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Robert B. Jacobson, Barry C. Poulton, and Linda C. Sappington
U.S. Geological Survey, 4200 New Haven Road, Columbia, MO 65201

Brian P. Kelly, U.S. Geological Survey, 401 NW Capital Drive,
Lee's Summit, MO 64086

William R. Mabee, Missouri Department of Conservation, Resource
Science Center, 1110 S. College Avenue, Columbia, MO 65201

Final Report to the U.S. Fish and Wildlife Service
Big Muddy National Fish and Wildlife Refuge, Columbia, MO
December 2002, revised December 2003

Open-File Report 2004-1036

U.S. Department of the Interior
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U.S. Geological Survey, Reston, Virginia: 2004
Revised and reprinted: 2003

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Chapter 3

Zooplankton of Lisbon Bottom Weltands

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Chapter 3. Zooplankton of Lisbon Bottom Wetlands

Duane C. Chapman, Barry C. Poulton and William R. Mabee

Abstract

In this study we examined the crustacean zooplankton assemblages of a continuum of wetland types at Lisbon Bottom and evaluated the zooplankton assemblages in relation to wetland limnology, hydrology and the fish community. Crustacean zooplankton were collected and identified in permanent and temporary wetlands of Lisbon Bottom, Missouri during the spring and early summer of 1999. Zooplankton were dominated by cladocerans and omnivorous copepods. Zooplankton density and diversity were related to flood events and nutrient pulses resulting from flood events. Topflooding wetlands had higher densities and diversities of zooplankton than backflooding wetlands, due to greater phytoplankton availability and possibly due to greater predation by fishes in the backflooding wetlands. Crustacean zooplankton density was much lower in stream-influenced wetlands than in the river-influenced wetlands, owing to lower nutrient availability and thus lower phytoplankton production in stream-influenced wetlands. Phytoplankton growth was accelerated by nutrients introduced during flood events and zooplankton populations increased thereafter, taking advantage of the increased resources.

Introduction

The Lower Missouri River system has been drastically altered over the past 50 years due to the combined effects of impoundment, channelization, bank stabilization, and levee construction. Collectively, these changes have resulted in the loss of backwater and wetland habitats. Many flood-plain-dependent fish species, including buffalos (*Ictiobus* sp.) and river carpsucker (*Carpiodes carpio*) that depend on these habitats for spawning and recruitment have also subsequently declined (Pflieger and Grace, 1987; Hesse and others, 1989).

Flooding of the vegetated flood plain is critical to these flood-plain-dependent fish species for several critical resources. Flood-plain-dependent species frequently deposit eggs on submerged vegetation as part of their specific reproductive strategy. Resulting larval fishes feed on zooplankton and other invertebrates that are produced in these nutrient and carbon-rich flooded backwater habitats. Abundant zooplankton food resources, in association with warmer temperatures of shallow water, contribute to enhanced bioenergetic conditions required for rapid growth and survival of young fishes. Numerous shorebirds and waterfowl also depend on zooplankton as food resources during late spring (Taylor, 1977; Crome, 1985). Invertebrates serve as high protein food resources necessary for egg production and feather regeneration during post-molt conditions.

Relatively little research has focused on the zooplankton assemblages of the Lower Missouri River. Early research was focused on the effects of power plant construction on fauna of the Lower Missouri River (Williams, 1973; Repsys and Rogers, 1982). This research indicated that zooplankton in the mainstem river were highly influenced by inputs from tributaries and upstream impoundments. Havel and Bethune (1999) examined the zooplankton of various permanent connected and non-connected scour habitats of the Lower Missouri River and determined that zooplankton assemblages differed depending on frequency of river exchange and associated trophic structure of various habitats; however, temporary, shallow habitats were not studied. Beaver and others (1999) studied the midsummer zooplankton assemblages in four wetland types in northern Ohio and found higher numbers of cladoceran zooplankton in temporary wetlands compared to more permanent constructed wetlands.

In this study, we investigated the dynamics of zooplankton communities in a continuum of Lower Missouri River wetlands ranging from temporary to permanent classes on the Lisbon Bottom Tract of the Big Muddy National Fish and Wildlife Refuge. This study was conducted to determine the importance of various factors that control zooplankton dynamics including wetland morphology (that is, depth, surface area, etc.), source and timing of flooding (for example, river-connected versus non-connected), and biological factors (that is, presence and absence of fish; algal biomass).

Methods

Zooplankton were collected approximately once weekly, one sample per wetland, when water stage permitted, between 4/16/99 and 6/16/99 from Wetlands 2, 4, 8, 9, 12, and 26 (fig. 3-1). In addition, Wetlands 5, 10, 11, 16, and 21 were sampled weekly during the caged fathead minnow growth study (see Chapter 2) to provide supporting data for that study. Because some of the wetlands were very shallow and all sampling was performed by wading rather than from a boat, a special zooplankton net was designed and constructed. The net was attached to a 7.5 by 20 cm frame with a handle, rather than being pulled on a cord, and consisted of 183 µm mesh. This design allowed sampling even in very shallow wetlands with good control of the depth sampled, and reduced the possibility of bottom contact when sampling. A sample consisted of a 1 m sweep of the net pulled just below the surface. This mesh size is appropriate for the capture of adult crustacean zooplankton. In this study rotifers and copepod nauplii and copepodids were identified and enumerated, but most rotifers and many copepod nauplii probably passed through the collection device. Zooplankton were rinsed from the net into vials and preserved with ethanol. Zooplankton were sampled as close as possible to the staff gages, which were located in the deepest part of all the wetlands except the deep scours. Zooplankton were enumerated and identified to genus by BSA Environmental Services, Beachwood, Ohio. Copepod nauplii were enumerated, but not further classified, while copepodids were classified to order.

Zooplankton densities (number of organisms per liter) were calculated by dividing the number of organisms in the sample by the volume of water sampled. The Shannon-Weaver index (Shannon and Weaver, 1949) was calculated to describe the zooplankton diversity within individual wetlands and between wetlands. Analysis of variance was used to test differences in density and relative abundance of zooplankton between wetland permanence categories (SAS, 1990). Also, analysis of variance was used to test differences in zooplankton density within wetland permanence categories. Duncan’s multiple range test was used to define differences. Percent relative abundance data was arc sine square root transformed before analysis (Snedecor and Cochran, 1989). A cluster analysis was performed using Ward's method to group wetlands by similarity of zooplankton assemblages. Only wetlands that were sampled for the duration of the period (4/16/99 to 6/16/99) were included in the analysis.

Results and Discussion

All zooplankton data are reported in Korschgen and others (ArcView-based spatial decision support system for the Lisbon Bottom Unit of the Big Muddy National Fish and Wildlife Refuge, unpub. data, 2001). Mean zooplankton densities from wetlands sampled over the course of the study are shown in table 3-1. A list of zooplankton genera captured is shown in table 3-2. Overall, cladocerans were more common than copepods. Wetland 26, a deep backflooding scour that had the most connectivity with the river, had the lowest zooplankton densities; and the shallowest, most ephemeral wetlands (2 and 9) had the highest. Wetlands 2 and 9 were recharged by topflooding, and at times by intermittent streams and overland runoff. Total number of organisms varied greatly within a site between sampling periods. For example, Wetland 2 had a total of 2.7 organisms/L on April 15 and over 6000 organisms/L on May 26. No ostracods were captured during this study.

The most common crustacean zooplankton genus overall was the calanoid copepod *Skistodiaptomus*, owing to its ubiquity in the wetlands, high concentrations in shallow Wetlands 2 and 12, and very high concentrations in the shallow and terrestrially vegetated Wetland 9. *Tropocyclops* was the only other common copepod genus, being found in fairly high numbers in every wetland except 4 and 9. *Tropocyclops* is a small omnivorous cyclopoid copepod. Seven genera of adult copepods were identified in all. All of the adult copepods captured were of either the Cyclopoida or Calanoida orders, which include nektonic species (Barnes, 1987) that are susceptible to our sampling gear. Calanoid and cyclopoid copepodids were also captured. Adult harpacticoid copepods are mostly benthic and were not captured in this study, but harpacticoid copepodids were captured.

The most common cladocerans in descending order of prominence were *Moina, Scapholeberis, Daphnia, Simocephalus, Chydorus*, *Bosmina,* and *Ceriodaphnia. Bosmina and Chydorus* are considered indicative of eutrophic conditions (Beaver and others, 1999). *Bosmina* and *Chydorus* never dominated the samples, but they were common. The average combined relative abundance of these two genera was 14%. Overall diversity of Cladocera in the wetlands was higher than that of the Copepoda, with 13 different genera of Cladocera identified. The above-listed seven genera accounted for >98% of the individuals.

Number of genera of crustacean zooplankton within an individual sample ranged from 1 to 13. Number of genera within a wetland (three to six sample dates per wetland) ranged from 7 to 15. Havel and Bethune (1999), who in a 1995 study of 12 unconnected scours in the Missouri River flood plain (4 to 6 sample dates per wetland) found species richness between 4 and 14.

Topflooding wetlands had higher number of genera and Shannon-Weaver diversity than did the backflooding Wetlands 22 and 26 (table 3-3), which were also the wetlands most connected to the Missouri River. Wetland 26, a backflooding wetland and the largest and deepest wetland in the study, had the lowest number of genera, averaging 3.6 per sample over the study. Backflooding Wetland 29 had higher diversity than backflooding Wetlands 26 and 22, but it was sampled on fewer dates and only during a period in which it was not connected to the river.

Zooplankton densities were highly influenced by river flooding and the subsequent production of phytoplankton. The river repeatedly flooded wetlands in the northern portion of the bottom (Wetlands 2, 4, and 8) between April 1 and May 8, 1999 (Chapter 2, fig. 2-4), resulting in high turbidity (fig. 3-2A) and low densities of zooplankton. Crustacean zooplankton densities in the Missouri River are usually much lower than the average densities we found in wetlands (Berner, 1951; Jennings, 1979). Chlorophyll *a* concentrations increased dramatically from May 11 to May 21, 1999 (fig. 3-2B) after the turbidity from the river settled out. (Note that turbidity increased again during this period (fig. 3-2A) because of the increase in phytoplankton.) This was followed by very high numbers of zooplankton in the May 26 and June 3 samples (fig. 3-2C). Number of genera also peaked on May 26, 1999 in the topflooding wetlands (fig. 3-3). Safety concerns precluded sampling in backflooding Wetlands 22 and 26 during the highest flooding periods, but they apparently followed a pattern similar to that of the topflooding wetlands, with turbidity, chlorophyll and zooplankton peaks on approximately the same dates, although overall zooplankton density was much lower (fig. 3-4 A-C).

Wetland 12, which was not flooded by the river and was dominated by aquatic macrophytes rather than phytoplankton, showed a very different pattern in turbidity, chlorophyll, and zooplankton density (fig. 3-2, A-C). Zooplankton density in Wetland 12 was highest early in the study and quite low in late May through June. After the ambient temperature increased in late April, macrophyte growth in Wetland 12 removed all available nutrients (Chapter 2, fig. 2-7) and phytoplankton density was very low. Without the phytoplankton forage base, zooplankton density also was low. Despite the low density of zooplankton, Wetland 12 had the second highest diversity and highest number of genera of crustacean zooplankton. This differs from the report by Havel and Bethune (1999), which found that connectivity between the wetland and the river was strongly and positively correlated with species richness. In this study, Wetlands 26 and 22, which had the highest connectivity to the river, had the lowest number of genera, and Wetlands 21 and 12, which were lowest in connectivity, had the highest number of genera.

Although chlorophyll *a* concentrations were somewhat lower in Wetland 26 and 22 than in the topflooding wetlands, the lower density of zooplankton in these wetlands may not be entirely due to higher turbidity and resulting lower primary and secondary productivity. Predation on zooplankton by planktivorous fish can strongly influence zooplankton density and species composition (Devries and Stein, 1992). The fish communities in these wetlands varied by wetland type and water source (see Chapter 5), and thus likely had different influences on zooplankton density in different wetlands. Wetlands 22 and 26 were connected to the river more often than the other wetlands, but the connection was via backflooding through Coopers Creek and water exchange was not high between the river and the wetlands except during periods of extreme flood. As evidence of low water exchange, turbidity in these wetlands was not higher than in the topflooding wetlands even though they were connected more often to the highly turbid river. The connection to the river apparently provides access to the wetlands by riverine fishes such as emerald, ghost, and mimic shiners (*Notropis atherinoides, N. buchanani,* and *N. volucellus,* respectively). The numbers of zooplankton in Wetlands 22 and 26 were likely impacted by these planktivorous fishes, which were captured in large numbers in these wetlands, but not in the topflooding wetlands (see Chapter 5). Wetland 21, a topflooding wetland located very near Wetland 22, also had a high density of small fish, but had a much higher zooplankton density. Young-of-theyear buffalo and common carp (*Cyprinus carpio*), which may not be as efficient predators of nektonic zooplankton, dominated Wetland 21.

Ephemeral wetlands in this study had the highest densities of crustacean zooplankton (table 3-4), followed by the permanent wetlands. Temporary (but not ephemeral) wetlands had the lowest densities. Ephemeral wetlands had higher numbers of calanoid than cyclopoid copepods, and permanent wetlands had higher numbers of cyclopoid than calanoid copepods. However, none of these differences were significant at the $\alpha = 0.05$ level. Beaver and others (1999) found that temporary wetlands had higher numbers of cladocerans and copepods than three categories (constructed, anthropogenically impacted, and non-impacted) of permanent wetlands, but he did not discriminate as to the degree of permanence of the temporary wetlands. Overall densities of copepods and cladocerans in permanent wetlands were higher in this study than in that of Beaver and others (1999) (table 3-4), and ephemeral wetlands in this study had higher densities than either permanent or temporary wetlands in that study. Forty-two percent of the crustacean zooplankton in temporary wetlands of the Beaver and others study were ostracods, which were not captured in any wetland in this study. Calanoid copepods were rare in the Beaver and others (1999) study. However, calanoid copepods were common in our study, especially in ephemeral basins where density was significantly higher than in temporary or permanent wetlands.

Densities of crustacean zooplankton at Lisbon Bottom were also much higher than that reported by Havel and Bethune (1999), who compared a scour wetland connected to the Missouri River to an unconnected scour on the Missouri River flood plain in March of 1997. In that study, density of crustacean zooplankton was 2.2/L in the connected scour and 7.6/L in the unconnected scour. In our study, the mean crustacean density (average of all samples in all wetlands) was 600/L. Of 64 samples analyzed in this study, only 7 had less than 10 crustacean zooplankton/L. In the study by Havel and Bethune, most of the crustacean zooplankton collected were the cyclopoid copepod *Diacyclops thomasi*. *Diacyclops* was not common in this study, occurring only in Wetland 9 on two sample dates.

Ward's minimum variance cluster analysis of the wetlands by zooplankton assemblages (fig. 3-5) identified ephemeral Wetland 2 as the most different from the others. Notably, Wetland 2 was also identified as the most different in the cluster analysis performed using large fish species assemblages. Wetland 9, the other ephemeral wetland, was most similar to Wetland 2. Wetlands 26 and 22, which were among the only backflooding wetlands in the study and the wetlands most connected to the Missouri River, were very similar. Wetlands 4 and 26, the only deep scours in the study, were grouped close together. Surprisingly, Wetlands 12 and 8 were grouped very close together, despite their very different hydrology, limnology, and fish assemblages. In general, though, wetlands that were similar in hydrology were most similar in zooplankton assemblages.

Soeken (1998) identified three genera of Cladocera (*Moina, Bosmina*, and *Diaphanasoma*) that are resistant to high turbidity and are often present in turbid rivers. Based on that study, it could be hypothesized that the relative abundances of these genera would be higher after a flood event, when turbidities are high and other zooplankton might have been flushed from the wetlands. However, we found no strong correlations between the density or relative abundances of these genera and turbidity, either when relative abundance was expressed as a percentage of total crustacean zooplankton or when expressed as a percentage of total Cladocera. This held true regardless of whether these three genera were grouped together or considered separately (fig. 3-6). It should be noted that *Moina* and *Diaphanosoma* densities were always low at turbidities below 30 ntu, but since periods of low turbidities had low densities of many zooplankton, relative densities of these genera were sometimes high even at low turbidities.

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List of Tables and Figures

Tables

Figures

Table 3-1. Mean number of zooplankton organisms per liter in Lisbon Bottom wetlands. Note that the gear incorporated a mesh size designed primarily for the capture of adult crustacean zooplankton and therefore underestimates the contribution of small nauplii and rotifers.

Wetland number	Cladocerans	Copepods	Rotifers	Total organisms
2	1011.1	161.2	83.2	1255.6
4	198.9	12.2	6.7	217.7
8	252.9	117.2	76.5	446.6
9	255.1	350.6	0.8	606.5
12	447.9	78.0	0.8	526.7
22	71.8	150.9	0.0	222.8
26	21.4	24.1	12.9	58.4
Overall mean	332.8	134.1	26.1	493.0

Table 3-2. List of zooplankton genera captured in wetlands of Lisbon Bottom between late March and the end of June 1999. Thirty-two genera were captured. Rotifer genera captured are listed here, but it should be noted that the net size used (183 μm) was chosen for capture of crustacean zooplankton, and may have been too large for efficient capture of rotifers.

Cladocera	Copepoda*	Rotifera
Alona		*Ascomorpha*
Bosmina	**Calanoida**	*Asplanchna*
Ceriodaphnia	*Diaptomus*	*Bdelloid*
Chydorus	*Skistodiaptomus*	*Brachionus*
Daphnia		*Conochiloides*
Diaphanosoma	**Cyclopoida**	*Filinia*
Kurzia	*Acanthocyclops*	*Keratella*
Leydigia	*Diacyclops*	*Lecane*
Macrothrix	*Eucyclops*	*Monostyla*
Moina	*Mesocyclops*	*Ploesoma*
Pleuroxus	*Tropocyclops*	*Polyarthra*
Simocephalus		*Trichocerca*
Scapholeberis		

* Harpacticoid copepodids were captured in this study, but no adults of that primarily benthic order were captured.

Table 3-3. Number of crustacean zooplankton genera and Shannon-Weaver diversity in Lisbon Bottom wetlands. All wetlands from which at least three samples were taken are shown.

Wetland number	Mean number of genera per sample	Shannon-Weaver Index	N	Water source
2	6.1	1.1	7	Topflooding and stream
4	6.9	1.3	7	Topflooding, some stream
5	7.3	1.0	3	Topflooding
8	7.9	1.2	7	Topflooding
9	6.2	1.0	8	Topflooding and stream
12	8.0	1.2	7	Stream
16	5.0	0.9	3	Topflooding
21	9.7	1.6	3	Topflooding
22	4.3	0.9	6	Backflooding
26	3.7	0.6	6	Backflooding

Table 3-4. Densities of crustacean zooplankton at Lisbon Bottom by wetland permanence, with data from Beaver and others (1999) for comparison. Wetlands 11 and 12 are excluded from this comparison because they were highly stream-influenced, and thus differed limnologically from the other wetlands. Total crustacean zooplankton may differ slightly from the horizontal sum because of the inclusion of copepod nauplii, which were not identified to order, and in the case of the Beaver and others data, from the inclusion of Ostracoda. Ostracoda were not found in this study. Different lower case superscripts indicate significant differences between wetland permanence types within zooplankton taxonomic groups ($\alpha = 0.05$, Duncan's multiple range test).

Permanence	Wetland	Mean cladocerans/L	Mean cyclopoids/L	Mean calanoids/L	Total crustacean zooplankton
Ephemeral	2	1011	78	83	1172
	9	255	27	323	606
	10	2583	70	55	2708
	Mean	**1283**	**58**	**154**[a]	**1495**
Temporary	8	253	92	25	370
	21	114	49	8	175
	22	29	19	122	170
	29	188	118	32	337
	Mean	**146**	**69**	**47**[b]	**263**
Permanent	4	203	7	6	215
	5	305	26	15	347
	16	1293	789	60	2143
	26	89	263	0	353
	Mean	**473**	**271**	**20**[b]	**764**
Temporary	Beaver and others, 1999	**152**	**85**	**0.3**	**533**
Permanent	Beaver and others, 1999	**55**	**59**	**2**	**226**

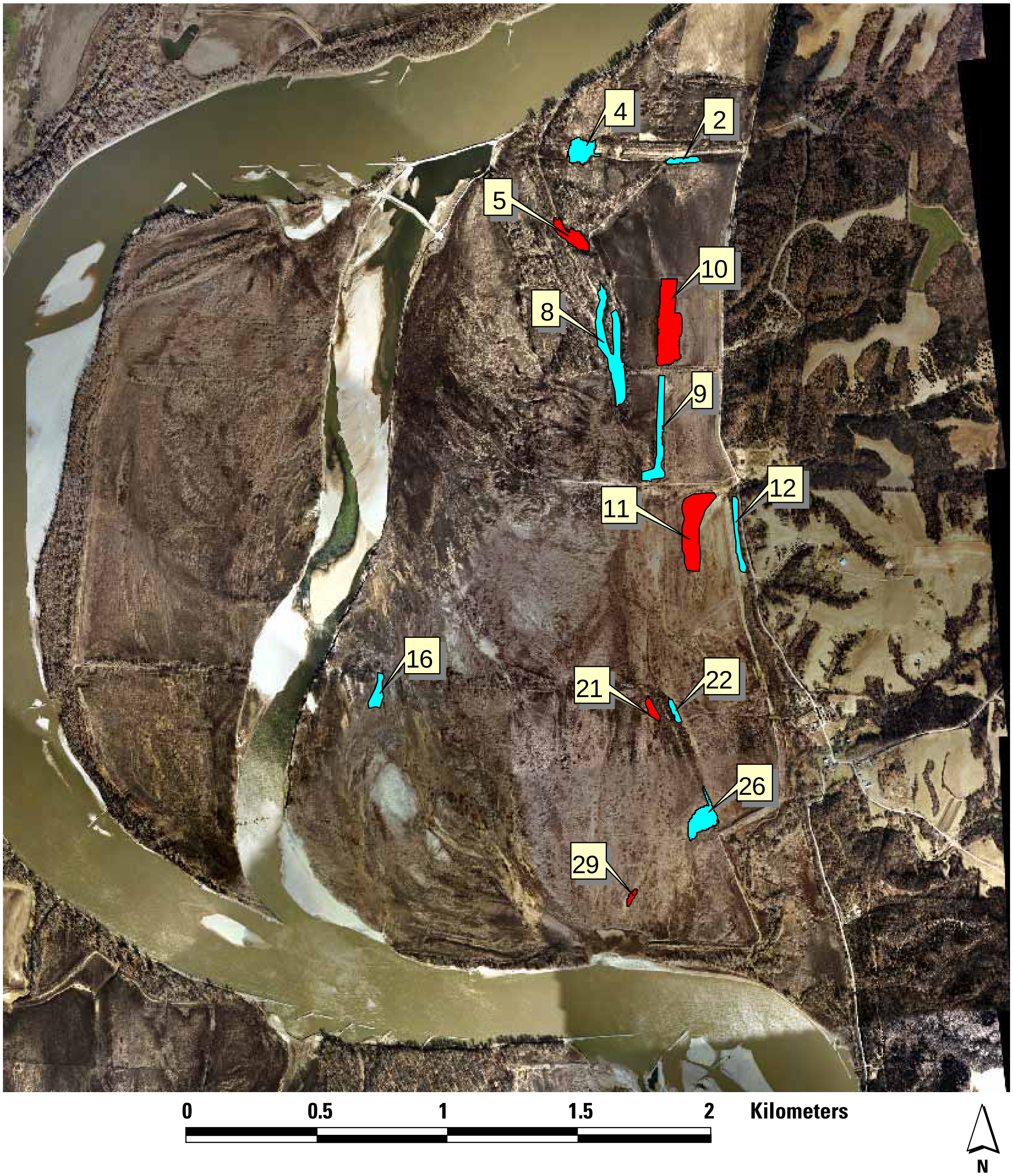
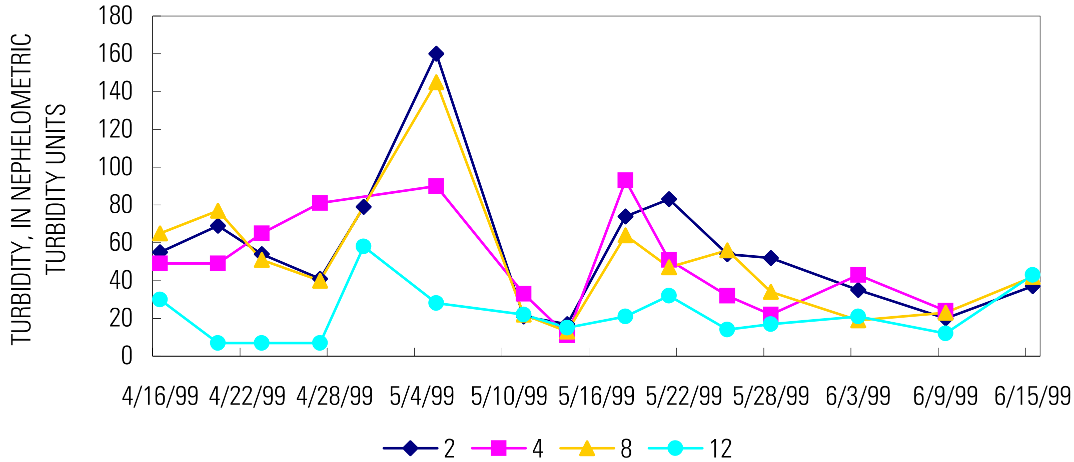


Figure 3-1. Lisbon Bottom wetlands in which zooplankton were sampled. Wetlands were sampled weekly; those illustrated in blue were sampled from April 15, 1999 through June 15, 1999; wetlands in red were sampled only during the fathead minnow growth study (May 27, 1999 through June 16, 1999). *Background photo courtesy of U.S. Army Corps of Engineers, Kansas City, MO, March 2000.*



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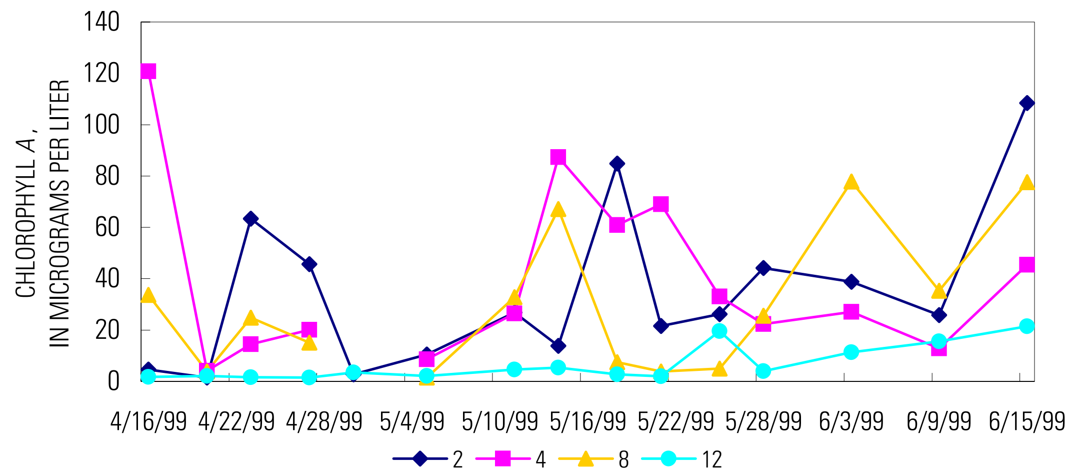

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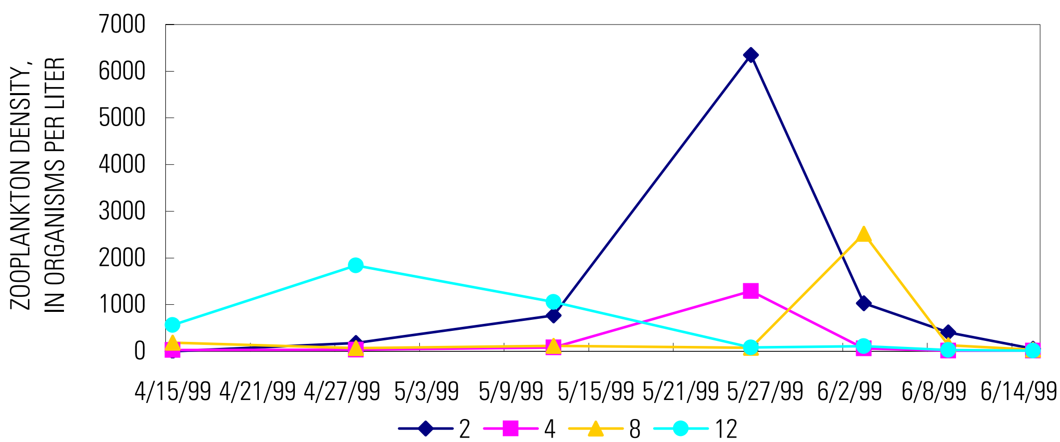

C

Figure 3-2. Turbidity (A), chlorophyll *a* (B), and zooplankton density (C) in Lisbon Bottom wetlands. Wetlands 2, 4, and 8 were flooded by the river between 4/16 and 5/7/99, whereas Wetland 12 was protected from flooding by a levee.

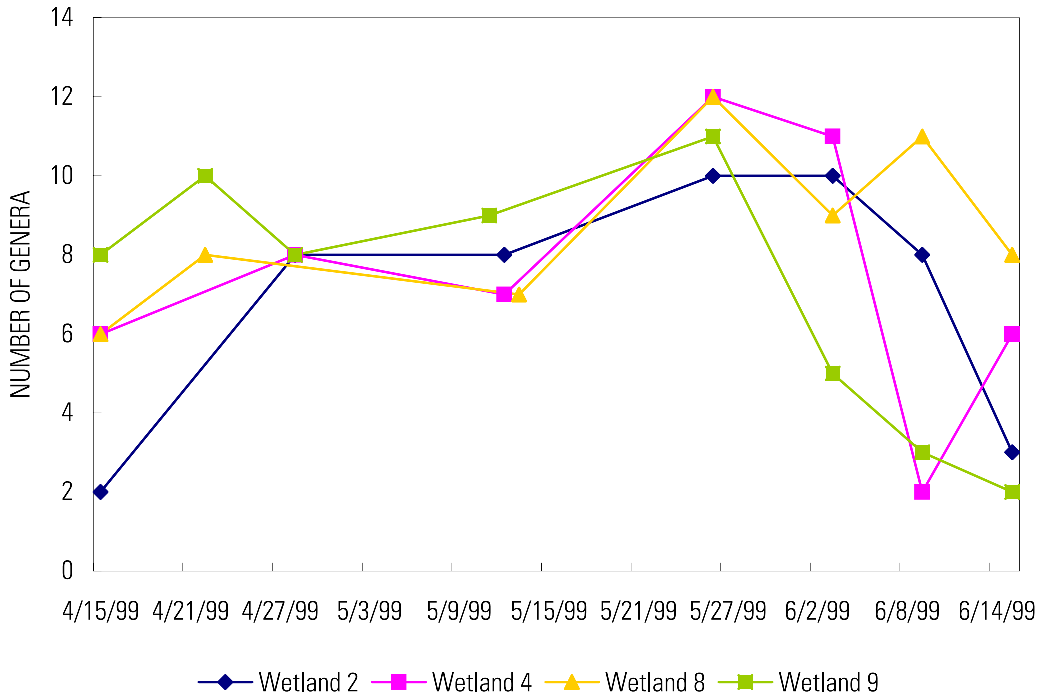

Figure 3-3. Number of crustacean zooplankton genera in topflooding wetlands of Lisbon Bottom.

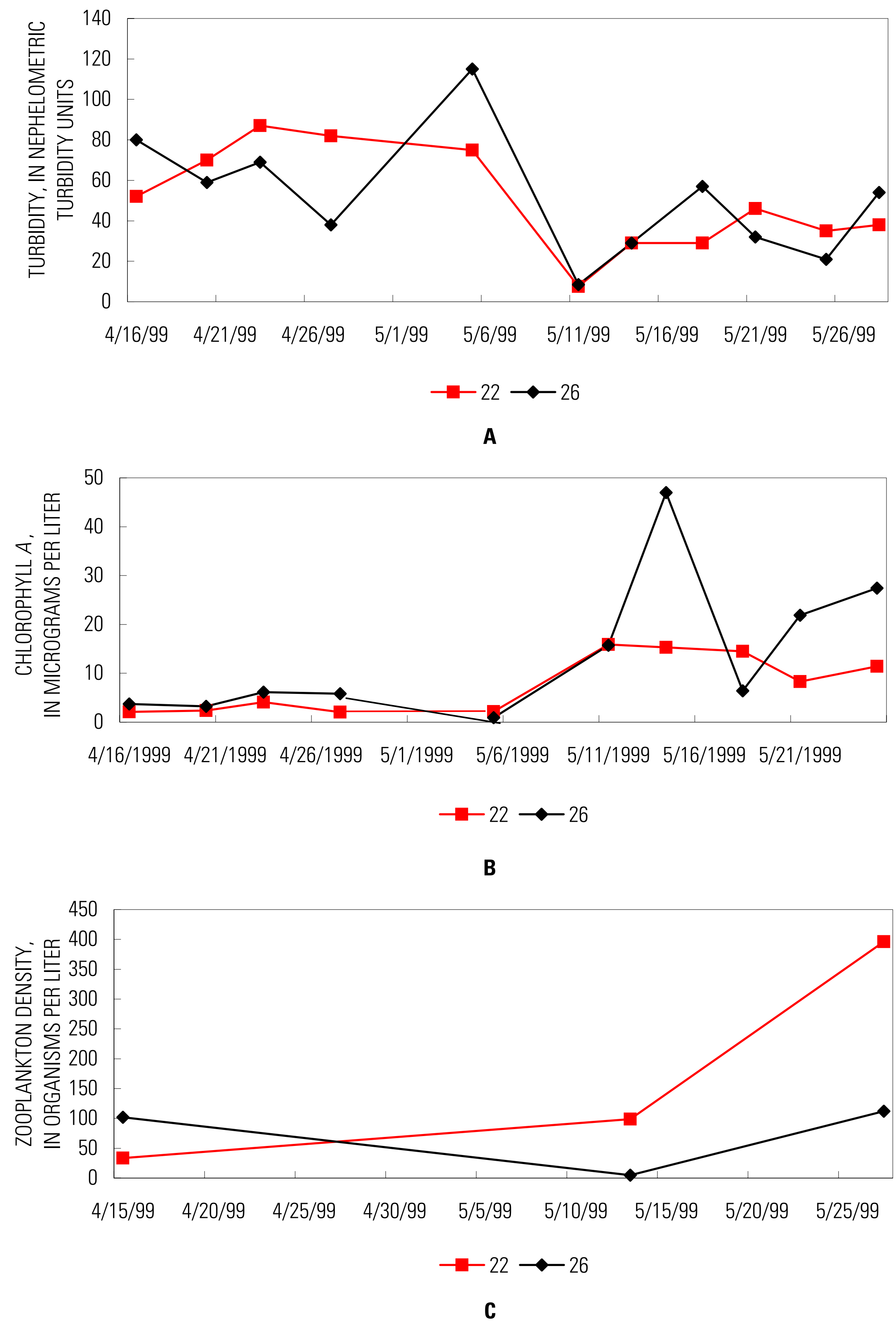

Figure 3-4. Turbidity (A), chlorophyll *a* (B), and zooplankton density (C) in two Lisbon Bottom wetlands. Wetland 26 is a large scour, often connected to the river by backflooding. Wetland 22 is connected to the river through Wetland 26 at higher water levels.

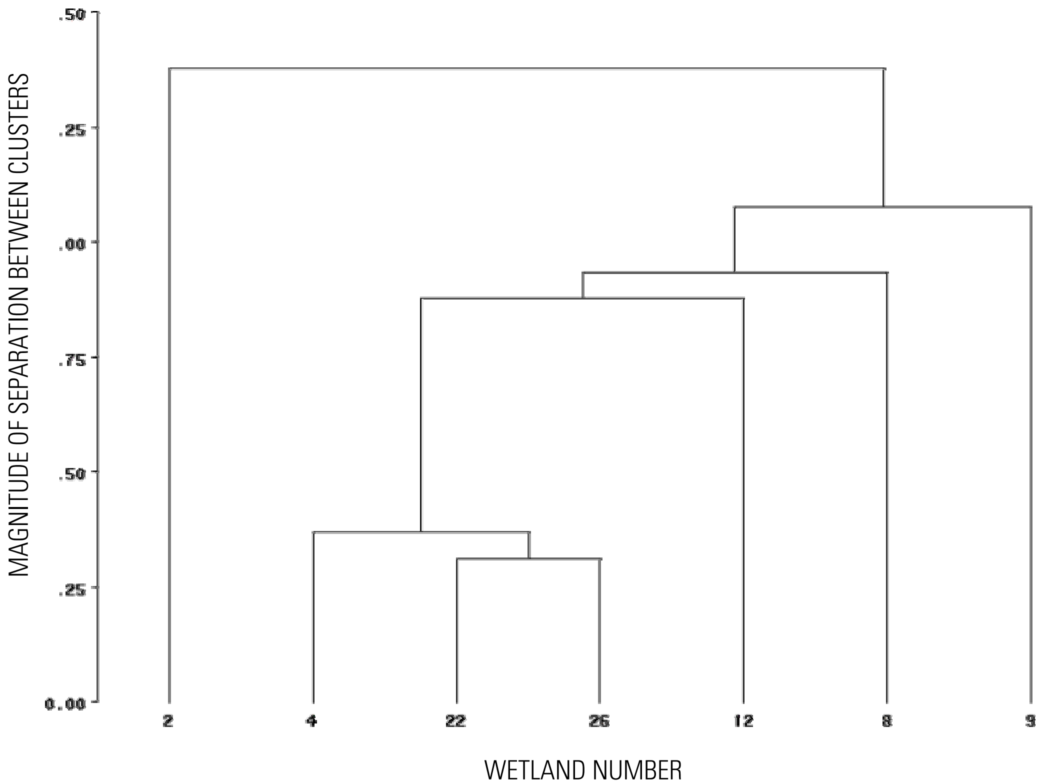

Figure 3-5. Ward's minimum variance cluster analysis of Lisbon Bottom wetlands by zooplankton genera assemblages, 4/16/99 to 6/16/99. Only wetlands that were sampled for the entire two-month period are included in this analysis.

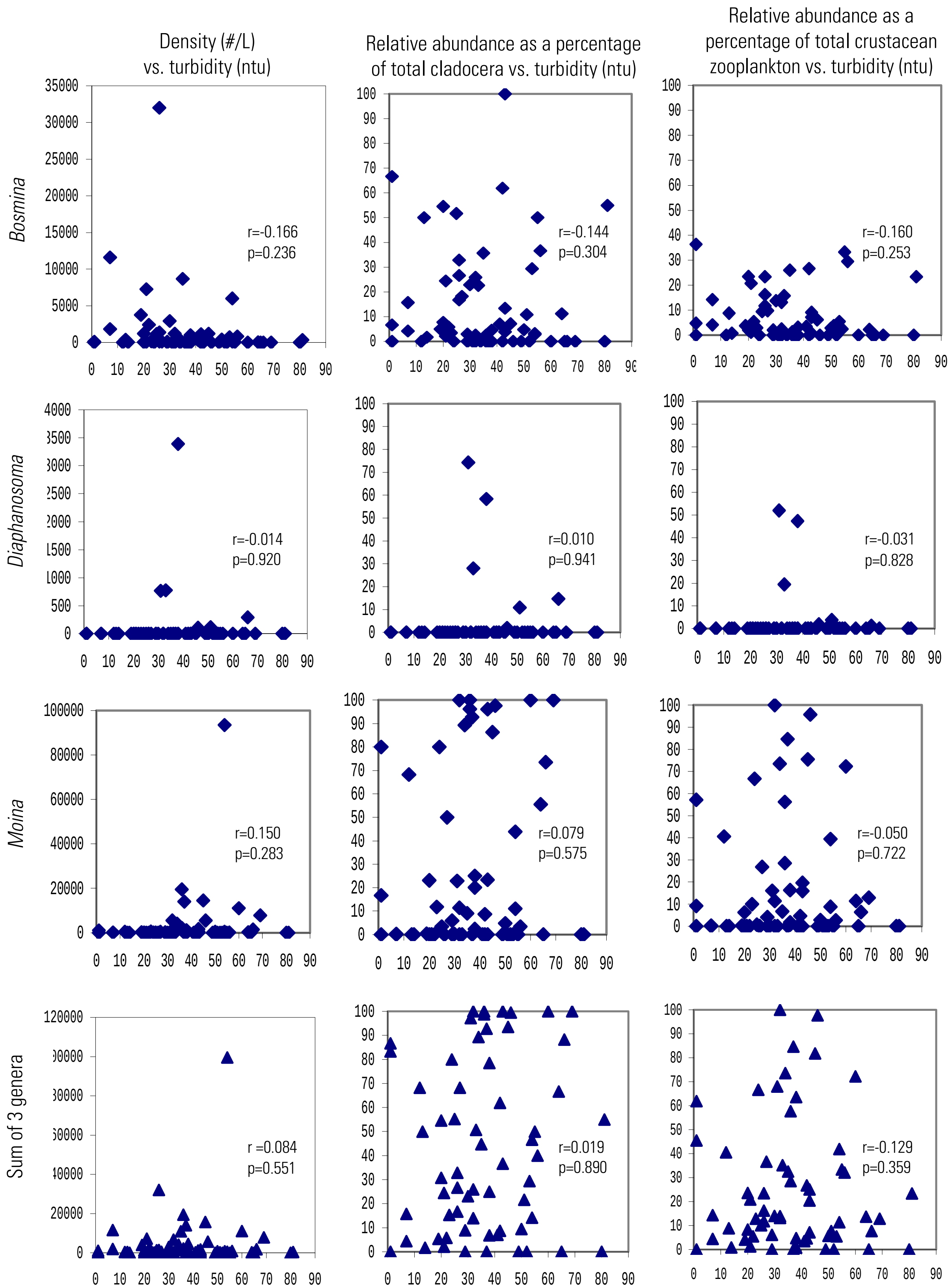

Figure 3-6. Scatterplots of density and relative abundances of three cladoceran genera that are reported to be adapted to high turbidity (Soeken, 1998) and are found in the Missouri River. Each data point represents a single sample. Samples were taken from a variety of wetland types at Lisbon Bottom, Missouri, between 4/16/99 and 6/16/99.