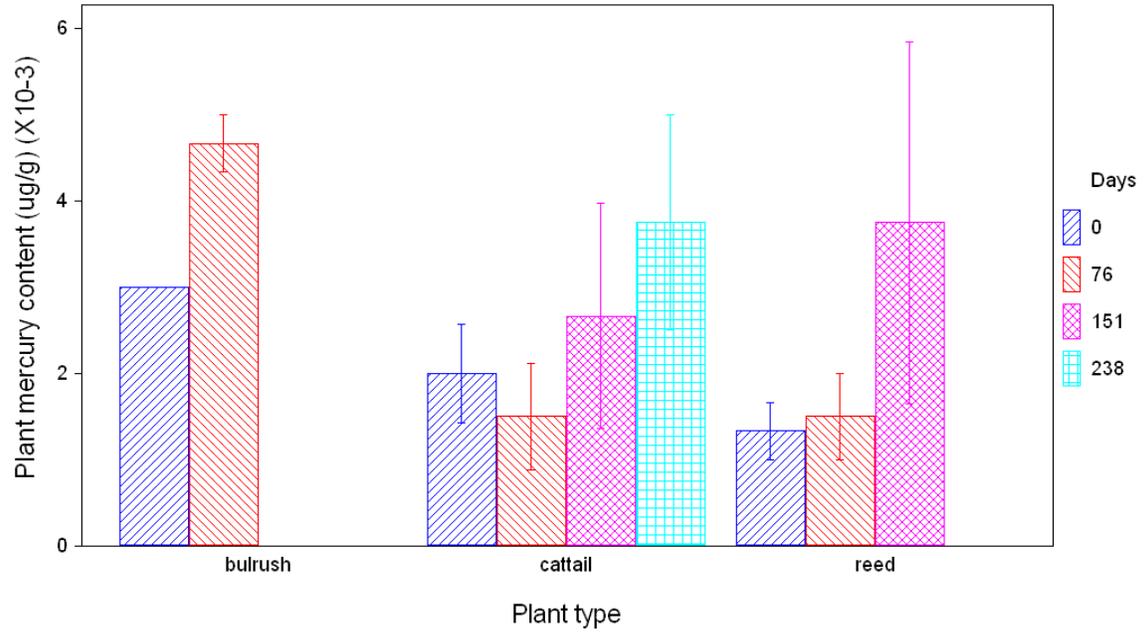


Figure 9. Functional feeding groups associated with decomposing macrophytes during different months in the Las Vegas Wash.

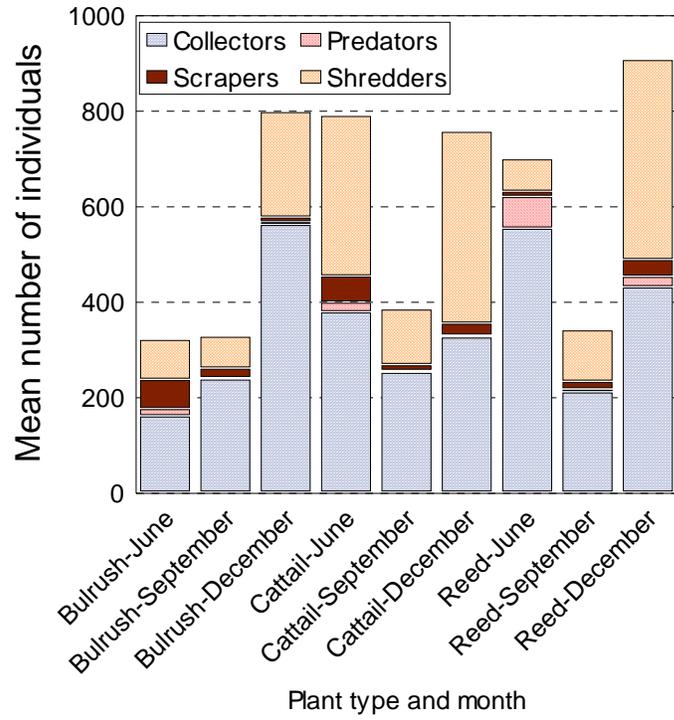
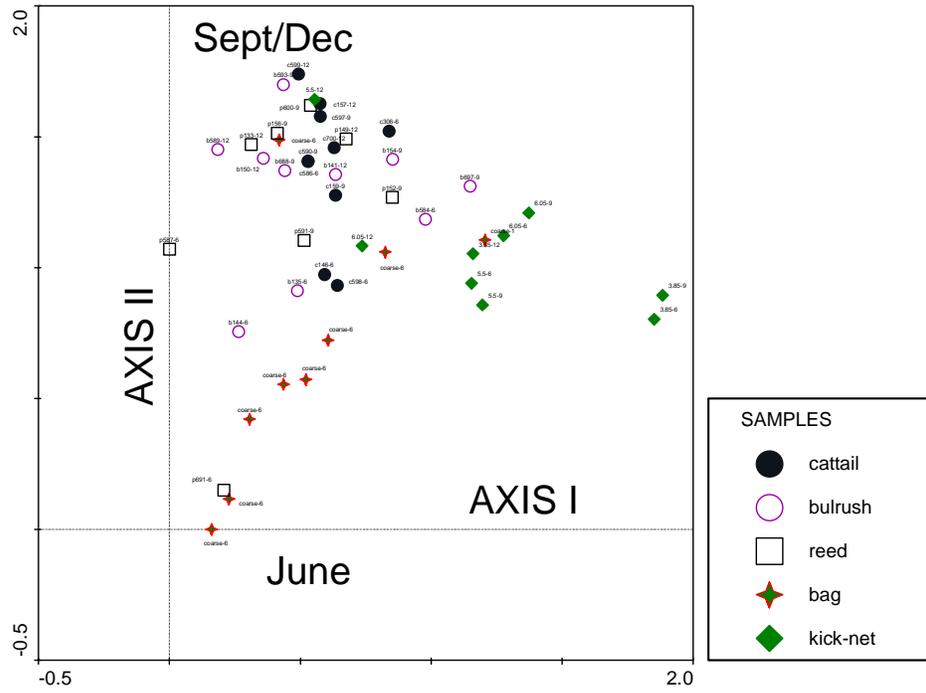
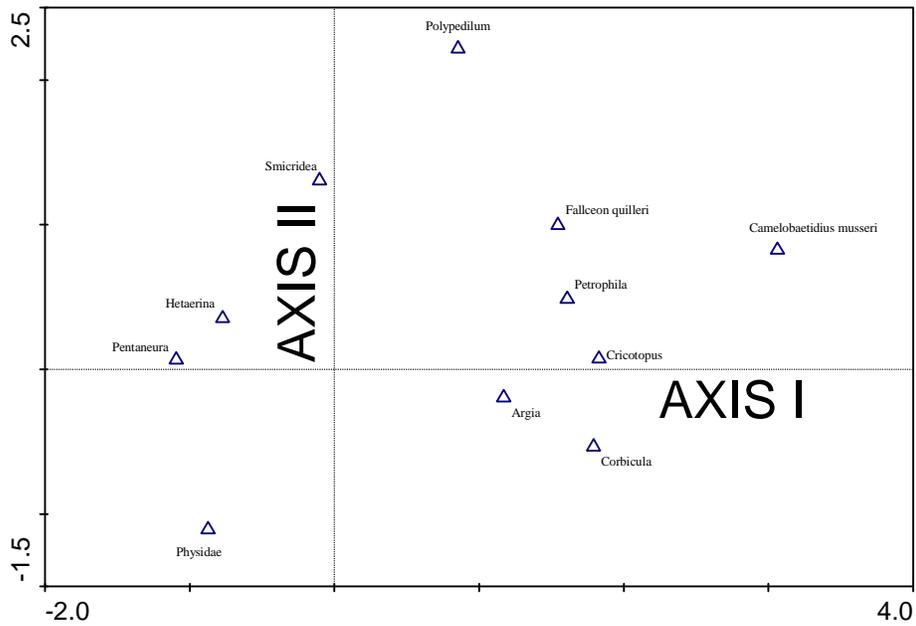


Figure 10. Biplots from data collected from Las Vegas Wash culm bags and kick-nets based on detrended correspondence analysis (DCA). Shown are samples (a) and taxa (b) in ordination space.



a



b

Figure 11. Biplot from DCA showing abundance of *Camelobaetidium musseri* for the various collected samples. Size of geometric shapes is associated with *C. musseri* abundance. Samples where *C. musseri* was absent are represented as '+'s.

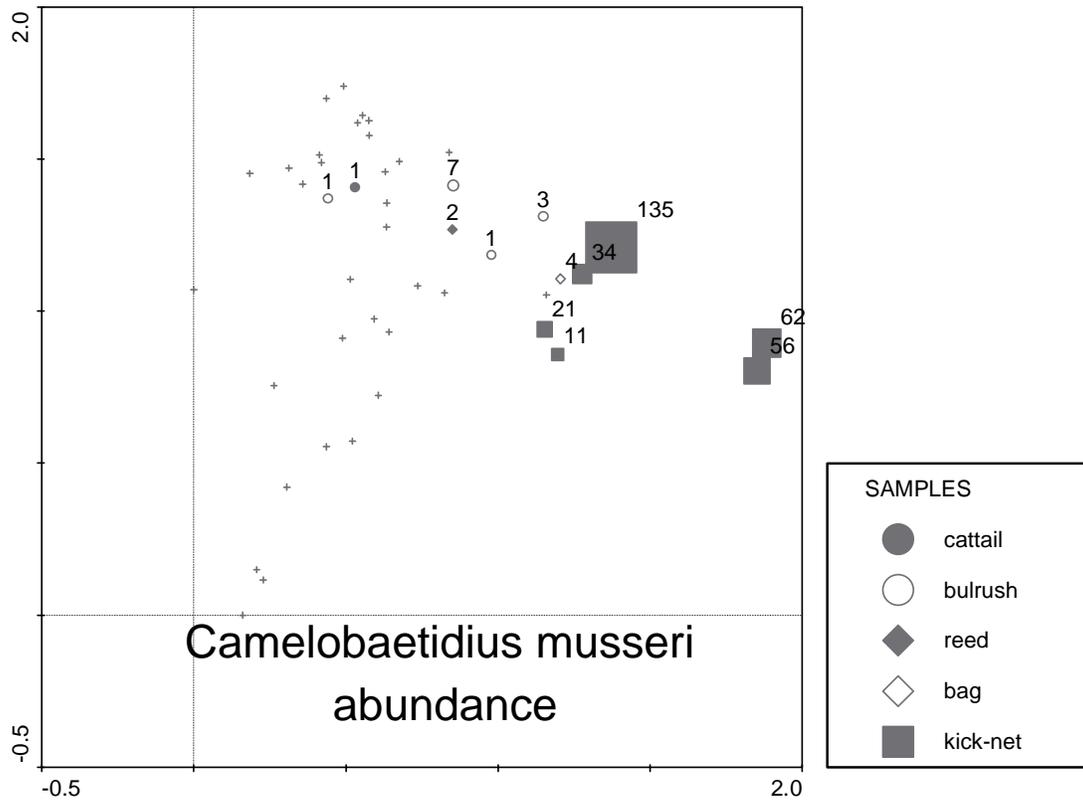


Figure 12. Biplot from DCA showing abundance of *Smicridea* for the various collected samples. Size of geometric shapes is associated with *Smicridea* abundance. Samples where *Smicridea* was absent are represented as '+'s.

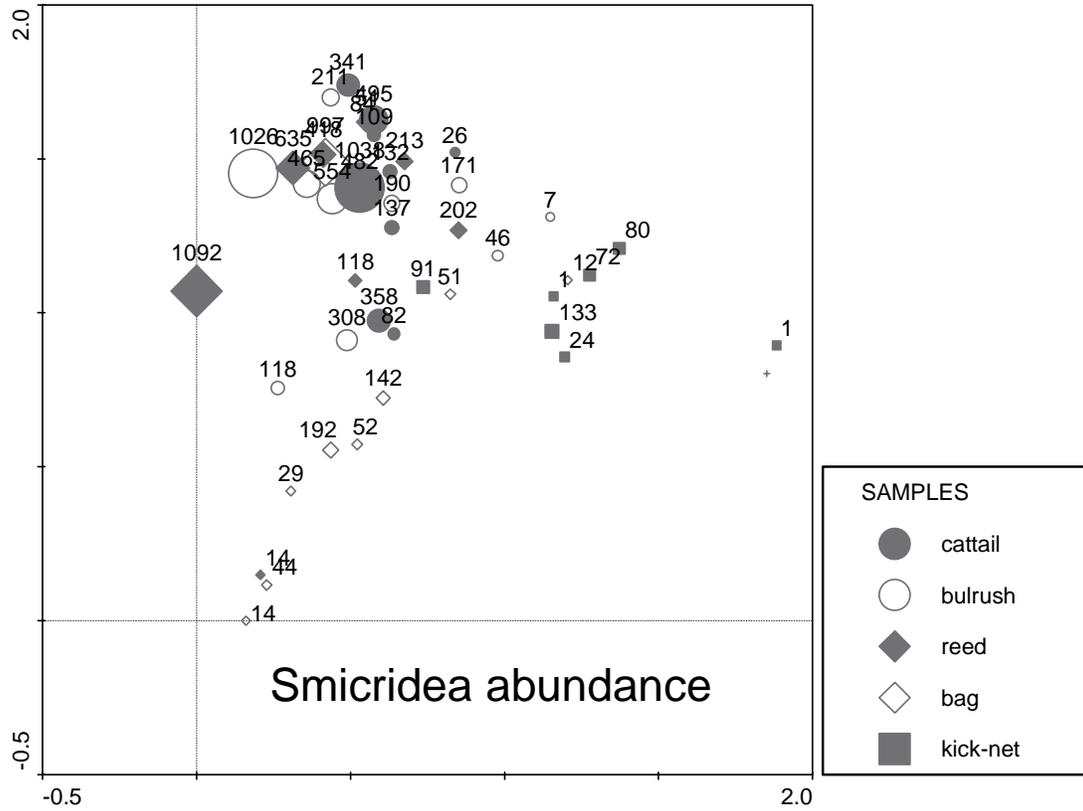


Figure 13. Biplot from DCA showing abundance of Physidae snails for the various collected samples. Size of geometric shapes is associated with Physidae abundance. Samples where Physidae was absent are represented as '+'s.

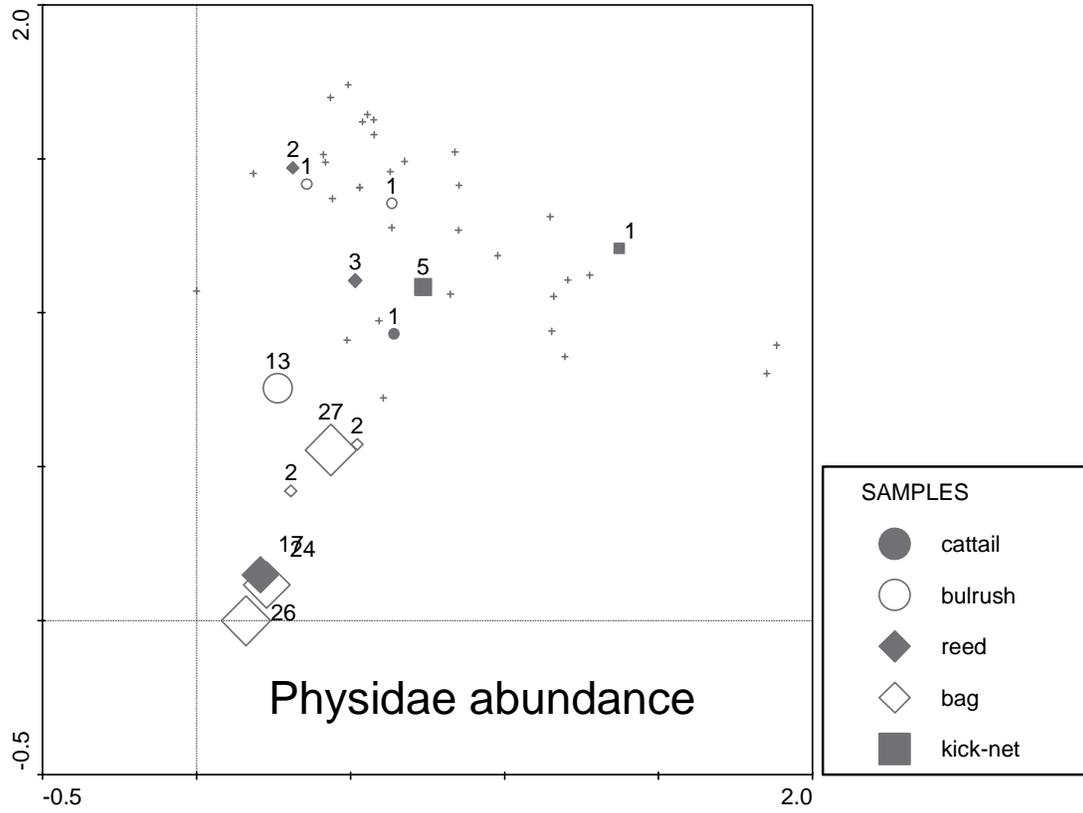
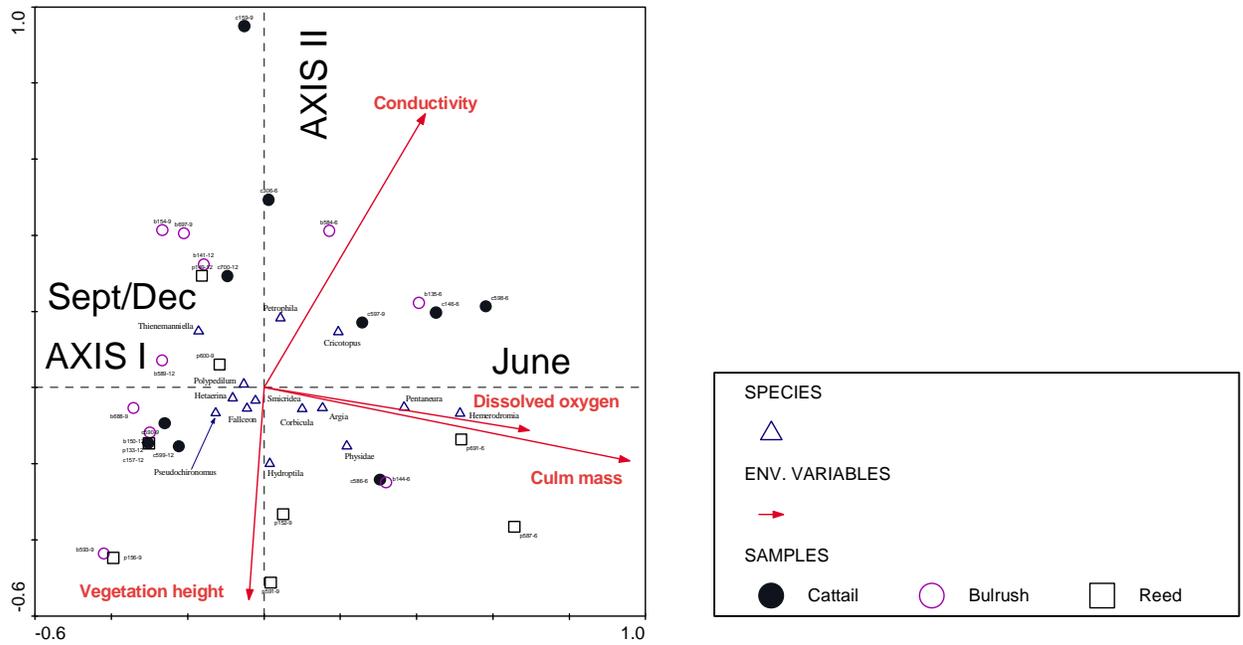


Figure 14. Triplot from data collected from Las Vegas Wash culm bags based on canonical correspondence analysis (CCA) of samples and taxa with respect to environmental variables. Environmental variables were related to community attributes as shown by arrows.



PEER REVIEW DOCUMENTATION

PROJECT AND DOCUMENT INFORMATION

Project Name Aquatic Invertebrates Study WOID LC926

Document Culm Breakdown of Three Types of Macrophytes in Las Vegas Wash and Associated Macroinvertebrates, Nutrients, and Trace Elements

Document Date June 2009

Team Leader S. Mark Nelson

Document Author(s)/Preparer(s) S. Mark Nelson

REVIEW REQUIREMENT

Part A: Document Does Not Require Peer Review

Explain

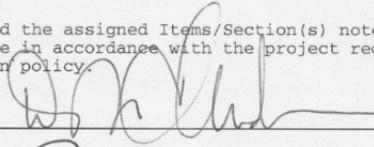
Part B: Document Requires Peer Review: SCOPE OF PEER REVIEW

Peer Review restricted to the following Items/Section(s): Document text

REVIEW CERTIFICATION

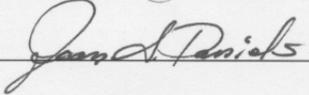
Peer Reviewer - I have reviewed the assigned Items/Section(s) noted for the above document and believe them to be in accordance with the project requirements, standards of the profession, and Reclamation policy.

Reviewer: Douglas Andersen
Signature



Review Date: 11 June 09

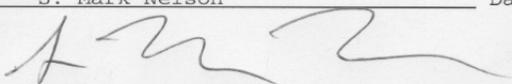
Reviewer: Joan Daniels
Signature



Review Date: 6-11-09

Preparer - I have discussed the above document and review requirements with the Peer Reviewer and believe that this review is completed, and that the document will meet the requirements of the project.

Team Member: S. Mark Nelson
Signature



Date: 6-22-09