Aquatic resource survey of the lower Mokelumne River and McCormack-Williamson Tract

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Abstract

Our goal was to quantify invertebrate resources of the McCormack-Williams Tract (MWT) and determine the seasonal changes in these resources that accompany different stages in the annual flooding cycle. The expectation is that these data will be used to guide future restoration planning for the MWT to maximize abundance and diversity of native species and to minimize the representation of exotic species. Our data are the results of boat-based surveys of the four main river and slough regions surrounding the MWT and capture the spatial and temporal variation in invertebrate abundance and diversity. We found significant seasonal variation in the biomass of invertebrates in sloughs and rivers surrounding the MWT with the highest levels in the spring of each year. This pattern was consistent across all sites regardless of the levels of flow and inferred residence times. We also found substantial spatial variation among the river and slough sites in the biomass of aquatic invertebrates. We found the highest biomass of invertebrates in Lost Slough and Snodgrass Slough, which have more restricted flows and are farther from the main stem of the Mokelumne River. The biomass of invertebrates was as much as ten times higher in Lost Slough and Snodgrass Slough when compared with Dead Horse Cut and the Mokelumne River. Lost Slough in particular is a dead end slough with one end closed with no outlet to other sloughs. Our results suggest that much of this difference in invertebrate biomass among the sloughs can be understood in terms of differences in residence time with longer residence times producing higher abundances. Although we have no formal estimates of residence time

for these four reaches, the channel morphology and connectivity together with thermal differences implies a qualitative ranking of these sites. The identification of non-native species among most groups of aquatic invertebrates is difficult and these groups are no exception. Although we found no exotics in our sampling, there are isolated records from upstream on the Cosumnes flood plain for the Chinese Mitten Crab (*Eriocheir sinensis*) and the non-native freshwater shrimp *Exopalaemon modestus* and extensive populations in the rivers above the MWT of the freshwater clam *Corbicula fluminea* and the red swamp crayfish *Procambarus clarkii*. Therefore, there is a high likelihood of these species becoming established on the MWT in the future. We have found no evidence for non-native zooplankton, although there are several examples of non-native calanoid copepods and mysids farther down the Delta towards San Francisco Bay. The lack of substantial numbers of invasive invertebrates in the immediate vicinity of MWT in stark contrast to the large numbers of non-native fishes (see section by Moyle et al.). Therefore, given the relatively small number of non-native invertebrate species that might potentially colonize the MWT relative to the large number of invasive fishes, we recommend that future management planning should focus on minimizing non-native fishes, although the same strategies for minimizing exotic fishes also apply to minimizing invertebrate invasions. Finally, we found that the aquatic invertebrates of the MWT were are similar to those of the lower Mokelumne River borders on side of the MWT and provides much of the biological inputs (see report on Lower Cosumnes and Mokelumne Rivers). Therefore, management activities on the Mokelumne such as dam release may significantly affect the invertebrate communities downstream at the MWT.

Introduction

Restoration of river floodplains and related shallow water habitats is an important focus of restoration efforts in the San Francisco Bay-Delta region. One of the key issues in these restoration efforts is create or recreate these areas in such as way as to maximize biological productivity and ecosystem function while at the same time minimizing the invasion of non-native species into restored areas.

This is nowhere a larger issue than in the efforts on the part of CALFED Bay-Delta Program and cooperating agencies to restore floodplains and shallow water habitats in the McCormack-Williamson Tract (henceforth MWT). The MWT is an artificially maintained island in the upper Delta region that is under consideration for restoring seasonal wetlands. Currently the island is mixed land use area with active and former agricultural zones as well some subsided areas with permanent water (see section by Moyle for details).

The focus of this report is the long-term management of the McCormack-Williamson Tract (henceforth MWT) is to provide data that will help with the decision process regarding several management scenarios that are being considered for restoring shallow water and upland habitats on the MWT. Therefore, in this section we provide data on the invertebrate portion of the aquatic resources present in the Mokelumne River and adjacent sloughs bordering the MWT that will be the source of biological productivity and ecosystem function for this area once managed flooding is established. Our aim is to provide recommendations that can be used be resource managers to maximize diversity and productivity of native invertebrate species, while at the same time minimizing the representation of exotic species.

We completed an approximately two year program of seasonal sampling and subsequent data analysis at several sampling sites along the four main reaches surrounding the MWT, Snodgrass Slough, Lost Slough, Dead Horse Cut and the Mokelumne River proper (see Table 1 and section by Moyle for sampling locations). These four main areas differ somewhat in hydrology and approximate residence time and consequently differ also in the levels of secondary production and standing biomass. Our goals involved quantifying the water column secondary production in terms of standing biomass of crustacean zooplankton and insects.

Our methods involved largely seasonal boat-based surveys of the four main river and slough regions surrounding the MWT. We gathered data on invertebrate abundances using both otter trawls, which sampled mobile benthic epifaunal invertebrates and plankton tows which sampled mobile and planktonic invertebrates in the water column. We quantified both the identity and diversity of species present, and then analyze the patterns of spatial and temporal variation in invertebrate abundance, diversity and biomass.

The primary focus for data collection and the core of this section is water column secondary production based on what represents the most important food sources for fishes in this region. Although we collected limited data from a small number of benthic trawls, no data are presented because trawls were very difficult to conduct in the snag-filled sloughs surrounding the MWT. Furthermore, we made no attempt to sample benthic invertebrate in the comparatively deep water sloughs and rivers surrounding the

MWT, because of the limitations of sampling logistics. Therefore, our report deals solely with water column invertebrate abundance and biomass. We briefly discuss the potential threats posed by larger invasive species such as the Chinese Mitten Crab (*Eriocheir sinensis*), the red swamp crayfish (*Procambarus clarkii*), the freshwater clam (*Corbicula fluminea*), the recently introduced freshwater shrimp (*Palaemon modestus*), which are present in the system, but were not sampled adequately in the surveys discussed here.

Methods

Aquatic Invertebrate Sampling. Sampling was conducted more or less seasonally during the sampling period. We show results for each season except summer months when aquatic macrophytes made sampling with tow nets difficult if not impossible. Data from different sampling sites are presented as representing each of the four slough and river sites Snodgrass Slough, Dead Horse Slough, Lost Slough and the Mokelumne River main stem (see Table 1 and section by Moyle).

To sample the aquatic invertebrates present in the water column, we used a plankton tow net (150 um mesh, 0.3 m wide, 5:1 l/w ratio) outfitted with a propeller flow meter (Ocean Dynamics) suspended in the middle of the opening of the net. The net was towed just below the surface on the back of a boat (see section by Moyle) at approximately 5 knots for approximately 2 minutes. Calculations of the volume sampled were based on the flow meter, however, and not the trawl time of the boat. In most cases we collected a single tow per station in parallel with the benthic otter trawls conducted to sample fishes (see section by Moyle). Otter trawls occasionally yield invertebrates, although these data were insubstantial and we do not present them here.

In the field, the invertebrates were collected from the net and transferred to labeled 500 ml Nalgene bottles and placed in a cooler until return to the laboratory. Once in the laboratory, all invertebrates were fixed with sweet Lugol's iodine and enumerated under a dissecting scope at 25 x on a plankton counting wheel.

Results

Temporal variation. Data from different sloughs and river reaches shows significant spatial variation in the abundance of zooplankton with an order of magnitude difference among seasons. The overall pattern is that there is greater biomass of invertebrates during the spring during the flood season when the rate of transport of invertebrates and the seasonal availability of some aquatic insect groups such as chironomids is highest. Spring 2002 had the highest overall abundance followed by spring 2001 and then winter and fall 2001 (Fig. 1). This suggests that the flooding cycle corresponds with the highest biomass of invertebrates. This may include contributions from farther up the watershed as well as inputs by local invertebrate populations.

Spatial variation. Variation among sites was also substantial with more than and order of magnitude difference in biomass among sites. Invertebrate biomass was much higher for Snodgrass Slough and Lost Slough than in Dead Horse Cut and the Mokelumne River and these differences were generally consistent across seasons (Fig. 2). Much of this biomass is made of dipteran larvae, primarily those of the midge family Chironomidae, which dominated the invertebrate biomass at all sites (Figs. 3-6). The next most common group of invertebrates consisted of calanoid and cyclopoid copepods (Figs 3-6). Cladocerans were only a minor part of the overall biomass of this system in contrast to floodplain areas farther up river and of these *Bosmina* were among the most abundant. The relative ranking in biomass of the invertebrate groups is generally very consistent across all four slough and river reaches despite an order of magnitude difference in total biomass among these locations (Figs. 3-6). That is also a strong similarity between the aquatic invertebrates found adjacent to the MWT and those on the lower Mokelumne River (see report on Lower Watersheds). Dam releases may strongly influence affect the invertebrate communities downstream at the MWT as they do in the river.

Invasive Species. We found no verified species of non-native invertebrates in our sampling. We hasten to add that records of introduced invertebrates in this area and in adjacent areas up river. We have isolated records from upstream on the Cosumnes flood plain for the Chinese Mitten Crab *Eriocheir sinensis* and the non-native freshwater shrimp *Exopalaemon modestus*. And from our work and others, we know that there are extensive populations in the rivers above the MWT of the freshwater clam *Corbicula fluminea* and the red swamp crayfish *Procambarus clarkii*. Therefore, there is a high likelihood of these species becoming established on the MWT in the future. We have found no evidence for non-native species in our zooplankton samples, although there are several examples of non-native cyclopoid copepods and mysid shrimp in the lower Delta. The identification of non-native species among most groups of aquatic invertebrates is difficult and these groups are no exception. Even with CDFG biologist verification of our copepod taxa, we have not found any non-native zooplankton or aquatic insects in the immediate vicinity of MWT in stark contrast to the large numbers of non-native fishes (see section by Moyle et al.).

Discussion

Our results support the ideas that the overall abundance of secondary producers in the form of aquatic invertebrates are strongly influenced by the flooding cycle on the one hand and the relative residence time of the particular slough or river reach on the other hand. The season of greatest abundance and assumed productivity is the spring, which had 3-10 times higher biomass of aquatic invertebrates than any other period of the year. We cannot make assumptions about the summer because of our lack of data, but from our understanding of seasonal dynamics elsewhere in the system, although the early summer is also likely to be a period of high productivity with the system then declining through the summer and into the fall where biomass values are at their lowest. This spring period of peak biomass coincides with nutrient and detrital inputs from up river areas and reinforces the notion that management activities up river can strongly influence processes in this part of the Delta. For instance dam releases on the Mokelumne River can drastically change the makeup of the water column invertebrates in the lower Mokelumne River (Grosholz and Gallo, unpubl. data) and thus influence the invertebrates in the river and slough areas surrounding the MWT.

We also found that some slough sites had 5-10 times higher biomass than others during the same time period. The values for Snodgrass Slough and Lost Slough were consistently higher than Dead Horse Cut and the Mokelumne River regardless of the time of year, although the magnitude of these differences was greater during the spring when overall biomass was greater. We infer that these differences are related to the relative residence time of the different slough and river reaches. Lost Slough in particular is a more or less dead end body of water with significantly less circulation and overall higher temperatures than the main stem Mokelumne River. Although not quite as restricted, Snodgrass Slough also has the characteristic features of an area with longer residence time than the main river. Dead Horse Cut connects directly with the Mokelumne River and presumably this is why the biomass values here are similar to the river and much lower than the other two slough sites. Although there are not enough sites to formally test this, there is a positive association between the physical distance from the Mokelumne River and the ranking of invertebrate biomass for each of the four areas. We also found strong congruence in the distribution of invertebrate taxa across sites. The most common invertebrates were midge larvae (chironomids) followed by cyclopoid and calanoid copepods and then small cladocerans such as *Bosmina* and *Pseudochydorus*. So although we found more than an order of magnitude difference in biomass among sites and substantial variation among seasons, this relative ranking of taxa remains quite constant over space and time.

We found no evidence for introduced invertebrates in our regular sampling of the slough and river areas surrounding the MWT. However, even with some outside expert verification of our species identifications (L. Mecum, pers. comm.) we were not able to identify any introduced species in this area. We quickly note that our sampling is not well suited to pick up benthic species such as Chinese mitten crabs (*Eriocheir sinensis*), freshwater clams (*Corbicula fluminea*), or red swamp crayfish (*Procambarus clarkii*, although our gear could have sampled the freshwater shrimp (*Palaemon modestus*) if they had been abundant. Data from other areas of the delta as well as up river from the MWT indicates that all of the species can become established. In particular, *Procambarus* and *Corbicula* have dense populations in up river areas and could become dominant in any permanent water bodies on the MWT. On the Cosumnes River Floodplain, these species are also almost entirely absent, so once again it appears that flood plain areas that are seasonally dry are much less susceptible to invasions by invertebrates than areas that are continuously inundated.

Management Recommendations

Given the relatively small number of non-native invertebrate species that might potentially colonize the MWT in comparison to the large number of invasive fishes, we recommend that future management planning should focus on minimizing non-native fishes. Luckily, most of the same strategies that would minimize the representation of invasive fishes would also apply to minimizing invasive invertebrates. We strongly recommend the establishment of seasonal floodplains that flood during the winter months and dry out during the later part of the year. Our data also indicate a strong similarity between the aquatic invertebrates found adjacent to the MWT and those on the lower Mokelumne River. Therefore, management activities on the Mokelumne such as dam release may significantly affect the invertebrate communities downstream at the MWT.

Table 1. Sampling locations for MWT monitoring

Sampling Site	Latitude	Longitude
Dead Horse Cut	38º 14.47'N	121º 29.79'W
Lost Slough #1	38º 16.07'N	121º 29.44'W
Lost Slough #2	38º 16.07'N	121º 29.13'W
Mokelumne River	38º 32.11'N	121º 45.15'W
Snodgrass Slough #1	38º 15.37'N	121º 28.59'W
Snodgrass Slough #2	38º 14.78'N	121º 28.72'W
Snodgrass Slough #3	38º 15.95'N	121º 29.77'W

Figure Legends

Figure 1. Plot of invertebrate water column biomass (per cubic meter) by season for 2001 and 2002. Note consistency of rankings of sites across different sampling dates.

Figure 2. Plot of invertebrate water column biomass (per cubic meter) by site 2001 and 2002. Note consistency of rankings of dates across different sampling sites.

Figure 3. Plot of invertebrate water column biomass (per cubic meter) for each of the most common taxa at Snodgrass Slough sampling sites for 2001 and 2002.

Figure 4. Plot of invertebrate water column biomass (per cubic meter) for each of the most common taxa at Lost Slough sampling sites for 2001 and 2002.

Figure 5. Plot of invertebrate water column biomass (per cubic meter) for each of the most common taxa at Dead Horse Cut sampling sites for 2001 and 2002.

Figure 6. Plot of invertebrate water column biomass (per cubic meter) for each of the most common taxa at the Mokelumne River sampling sites 2001 and 2002.

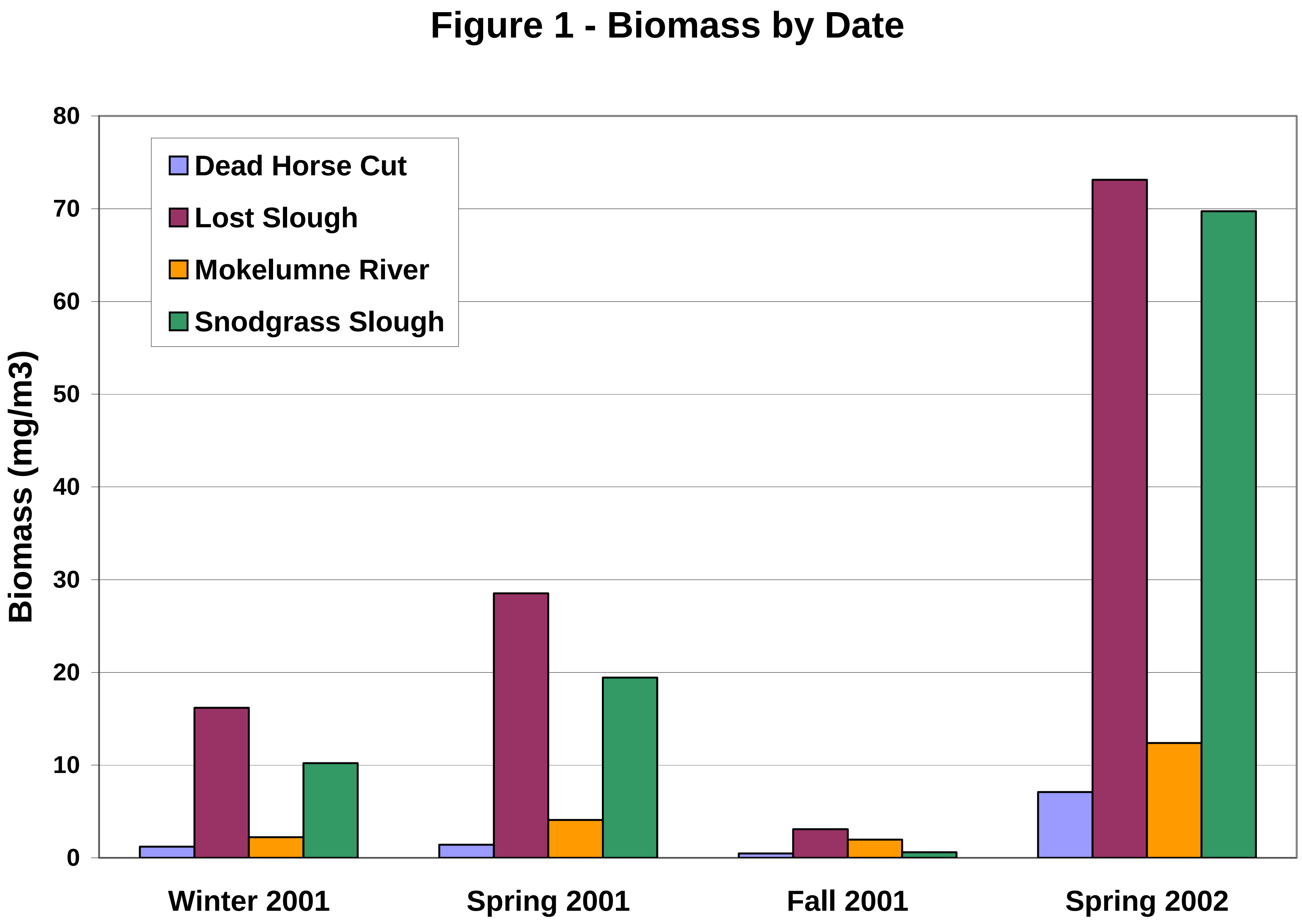
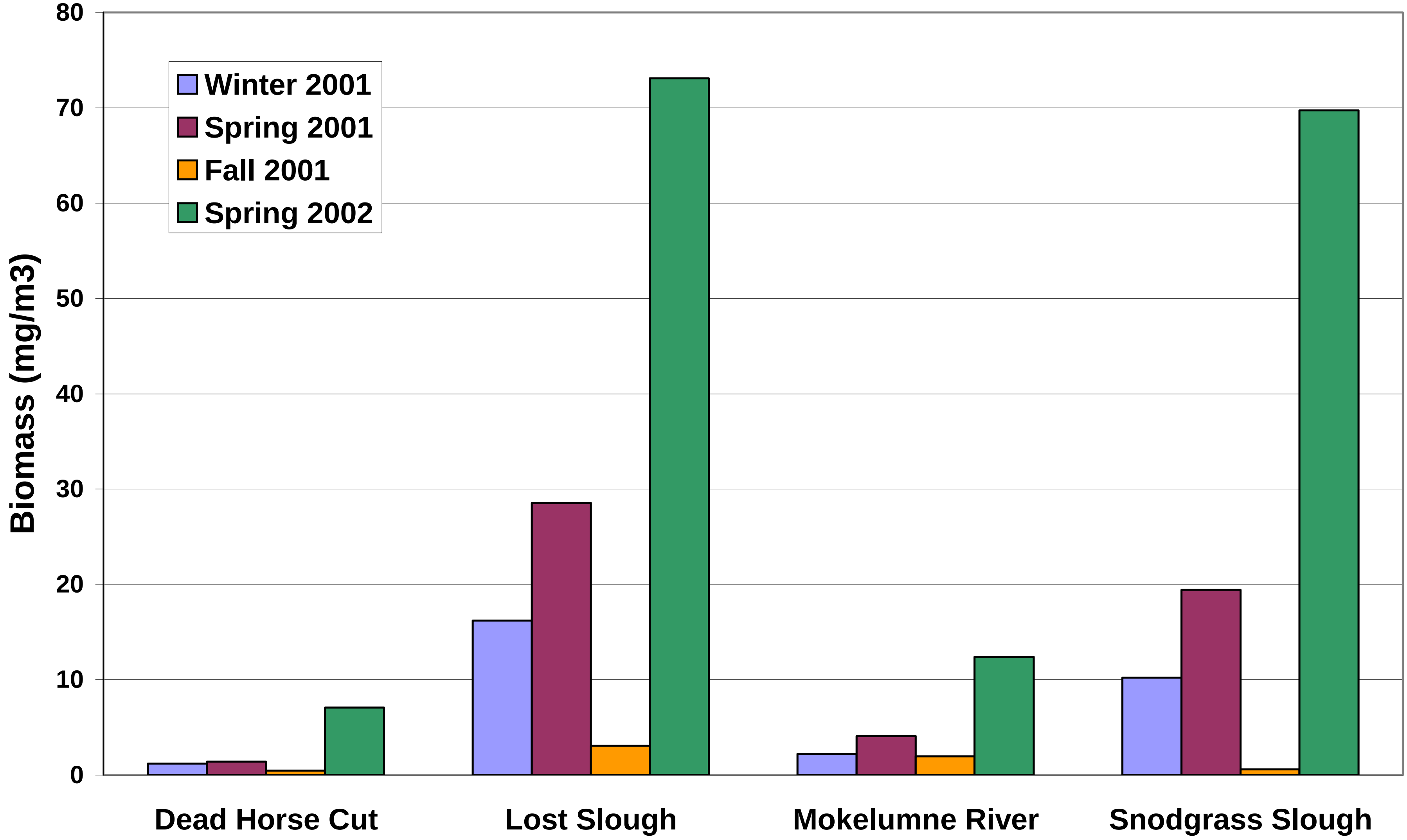


Figure 1 - Biomass by Date
Biomass (mg/m3)
80
70
60
50
40
30
20
10
0
Dead Horse Cut
Lost Slough
Mokelumne River
Snodgrass Slough
Winter 2001
Spring 2001
Fall 2001
Spring 2002

Figure 2 - Biomass by Site



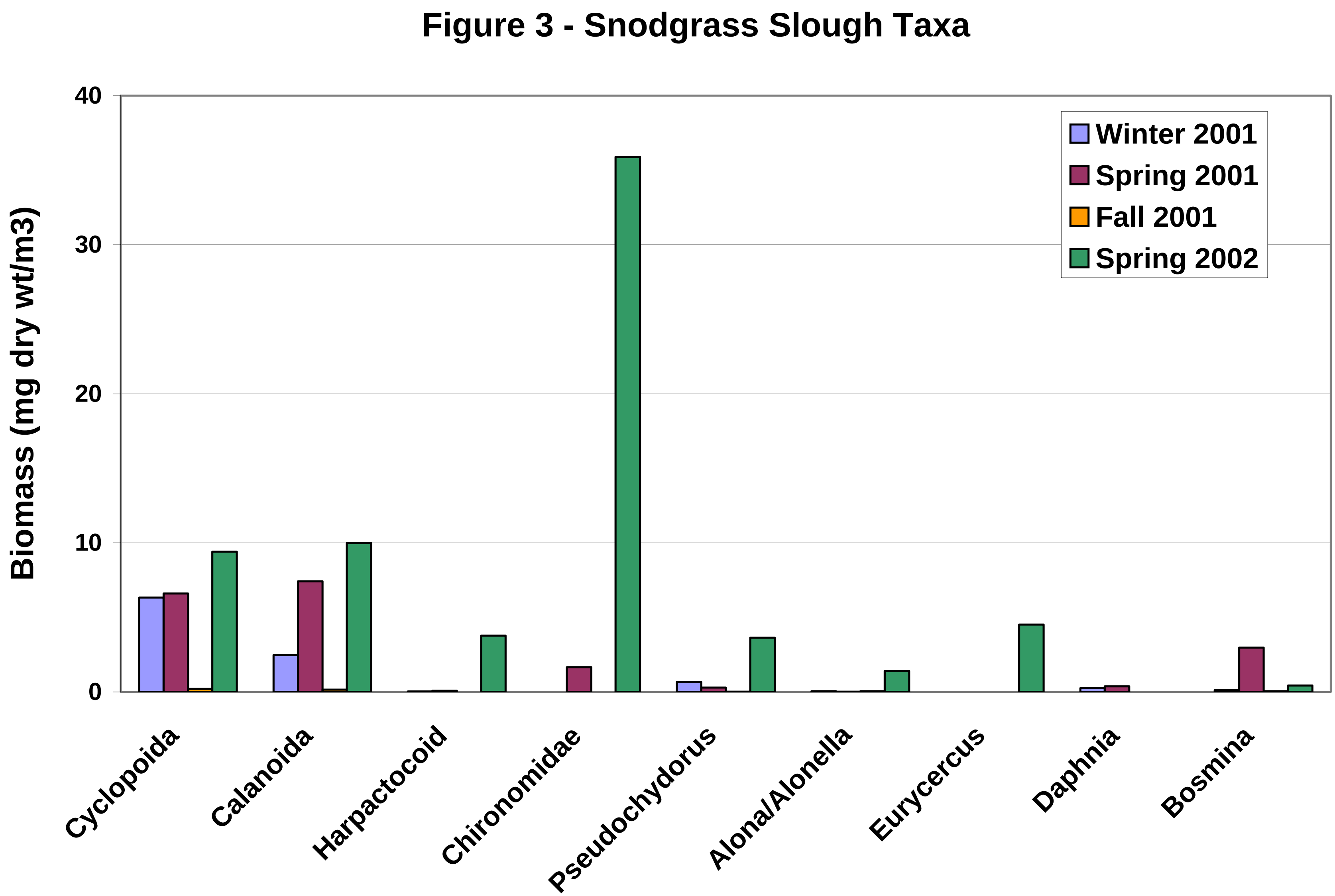


Figure 3 - Snodgrass Slough Taxa
Biomass (mg dry wt/m3)
40
30
20
10
0
Winter 2001
Spring 2001
Fall 2001
Spring 2002
Cyclopoida
Calanoida
Harpactocoid
Chironomidae
Pseudochydorus
Alona/Alonella
Eurycercus
Daphnia
Bosmina

Figure 4 - Lost Slough Taxa

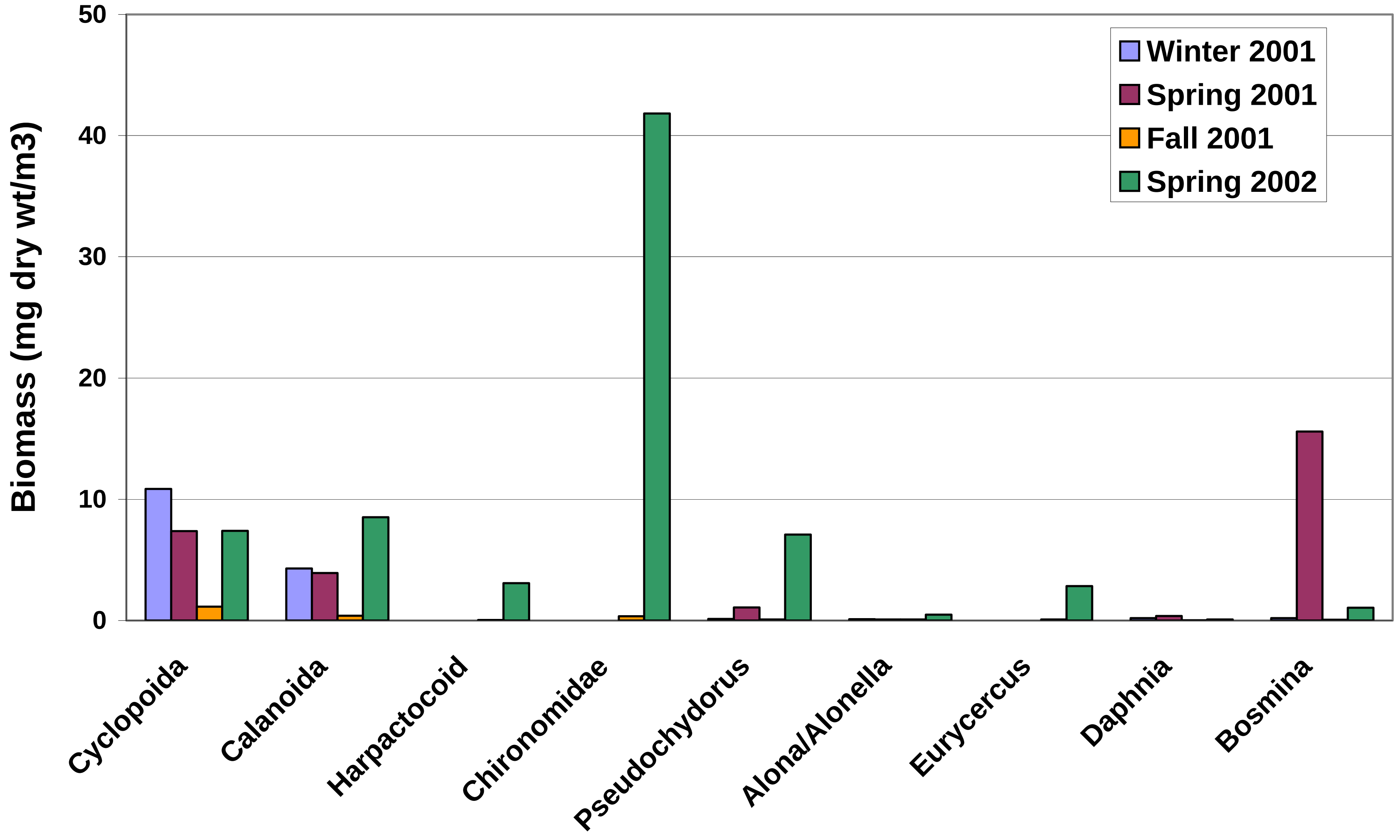


Figure 5 - Dead Horse Cut Taxa

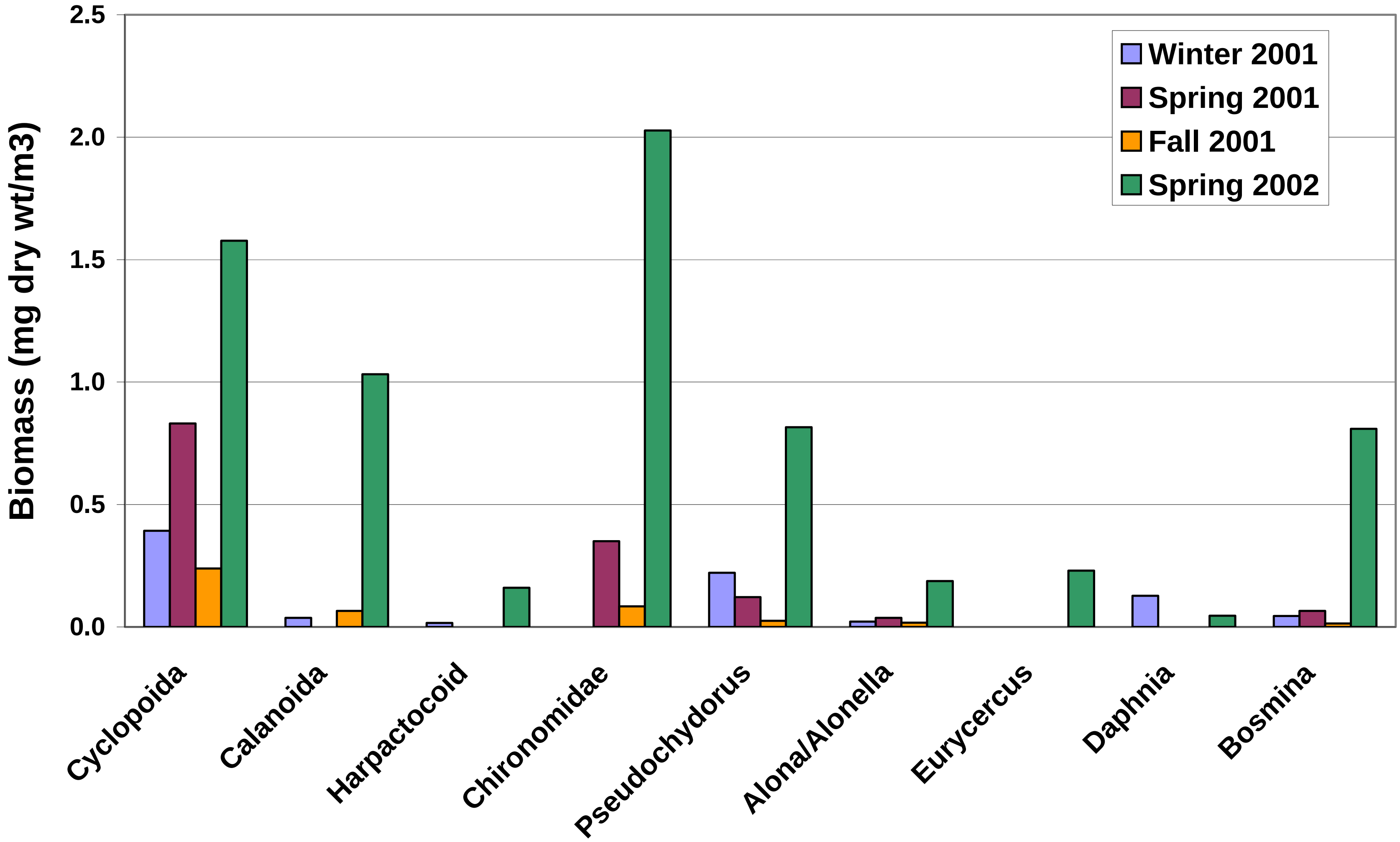


Figure 6 - Mokelumne River Taxa