AQUATIC RESOURCE PROGRAM REPORT

3. Impact of seasonal flooding on native and non-native aquatic species in the Cosumnes and Mokelumne Rivers

This section consists of four reports:

3A. An analysis of the use of the floodplain by invertebrates, examining seasonal patterns of diversity and abundance.

3B. An analysis of the use of the Cosumnes River floodplain by native and alien fishes in which the fish assemblages are compared to those of adjacent sloughs and the Cosumnes River itself, as well as to those of the Mokelumne River.

3C. A study of the importance of the floodplain for the early life history stages of native and alien fishes.

3D. A study of the use of condition factor as a new technique for determining the relative importance of different habitats for the rearing of fishes in their early life history stages.

For fishes of the lower Mokelumne River (below Camanche Dam) we relied on data that was collected by East Bay Municipal Utility District during the same period of time as our studies. Only limited comparisons were possible because the Mokelumne is a highly regulated river without significant floodplains.

3A. Impact of Seasonal Flooding on Native and Non-native Species, Cosumnes and Mokelumne Rivers

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Abstract

Our results show a predictable pattern following the cycles of initial spillover, ponding up of flood areas, drying of ponded areas, secondary spillover events, and ultimate end of season dry out. Among the most striking patterns seen is the cycle of flood, which produces an initial decline due to dilution and then a rapid buildup of the biomass of aquatic invertebrates. After the initial spillover event rapidly reduces the biomass of zooplankton and insects, within two weeks, the biomass of zooplankton and benthic invertebrates rises rapidly often to a point above the levels prior to flooding. These cycles show strong differences among sites with 10-100 times more zooplankton biomass and at least 10 times more benthic invertebrate biomass at sites with higher temperatures, higher primary production (see Section 4) and presumably higher residence times. River sites never experience the same cycling and degree of zooplankton abundances as do floodplain sites.

Introduction

The patterns of diversity, abundance and production of invertebrates on river floodplains, just as with any habitat, are driven both by the physical forces determining the magnitude, frequency, duration and timing of flood events, but also the limits to growth dictated by primary production and limits to survival dictated by predators (Power

2001. In this section, we address the importance of the first part, the seasonally driven flood cycle that is a critical determinant of the biological cycles of any naturally flowing river such as the Cosumnes. Flooding produces first an immediate disturbance moving sediments, organisms and detritus downstream which produces concomitant changes in the food web. In rivers like the Mokelumne, which lack of any appreciable seasonality, the cycling of biological production will be very different.

In this section, we analyze the influence of the timing, duration, and magnitude of flooding events on the changing patterns of abundance and distribution of aquatic invertebrates on the Cosumnes River Floodplain (CRP). We show that the temporal and spatial patterns of species abundances and biomass change rapidly and dramatically in response to the flooding events that occur seasonally between (typically) December and May. The mechanisms driving these changes include the physical process of flooding that produce initial dilution of the standing biomass of zooplankton and phytoplankton. However there are several other mechanisms involved including the renewal of nutrients, changes in the abundances of predators. All of these mechanisms we discuss in Section 4 and simply describe the patterns in this section.

Methods

The methodology for monitoring the diversity and abundances of aquatic invertebrates in these systems is largely the same as outlined in other sections. We used several methods of quantifying the abundance, diversity and biomass of aquatic invertebrates in this system in habitats ranging from deep river channels to shallow, vegetated floodplain areas to agricultural sloughs.

Zooplankton. We used a plankton 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 tossed into the current and maintained just below the surface for a period long enough to allow a standard count of >1000 units on the flow meter (typically about 30 seconds in ~ 1 m/s flow). In sites with no or little flow, the net was pulled through the water column by hand with the net extended to avoid capturing benthos kicked up by the person sampling. We took two replicate tows in adjacent areas per sampling site. We collected zooplankton from the net into labeled 500 ml Nalgene bottles and placed in a cooler until return to the lab. In the lab, zooplankton were fixed with sweet Lugol's iodine and enumerated under a dissecting scope at 25 x on a plankton counting wheel.

Benthic Invertebrates. We sampled aquatic invertebrates living on the substrate or attached to emergent vegetation using a sweep net (0.5 x 0.3 m). At each site, we pushed the sweep net along the bank through vegetation bouncing it up and down along the substratum over a distance of 2 meters. We took two replicate sweeps in adjacent areas per sampling site. Insects were then rinsed from the net into labeled plastic Ziploc bag and placed in a cooler until return to the lab. In the lab, invertebrates were rinsed and picked off of vegetation and debris and fixed in 70% EtOH and enumerated under a dissecting scope at 25 x.

Physical Parameters. At each site we took basic measures of water column parameters including temperature, conductivity, specific conductivity, salinity and dissolved oxygent with a YSI 85 and measure directional flow with a Marsh McBirney Flow Mate 2000.

Results

Our results show a predictable pattern following the cycles of initial spillover, ponding up of flood areas, drying of ponded areas, secondary spillover events, and ultimate end of season dry out. Among the most striking patterns seen is the cycle of flood, which produces an initial decline due to dilution and then a rapid buildup of the biomass of aquatic invertebrates.

Zooplankton. In all three years we found the repeatable trend of a rapid increase in zooplankton abundances within two weeks of a new flooding event (Figs. 3-1 to 3-11) indicated by the hydrograph in each figure exceeding 800 cfs. In all three years (2000-2002), we see that the abundances of zooplankton are 10-100 times greater at floodplain sites (Pond 1, Pond 2, Site 3, Site 7, Site 11) than in river sites (Corp Breach, Rail Road Bridge) (Figs. 3-1, 3-4, 3-9). Data for individual taxa for different sites shows that although there are some site specific differences (Fig. 3-2, 3-3, 3-5, 3-6, 3-7, 3-8, 3-10, 3-11), within and among years, the species identities do not differ as strongly as the magnitude of the biomass differences (10-100 X) among sites.

Benthic Invertebrates. We see the same patterns with benthic invertebrates with repeatable trends following flooding events with strong increases in the biomass of aquatic invertebrates (Fig. 3-12 to 3-15). We see that within 2-3 weeks, the abundance of aquatic invertebrates increases markedly relative to that before or during the flooding period (we present data only for 2002). We also see large differences between the biomass of aquatic inverts at floodplain sites (Figs. 3-12 and 3-13) relative to river sites (Figs. 3-14 and 3-15). The biomass of aquatic invertebrates on the floodplain is 5-10 X greater than the river sites, a difference that is far below the extreme differences seen in zooplankton, but nonetheless are significant.

Non-native species. With respect to introduced species, we found only one species that is abundant and established on the Cosumens River Floodplain (see Section 5) that is clearly non-native, the red swamp crayfish, *Procambarus clarkii*. Our sampling was inadequate to properly quantify the presence of crayfish on the floodplain, although our sweep nets do provide a reasonable comparative estimate of abundance, especially of young-of-the-year crayfish. We found that WDS had by far the highest abundances of crayfish with at least ten times the abundance of the floodplain sites and river sites (Fig. 3-16). We suppose that this species is also abundant in slower areas on the main stem of the river. Here also, the freshwater clam *Corbicula fluminea* is also abundant is slower areas of the river where there was appropriate substratum, however we never found this on the floodplain. Finally, we also note that rare individuals of the freshwater shrimp *Exopalaemon modestus* were found on the floodplain and that rare individuals of the Chinese Mitten crab were reported from the river channel. Neither of these is established or even repeatably found on the CFP, although this could change in subsequent years.

Discussion

The influence of the flood cycle on the abundance of native aquatic invertebrates appears to be one where the floods produces a cycle on increase in response to the initial flood, a decrease as the floodwaters rapidly dilute the standing abundance of zooplankton and to a lesser degree invertebrates, a subsequent increase as the zooplankton and benthic invertebrates respond to the reduced flows (increased residence time) and the increased temperature of the floodplain once disconnected from the river. Over time, these increases begin to slow down and then a period of decline occurs, only to be followed by cycle of increase after the next flood and spillover.

The forces driving these increases and decreases include a mix of predation, and food limitation. Section 4 will cover the roles of nutrient limitation in the production of periphyton and zooplankton.

References

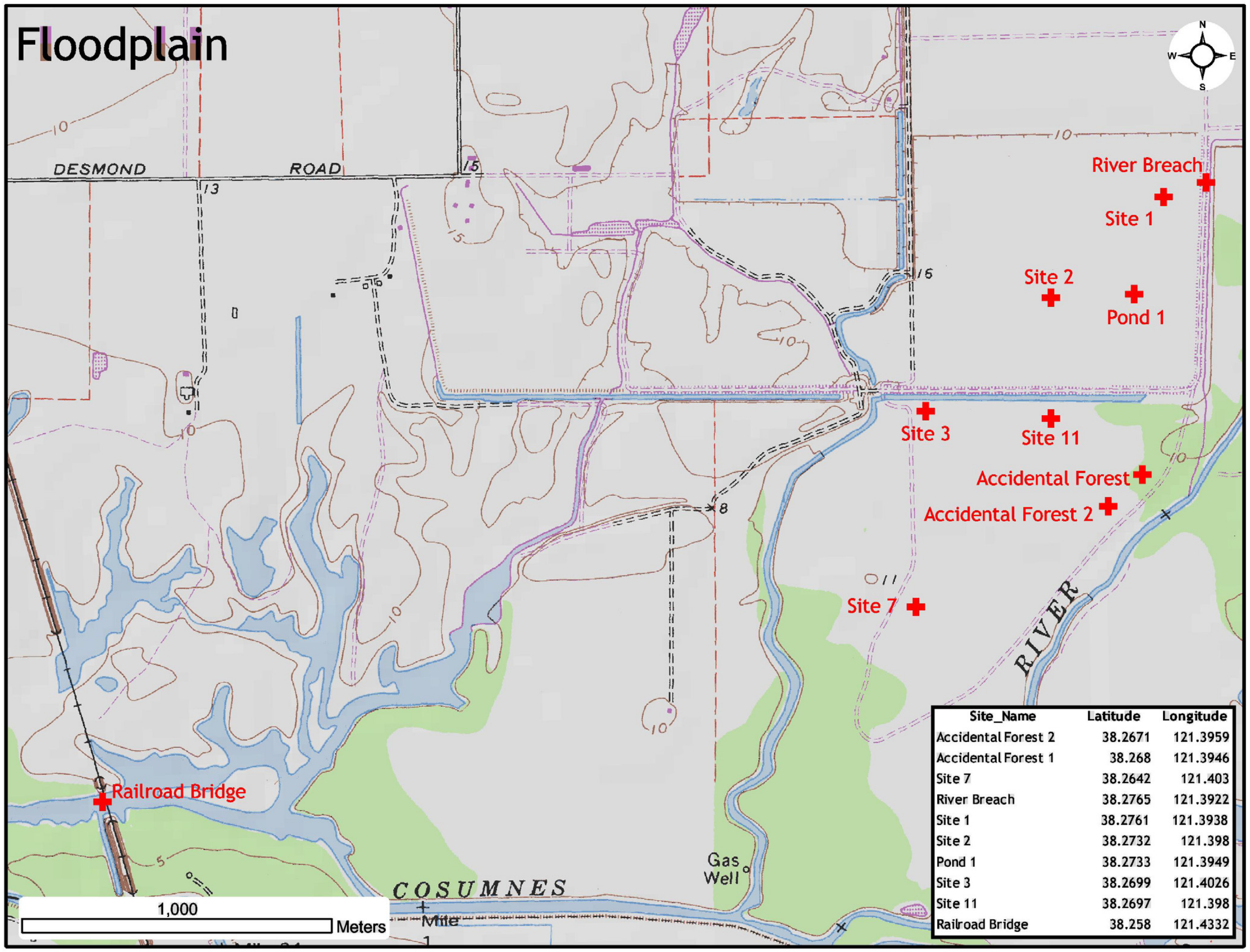
Brett, M.T., Goldman, C.R. 1997. Consumer versus resource control in freshwater pelagic food webs. Science 275: 384-386.

Polis, G.A. 1994. Food webs, trophic cascades and community structure. Aust. J. Ecology 19: 121-136.

Power M.E., Sun, A; Parker, G., Dietrich, W.E. 1995. Hydraulic food chain models. Bioscience 45:159-167.

Power, M.E. 2001. Prey exchange between a stream and its forested watershed elevates predator densities in both habitats. Proc. Natl. Acad. Sci. 98:14-15.

Map of floodplain sites and river sites.



Site_Name	Latitude	Longitude
Accidental Forest 2	38.2671	121.3959
Accidental Forest 1	38.268	121.3946
Site 7	38.2642	121.403
River Breach	38.2765	121.3922
Site 1	38.2761	121.3938
Site 2	38.2732	121.398
Pond 1	38.2733	121.3949
Site 3	38.2699	121.4026
Site 11	38.2697	121.398
Railroad Bridge	38.258	121.4332

Table 1.

General Taxa	Specific Taxa	Genus
Copepoda	Calanoida	Diaptomus
Copepoda	Calanoida	Osphranticum
Copepoda	Cyclopoida	
Copepoda	Harpacticoida	
Cladocera	Daphnidae	Alona
Cladocera	Daphnidae	Alonella
Cladocera	Daphnidae	Daphnia spp.
Cladocera	Daphnidae	Diaphanosoma
Cladocera	Daphnidae	Bosmina
Cladocera	Daphnidae	Ceriodaphnia
Cladocera	Daphnidae	Daphniopsis
Cladocera	Daphnidae	Eurycercus
Cladocera	Daphnidae	Pseudochydorus
Cladocera	Daphnidae	Sida
Cladocera	Daphnidae	Simocephalus
Cladocera	Daphnidae	Scapholeberis
Cladocera	Macrothricidae	
Diptera	Chironomidae	

Table 2.

Order	Family	Genus	Life Phase
Acari			
Amphipoda	Hyalellidae	Hyallella	
Amphipoda	Gammarridae	Gammarus	
Oligochaeta			
Coleoptera	Elmidae		Larva
Coleoptera	Dytiscidae		Larva
Coleoptera	Hydrophilidae		Adult
Coleoptera	Chrysomelidae	Disonycha	Adult
Coleoptera	Curculionidae		Adult
Coleoptera	Staphylinidae		
Coleoptera	Carabidae		Larva
Coleoptera	Curculionidae	Listronotus	Adult
Coleoptera	Elmidae		Adult
Collembola	Entomobryidae		Adult
Decapoda	Cambaridae	Procambarus	
Diptera	Ceratopogonidae		Larva
Diptera	Chironomidae		
Diptera	Simuliiae		Larva
Diptera	Ephydridae	Discocerina	Larva
Diptera	Nematocera		Pupa
Diptera	Tipulidae		Adult

Order	Family	Genus	Life Phase
Ephemeroptera	Baetidae		
Ephemeroptera	Caenidae	Cerobrachys	Larva
Hemiptera	Corixidae		Adult
Hemiptera	Corixidae		Nymph
Hemiptera	Saldidae		Nymph
Homoptera			Adult
Lepidoptera	Noctuidae	Bellura	Larva
Mollusca	Physidae		
Mollusca	Planorbidae		
Mollusca	Lymnaeidae		
Mollusca	Gastropoda		
Mollusca	Bivalva		
Odonata	Aeshnidae		Larva
Odonata	Coenagrionidae		Larva
Odonata	Libellulidae		
Plecoptera	Perlodidae	Isoperla	Larva
Podocopida	Ostrocoda		
Tricoptera			Larva

Figure 1. Zooplankton biomass (mean of two tows) summed over all zooplankton taxa for various floodplain sites vs. river discharge (measured at Michigan Bar) in 2000. Zooplankton biomass is on the left axis and discharge on the right axis. Discharge values over 800 represent flooding events. Note differences between floodplain sites (Pond 1, Site 3, Site 11) and river sites (Corp Breach, RR Bridge).

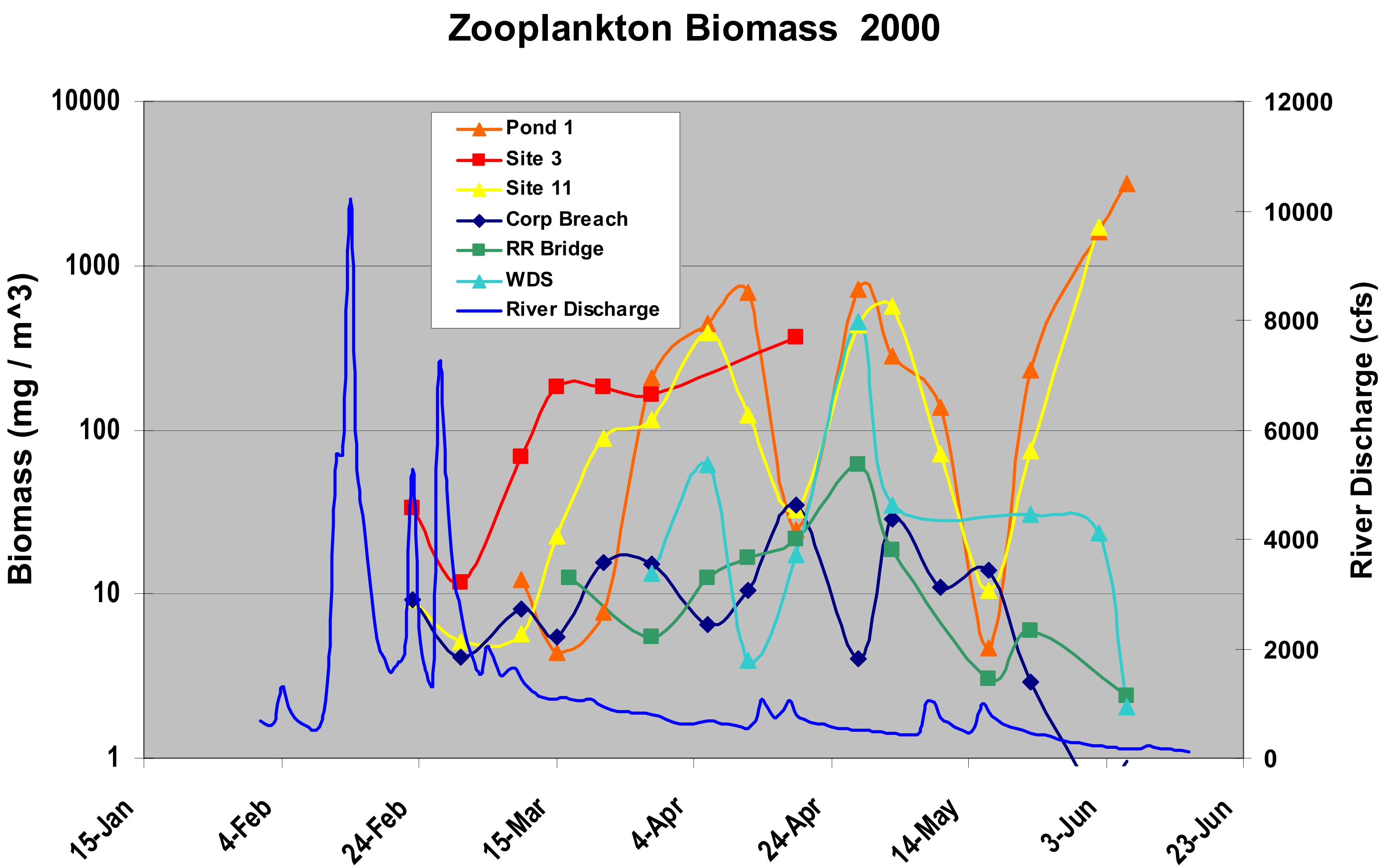


Figure 2. Zooplankton biomass (mean of two tows) for major taxa in 2000 for floodplain Site 11. Compare scale of biomass with Fig. 3.

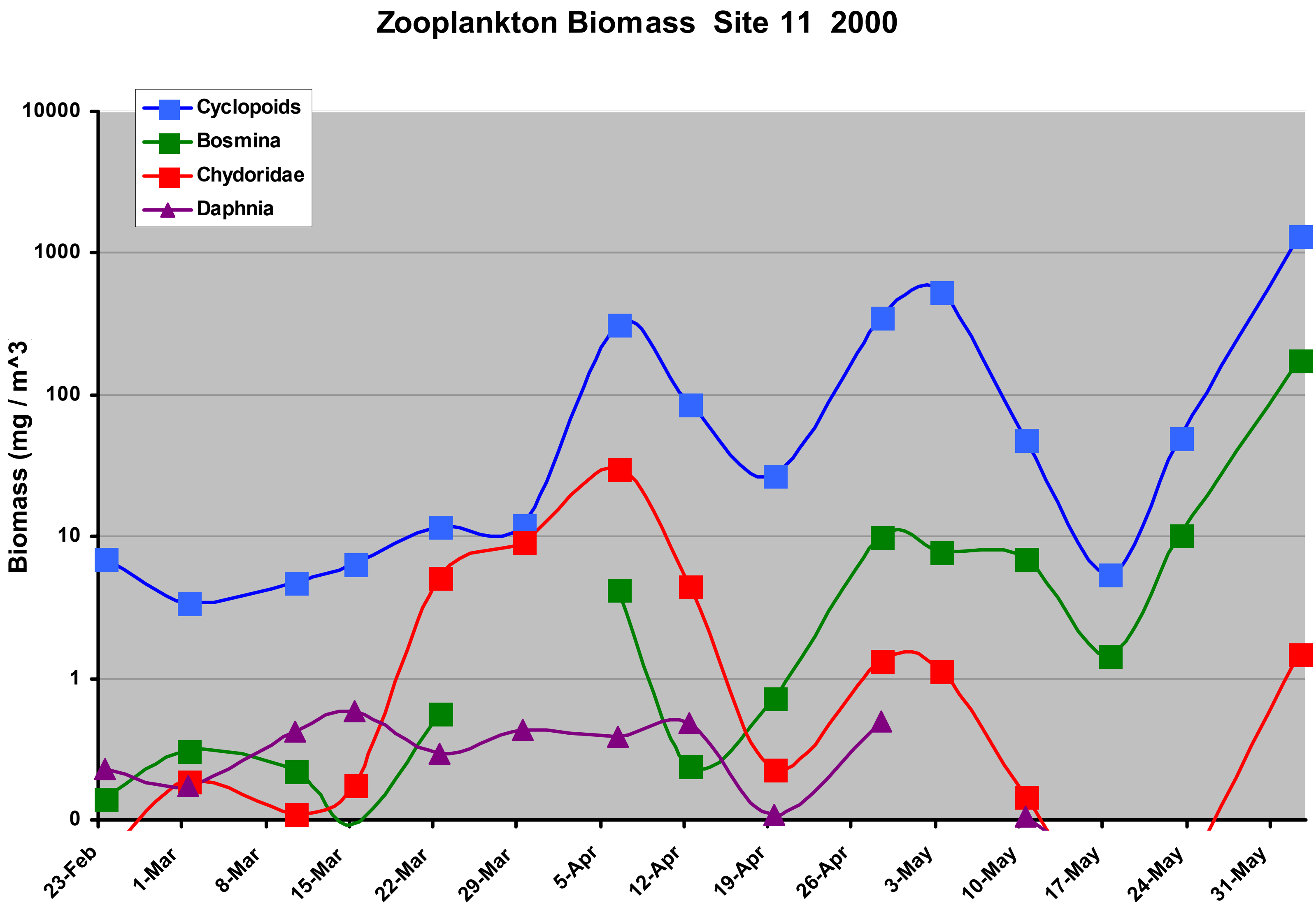


Figure 3. Zooplankton biomass (mean of two tows) for major taxa in 2000 for river site Rail Road Bridge (RRB). Compare scale of biomass with Fig. 2.

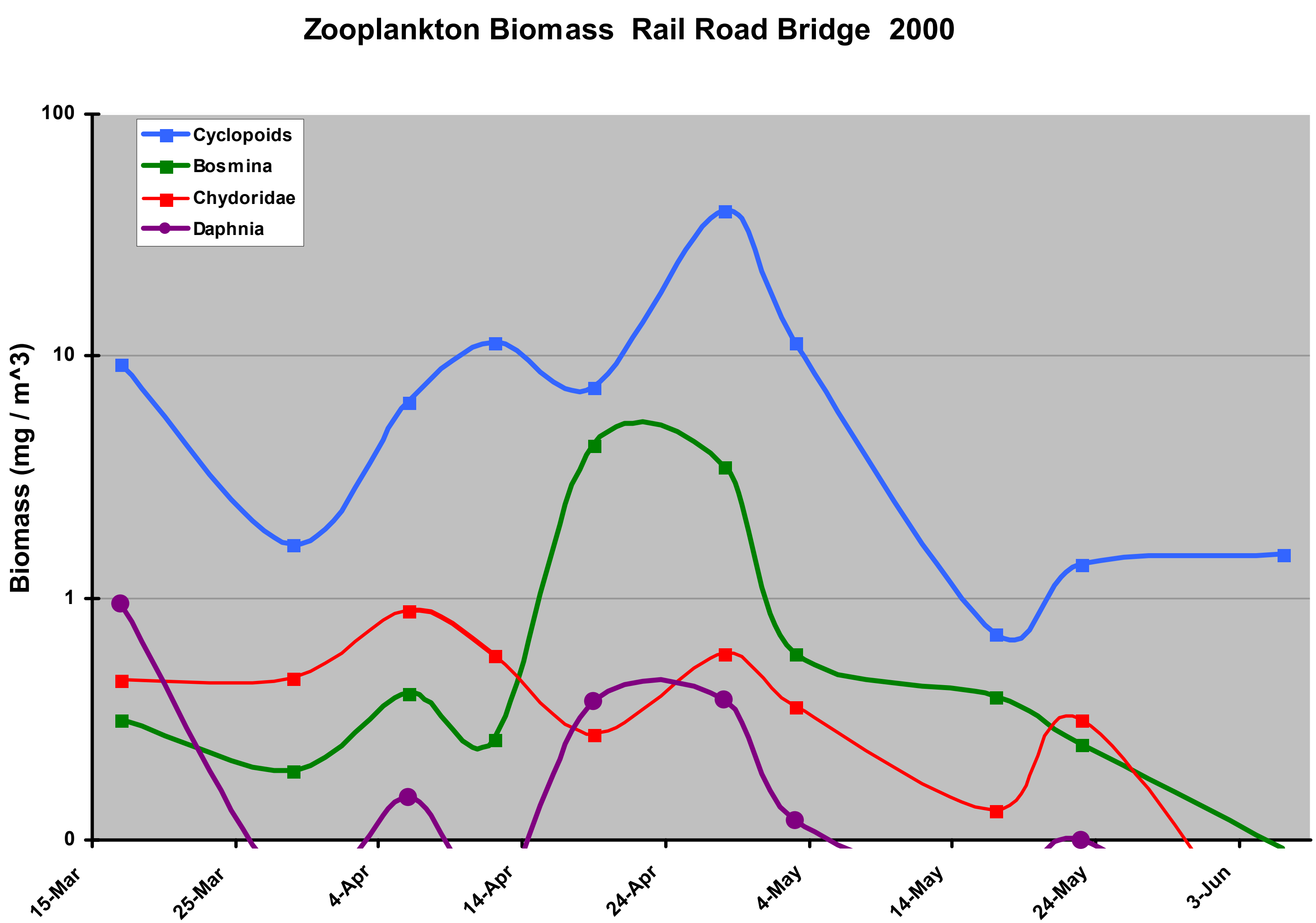


Figure 4. Zooplankton biomass (mean of two tows) summed over all zooplankton taxa for various floodplain sites vs. river discharge (measured at Michigan Bar) in 2001. Zooplankton biomass is on the left axis and discharge on the right axis. Discharge values over 800 represent flooding events. Compar floodplain sites (Site 7, Pond 1, Pond 2, Site 7, Site 11) and river sites (Corp Breach, RR Bridge).

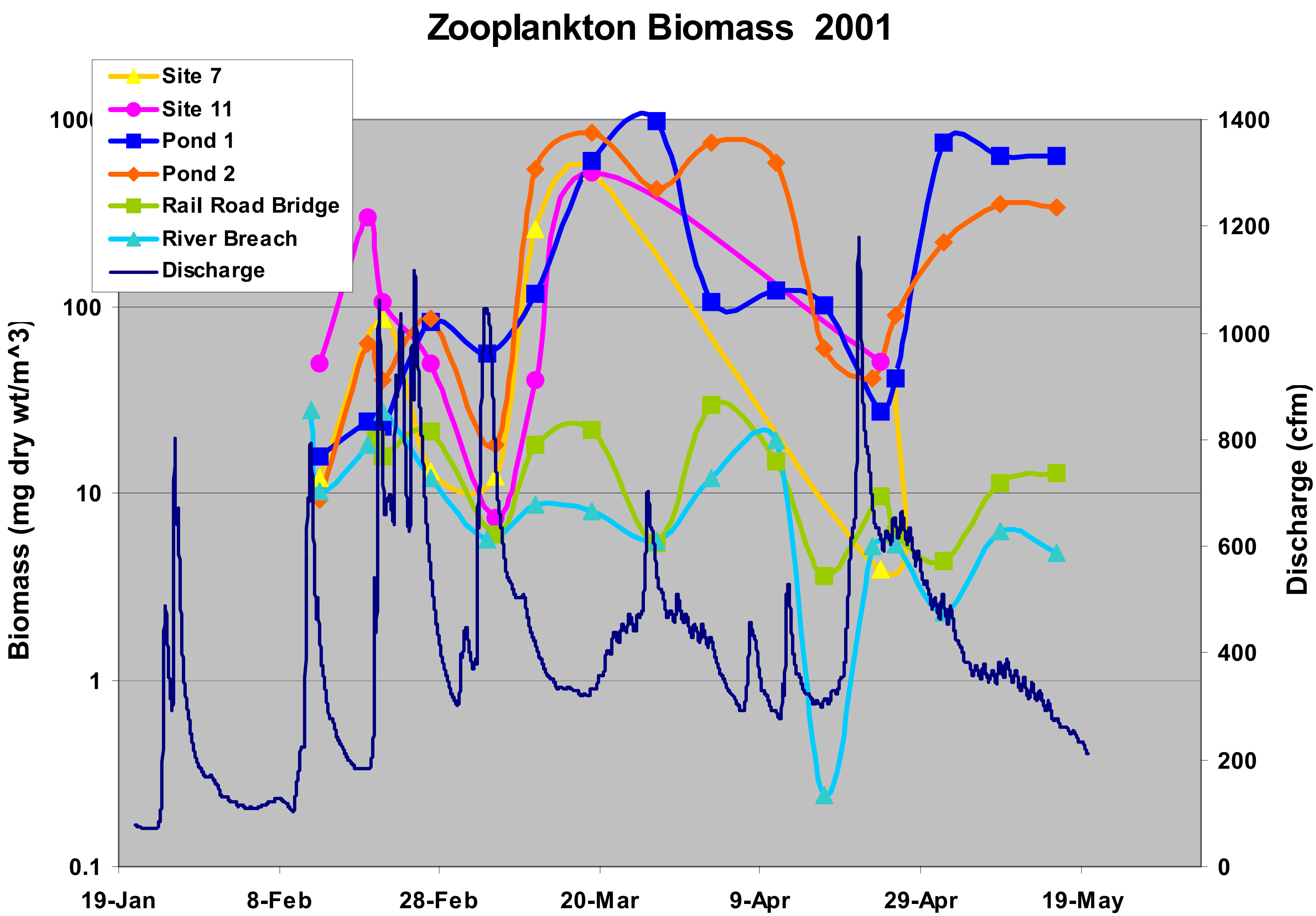


Figure 5. Zooplankton biomass (mean of two tows) by taxa for open floodplain sites (Site 7, Pond 2) and flooded forest sites (Accidental Forest 1 and 2) for March 7, 2001 (mid-flood season).

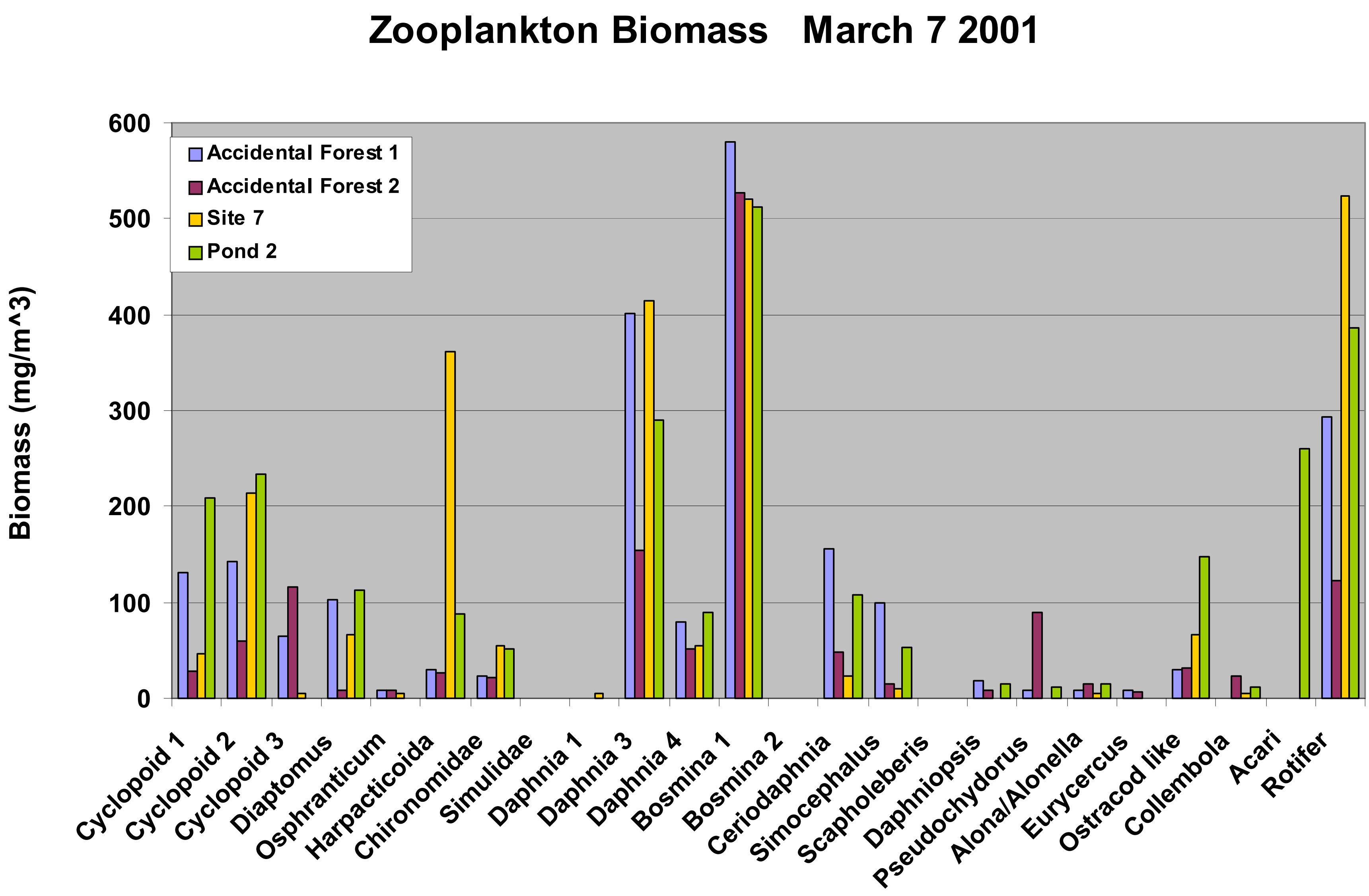


Figure 6. Zooplankton biomass (mean of two tows) for major taxa in 2001 for floodplain site Pond 1. Compare scale of biomass with Fig. 7 and 8.

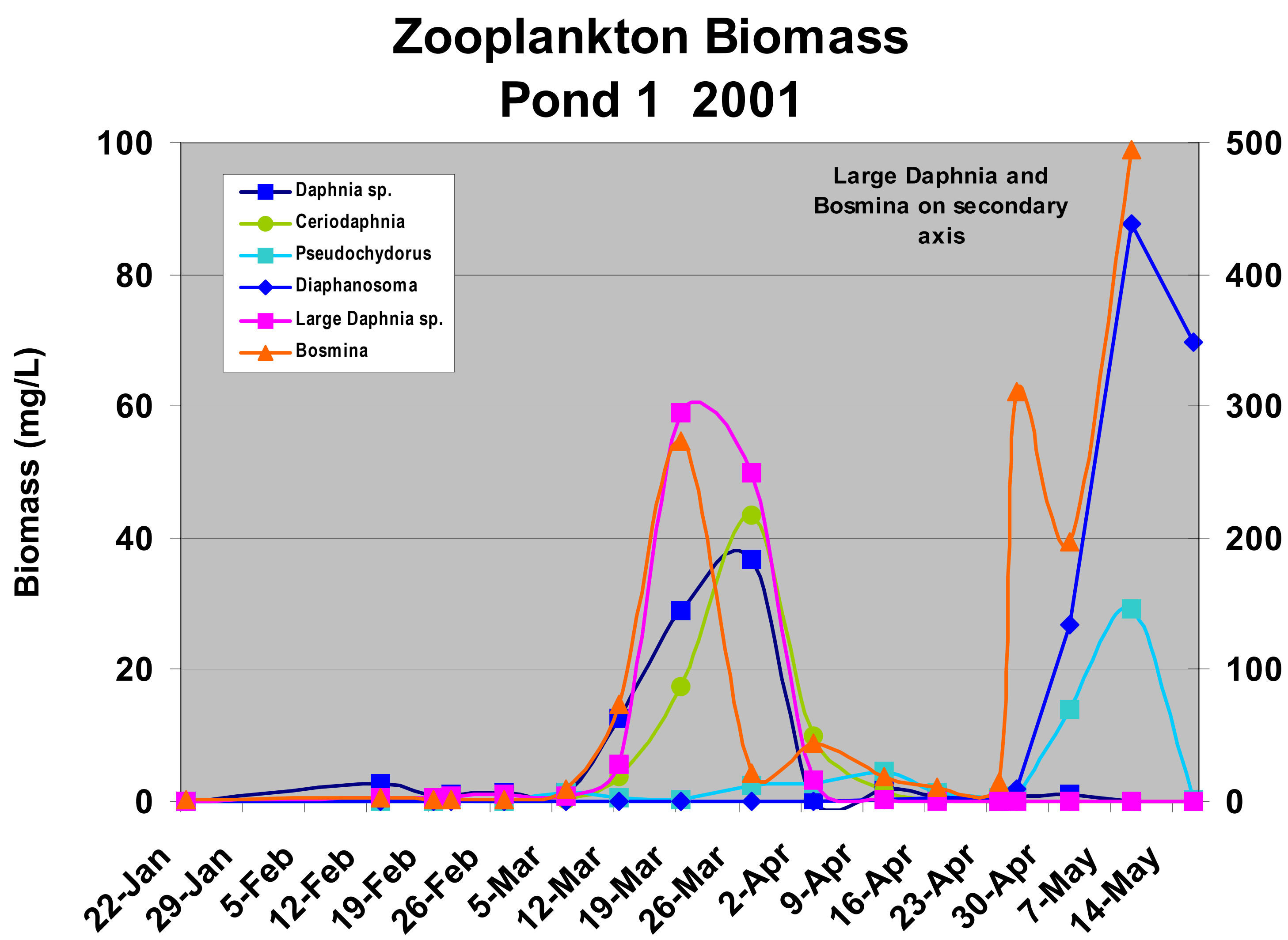


Figure 7. Zooplankton biomass (mean of two tows) for major taxa in 2001 for slough site Wood Duck Slough (WDS). Compare scale of biomass with Fig. 6 and 8.

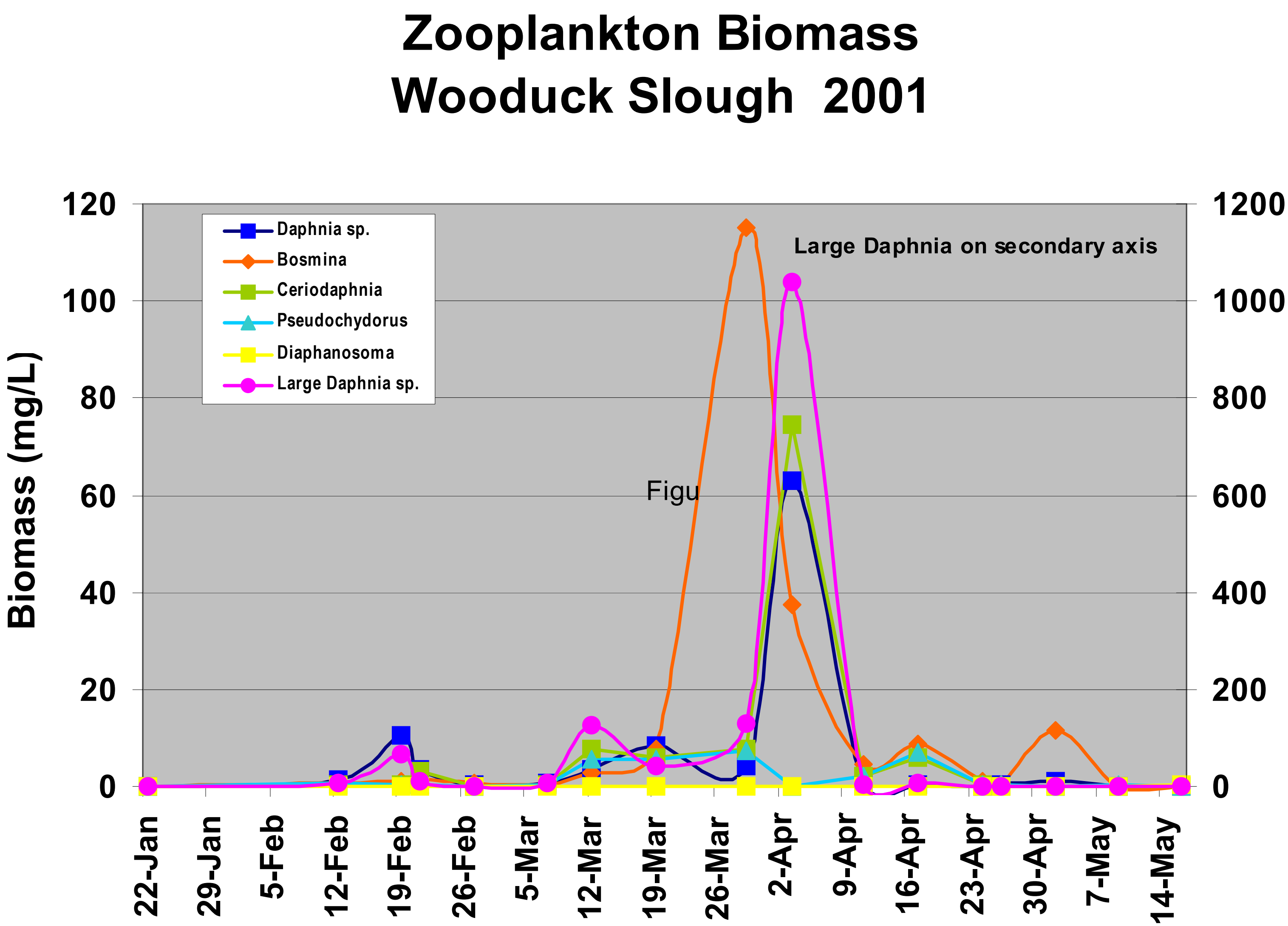


Figure 8. Zooplankton biomass (mean of two tows) for major taxa in 2001 for river site River Breach (=Corp Breach). Compare scale of biomass with Fig. 6 and 7.

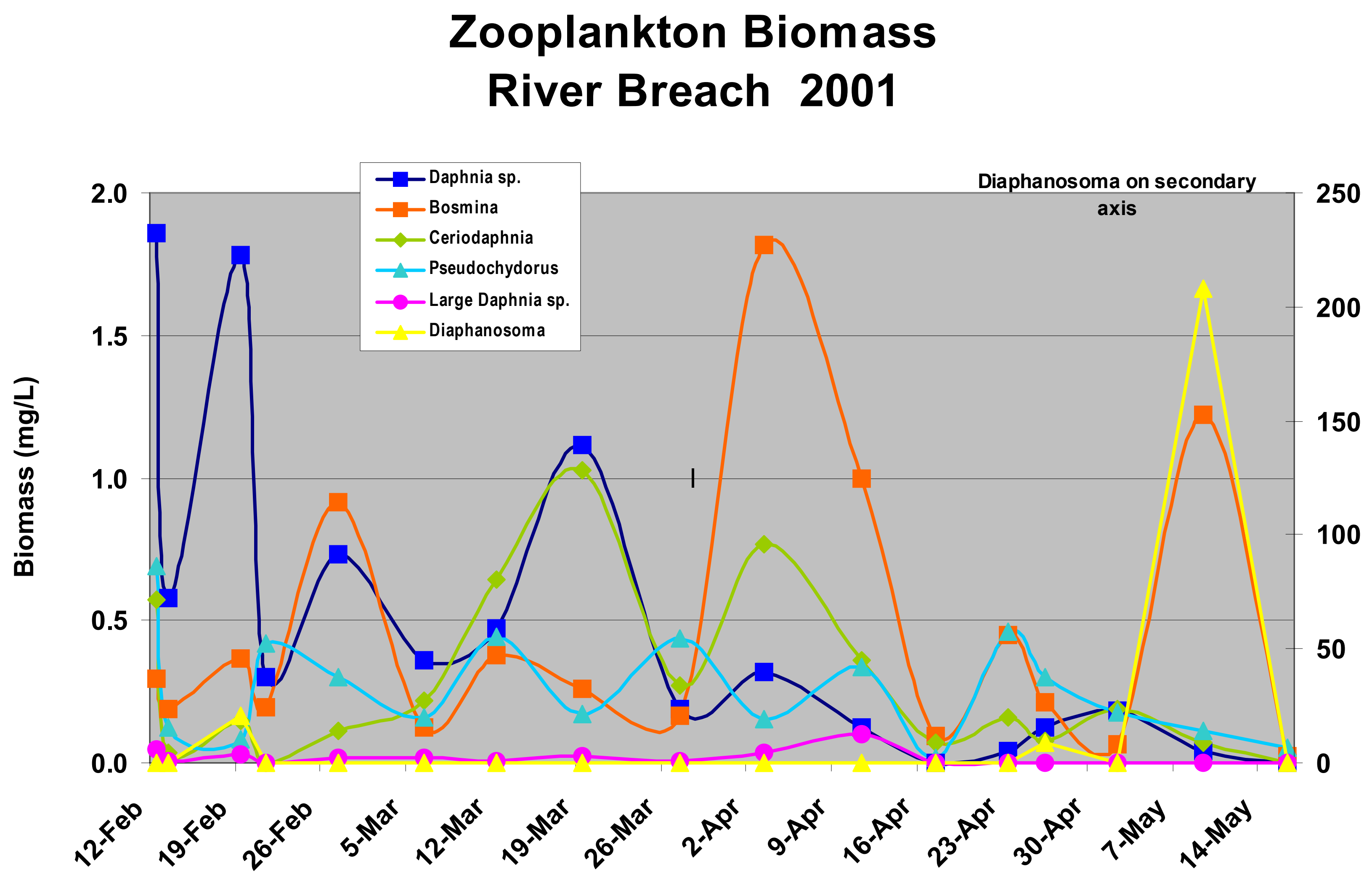


Figure 9. Zooplankton biomass (mean of two tows) summed over all zooplankton taxa for various floodplain sites vs. river discharge (measured at Michigan Bar) in 2002. Zooplankton biomass is on the left axis and discharge on the right axis. Discharge values over 800 represent flooding events. Note differences between floodplain sites (Pond 1, Site 7) and river sites (Corp Breach, RR Bridge).

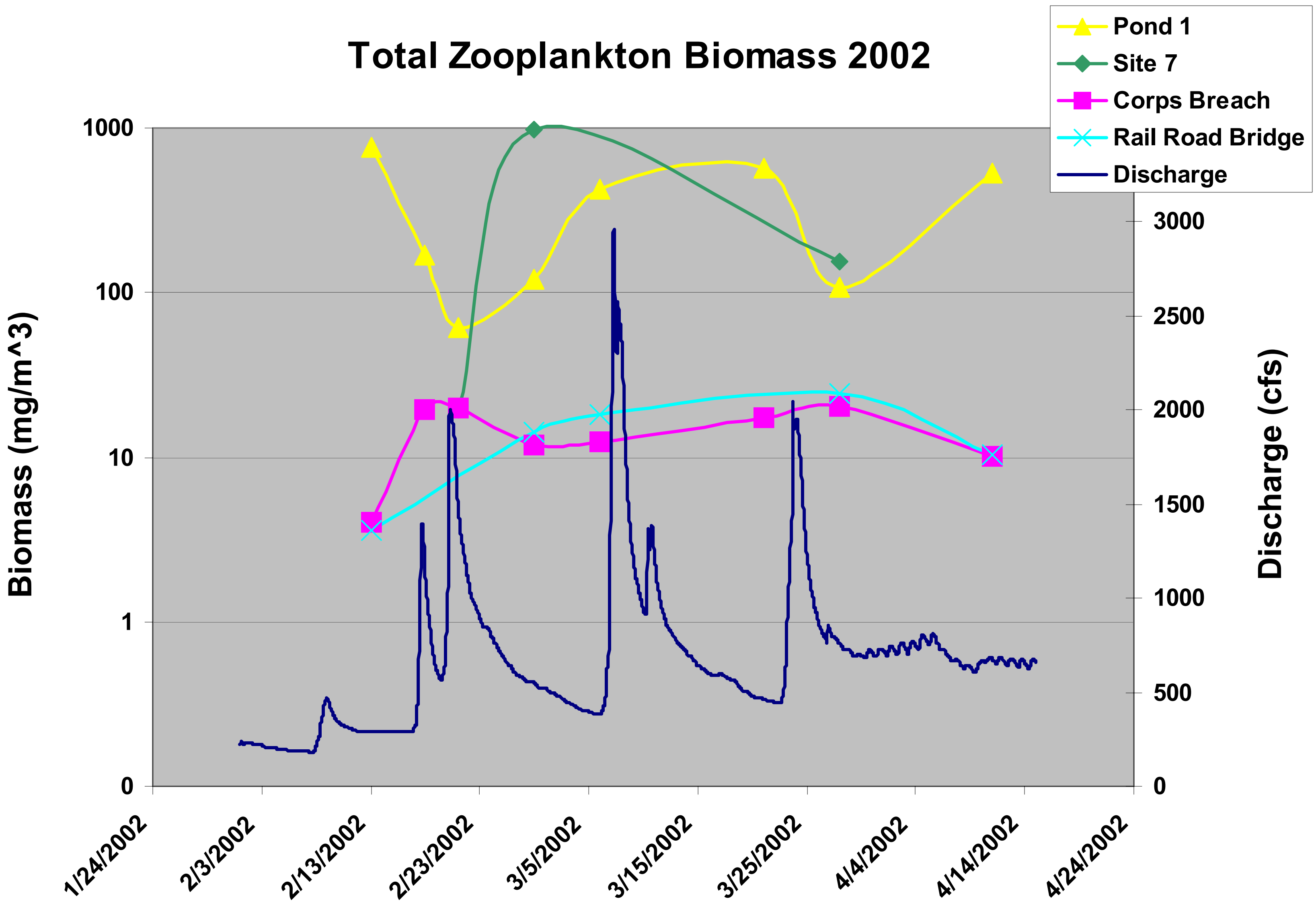


Figure 10. Zooplankton biomass (mean of two tows) for major taxa in 2000 for river site Corp Breach. Compare scale of biomass with Fig. 11.

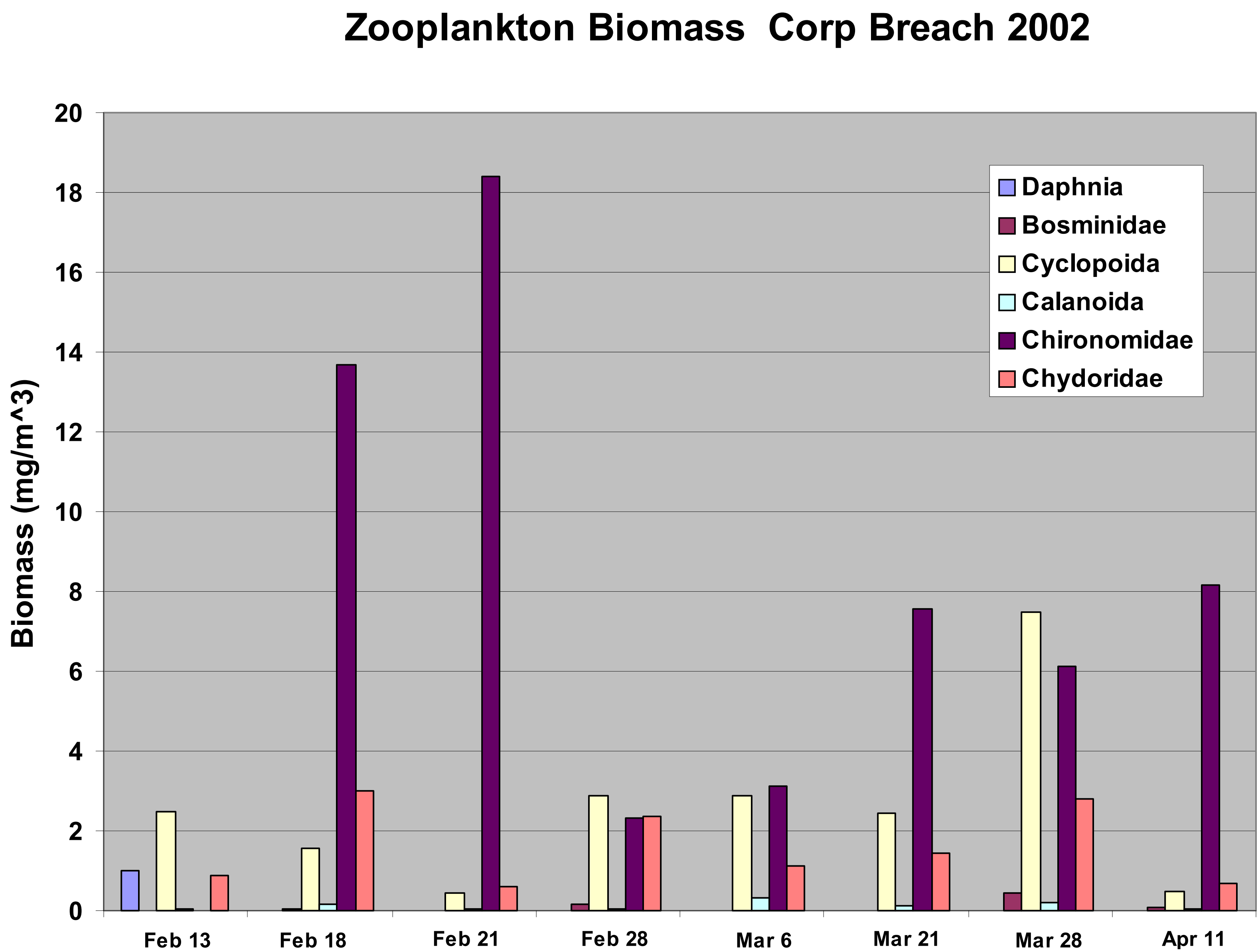


Figure 11. Zooplankton biomass (mean of two tows) for major taxa in 2000 for floodplain site Pond 1. Compare scale of biomass with Fig. 10.

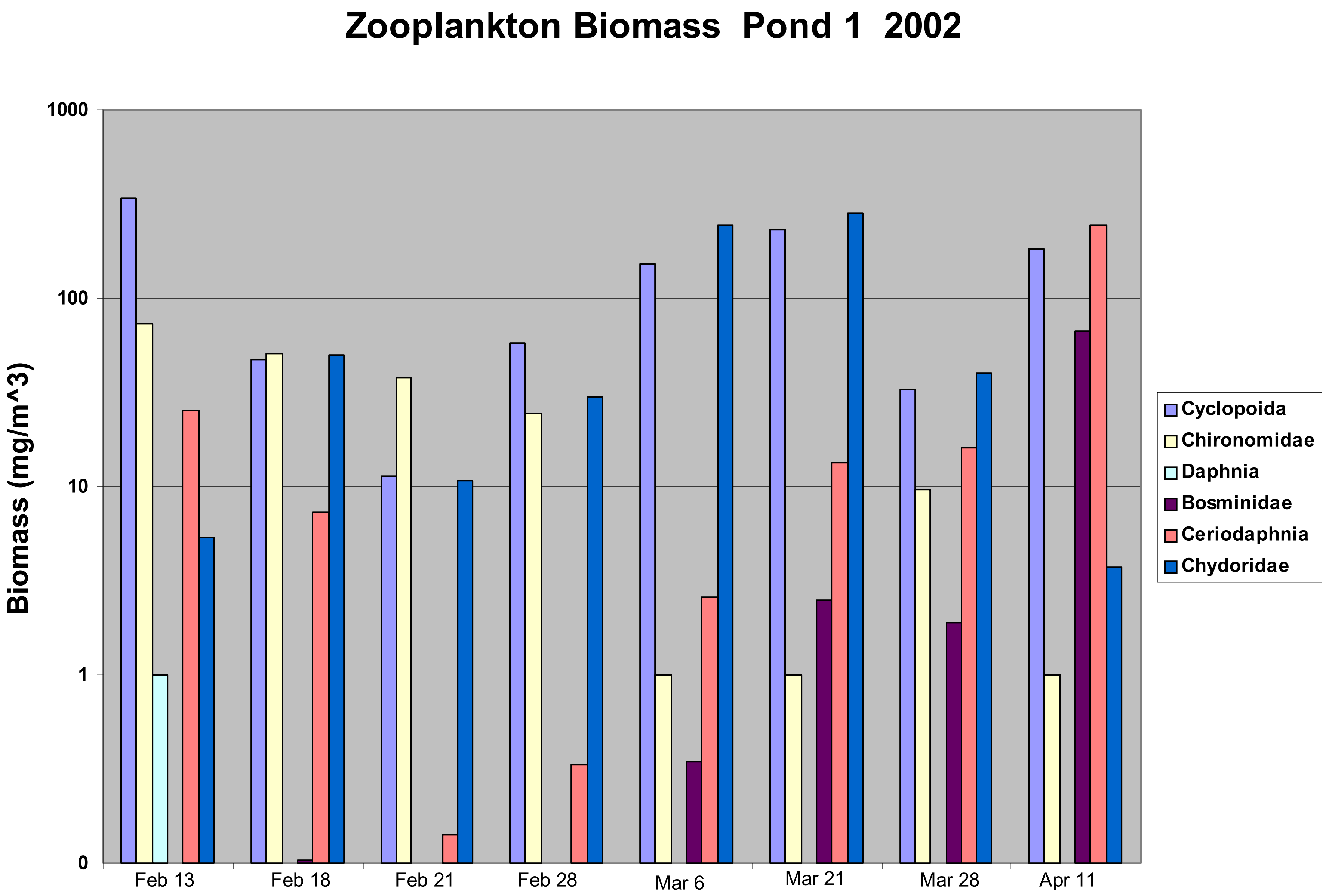


Figure 12. Benthic aquatic invertebrate abundance (mean of two sweeps) for 2002 from floodplain site Pond 2 showing major taxa vs. river discharge (measured at Michigan Bar) in 2002. Invertebrate biomass is on the left axis and discharge on the right axis. Discharge values over 800 represent flooding events. Compare biomass with Fig. 14 and 15.

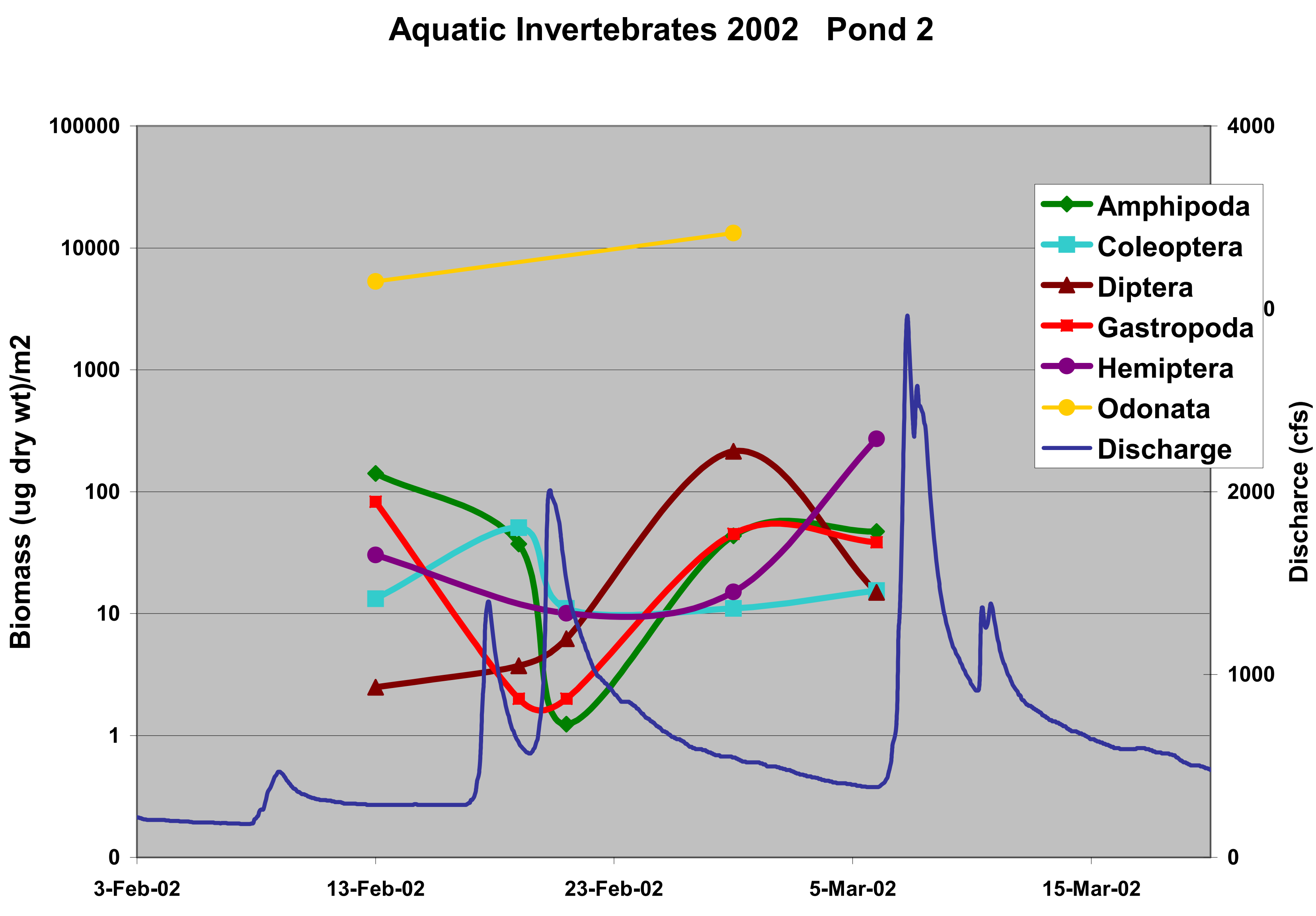


Figure 13. Benthic aquatic invertebrate abundance (mean of two sweeps) for 2002 from floodplain site Pond 1 showing major taxa vs. river discharge (measured at Michigan Bar) in 2002. Invertebrate biomass is on the left axis and discharge on the right axis. Discharge values over 800 represent flooding events. Compare biomass with Fig. 14 and 15.

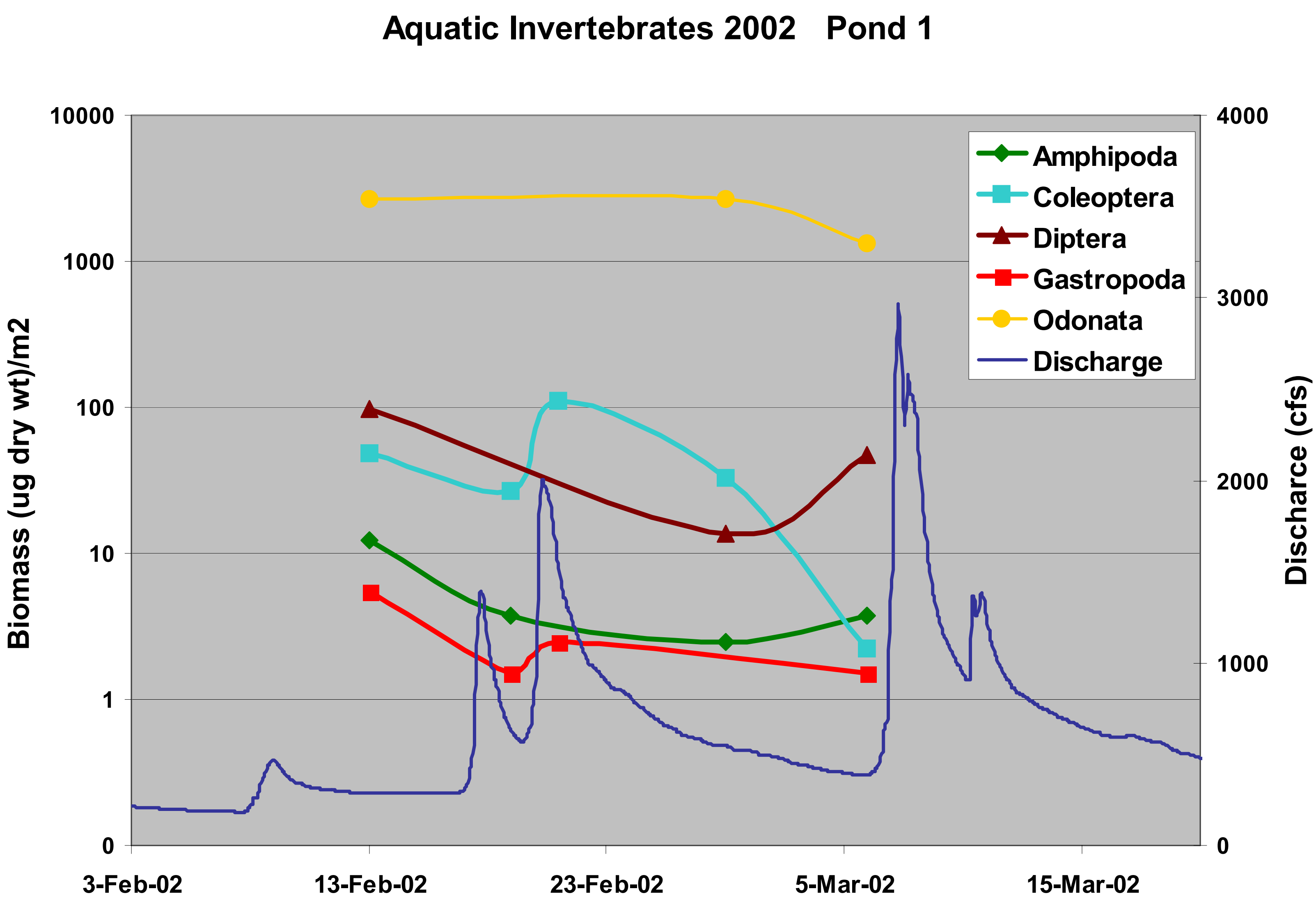


Figure 14. Benthic aquatic invertebrate abundance (mean of two sweeps) for 2002 from river site Corp Breach showing major taxa vs. river discharge (measured at Michigan Bar) in 2002. Invertebrate biomass is on the left axis and discharge on the right axis. Discharge values over 800 represent flooding events. Compare biomass with Fig. 12 and 13.

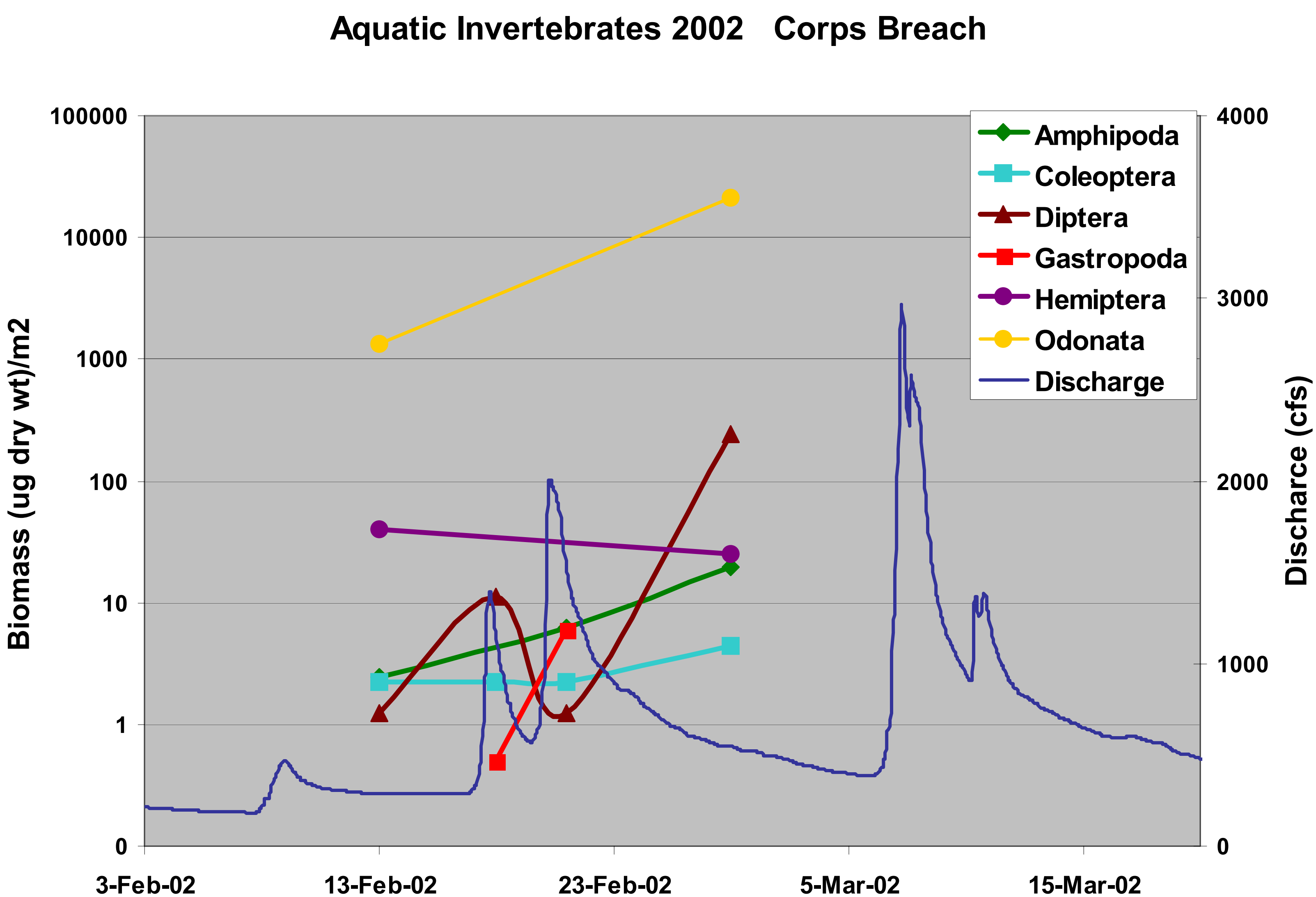


Figure 15. Benthic aquatic invertebrate abundance (mean of two sweeps) for 2002 from river site RRB showing major taxa vs. river discharge (measured at Michigan Bar) in 2002. Invertebrate biomass is on the left axis and discharge on the right axis. Discharge values over 800 represent flooding events. Compare biomass with Fig. 12 and 13.

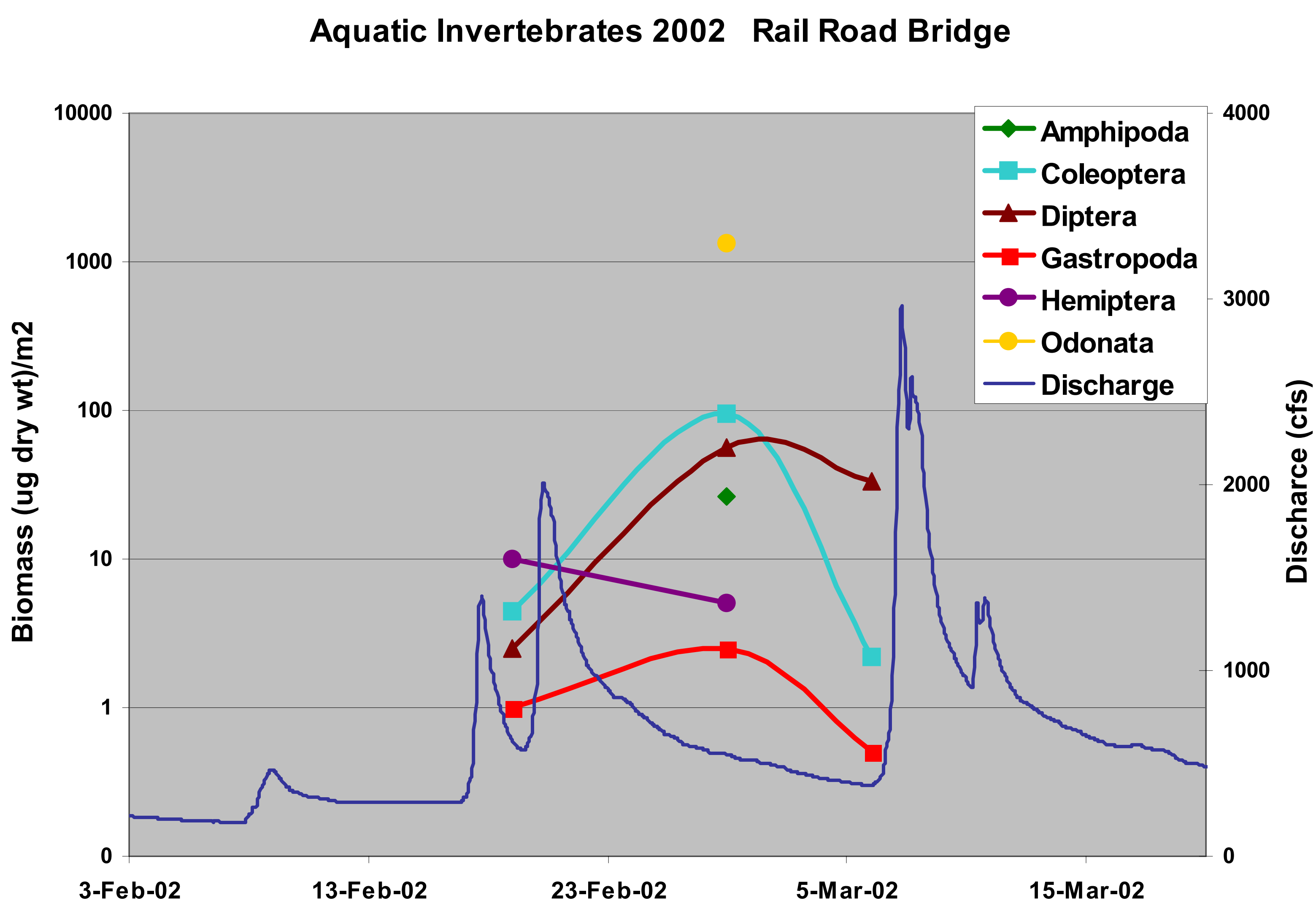


Figure 16. Density of non-native crayfish *Procambarus clarkii* in sweep samples (mean of two sweeps) for two dates in 2001 comparing abundances in slough site Wood Duck Slough (WDS) vs. floodplain site Pond 2 and the river.