Neosho Madtom and Other Ictalurid Populations in Relation to Hydrologic Characteristics of an Impounded Midwestern Warmwater Stream: Update

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Conversion Factors

Multiply	By	To obtain
Length		
inch (in.)	2.54	centimeter (cm)
centimeter (cm)	0.3937	inch (in.)
inch (in.)	25.4	millimeter (mm)
millimeter (mm)	0.03937	inch (in.)
foot (ft)	0.3048	meter (m)
meter (m)	3.281	foot (ft)
mile (mi)	1.609	kilometer (km)
kilometer (km)	0.6214	mile (mi)
Area		
square inch (inch^2)	645.16	square millimeter (mm^2)
square millimeter (mm^2)	0.00155	square inch (inch^2)
square meter (m^2)	10.76	square foot (ft^2)
square foot (ft^2)	0.09290	square meter (m^2)
Volume		
cubic meter (m^3)	35.31	cubic foot (ft^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
Flow rate		
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
centimeter per second (cm/s)	0.3937	inch per second (in/s)
inch per second (in/s)	25.4	centimeter per second (cm/s)
meter per second (m/s)	3.281	foot per second (ft/s)
foot per second (ft/s)	0.3048	meter per second (m/s)

Water year is the 12-month period from October 1 through September 30. The water year is designated by the calendar year in which the water year ends and that includes 9 of the 12 months.

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By Janice L. Bryan[1], Mark L. Wildhaber[1], William B. Leeds[2], and Rima Dey[2]

Abstract

The Neosho madtom, *Noturus placidus,* is a small (less than 75 millimeters in total length) ictalurid that is native to the main stems of the Neosho and Cottonwood Rivers in Kansas and Oklahoma and the Spring River in Kansas and Missouri. The Neosho madtom was federally listed as threatened by the U.S. Fish and Wildlife Service in May 1990. The U.S. Fish and Wildlife Service has been monitoring Neosho madtoms since 1991, and questioned whether or not Neosho madtom densities were affected by other catfish species, reservoirs, and hydrologic characteristics. Using the first 8 years of U.S. Fish and Wildlife Service monitoring data, Wildhaber and others (2000) analyzed whether or not Neosho madtom densities were related to these environmental characteristics. The goal of this report is to update these results with data from 1999 to 2008. The trends of Neosho madtom densities in respect to John Redmond Reservoir and other catfish species remains consistent with the previous report. In both the Neosho and Spring Rivers, Neosho madtoms had a significant positive association with all catfish species. Of those species tested, only in the population of Neosho madtoms were significantly different in density above verses below the John Redmond Reservoir after accounting for the yearly variation. The average density of Neosho madtoms at the streamgage immediately below the reservoir had the second lowest density compared to the other streamgages. The positive associations with Neosho madtoms that remained consistent from the previous report included the 1-, 3-, and 7-day minima discharges and the annual minimum discharge from the previous water year (water year prior to when the fish were sampled) and the 1-, 3-, 7-, and 30-day minima discharges from the current water year (same water year fish were sampled).

Introduction

The Neosho madtom, *Noturus placidus,* (Taylor, 1969) is a small [less than 75 millimeters (mm) in total length] ictalurid that is native to the main stems of the Neosho and Cottonwood Rivers in Kansas and Oklahoma and the Spring River in Kansas and Missouri (Luttrell and others, 1992; Cross and Collins, 1995; Wilkinson and others, 1996). The Neosho madtom was federally listed as threatened by the U.S. Fish and Wildlife Service (USFWS) in May 1990 (U.S. Fish and Wildlife Service, 1991). This species occupies parts of riffles with mean current velocity of 79 centimeters per second (cm/s), mean depth of 0.23 meter (m), and unconsolidated pieces of pebble and gravel substrate, 2 to 64 millimeters (mm) in diameter (Moss, 1983). Neosho madtoms feed at night on larval insects found among the gravel (Cross and Collins, 1995). Based on samples collected throughout the year (day and night), the greatest numbers of Neosho madtoms occur in riffles during daylight hours in late summer and early fall after young-of-year are believed to have been recruited to the population (Moss, 1983; Luttrell and others, 1992; Fuselier and Edds, 1994). Previous research indicates that Neosho madtoms have a life cycle that is annual in nature, with recruitment of young-of-year into adult collection gear about the time the adults begin to disappear from collections (Fuselier and Edds, 1994).

The USFWS has been monitoring Neosho madtoms since 1991. Using the first 8 years of USFWS monitoring data, Wildhaber and others (2000) analyzed whether or not Neosho madtom densities were affected by other catfish species, reservoirs, and hydrologic characteristics. The USFWS requested an update of this report including the years 1999 through 2008. In addition to the USFWS monitoring data, permission was given to use additional data from the Spring River collected by the Missouri Department of Conservation (MDC) as part of that agencies' conservation efforts for Neosho madtoms (Doug Novinger, Missouri Department of Conservation, oral commun., 2009).

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Methods

The following methods are relevant to the data collected by USFWS for this analysis, and specifics are described in Wildhaber and others (2000). Data from the Missouri section of the Spring River after 1995 were collected by MDC using slightly different methods (Doug Novinger, unpub. data, 2007–2008). The main difference between these two datasets are specified in the sections below; however, the methods were similar enough at the gravel-bar level that combining data is appropriate. Because of sampling, chemical, and geographic differences between the Spring River and the Cottonwood/Neosho Rivers, we performed separate analyses for these two systems. A brief summary of relevant methods follows.

Gravel-Bar Sampling

From 1991 to 2008, gravel bars (shoreline collections of pebbles up to 38 mm in diameter that extend out into the river and were believed to provide suitable habitat for Neosho madtoms) were sampled by USFWS for monitoring Neosho madtom populations (U.S. Fish and Wildlife Service, 1991). Generally, the same gravel bars, or those in the same river reaches, were sampled each year. Sampling at all locations occurred during daylight hours between August and October, after Neosho madtom young-of-year recruitment was expected to have occurred.

Before sampling, three to five transects perpendicular to the river channel were equally spaced to span the length of the gravel bar. In most instances, five stations were spaced equally along each transect with a minimum distance of 2 m between adjacent stations. The MDC randomly selected five transects within six equal-length longitudinal sections of the gravel bar perpendicular to the river channel. Five stations along each transect were selected by MDC using a random distance offset (transect length multiplied by one-fifth, multiplied by random proportion). For all sampling, fewer than five stations were established if the river channel was less than 10 m wide or if a station occurred at a depth too great to seine (less than 1.25 m). Transects on a gravel bar were sampled from downstream to upstream. On each transect, stations were sampled from nearest to most distant from the streambank.

At each location, sampling proceeded in the following order to minimize the impacts of samples on each other: fish were collected, then water depth and water velocity measurements were made. The counts of all benthic fishes were recorded, and the fish were released. This study analyzes only captured ictalurid species that included black bullhead, *Amei-urus melas;* blue catfish, *Ictalurus furcatus;* brindled madtom, *N. miurus;* channel catfish, *I. punctatus;* flathead catfish, *Pylodictis olivaris;* freckled madtom, *N. nocturnus;* Neosho madtom; slender madtom, *N. exilis;* stonecat, *N. flavus;* and Tadpole madtom, *N. gyrinus*. Fishes were collected from a 4.5-square meter (m^2) area by disturbing the substrate by kicking, starting 3 m upstream from a stationary seine (3.0-square

millimeter (mm^2) mesh) and proceeding downstream to the seine. The MDC collected fish from a 3.6 m^2 area by disturbing the substrate, starting 2 m upstream from a stationary seine (3.2 mm^2 mesh). For all sampling, water depth and water velocity at 60 percent of water depth was measured.

Hydrologic Data

We obtained U.S Geological Survey (USGS) hydrologic data in the form of daily mean flows from streamgages on the Neosho, Cottonwood, and Spring Rivers. We used hydrologic data from the streamgages recorded during 1990 to 2008 at Americus, Plymouth, Burlington, Iola, and Parsons, Kans., Commerce, Okla., and Waco, Mo., to test relations among Indicators of Hydrologic Alteration (IHA) parameters and Neosho madtom densities (fig. 1).

For the sampling location downstream of the confluence of the Neosho and Cottonwood Rivers and upstream from John Redmond Reservoir (fig. 1), we added hydrologic data together from two streamgages, one near Americus, Kans. on the Neosho River and one near Plymouth, Kans. on the Cottonwood River. The streamgage near Americus is 38.6 kilometers (km) upstream from the mouth of the Cottonwood River. The streamgage near Plymouth is 63.1 km upstream from the confluence with the Neosho River. The Americus and Plymouth streamgages are the nearest ones upstream from John Redmond Reservoir. There are no streamgages between the confluence of the Neosho and Cottonwood Rivers and the reservoir. Because the hydrologic data used consisted of daily means, the data from the Americus and Plymouth streamgages could be considered synchronized; therefore, as a conservative estimate, we summed the hydrologic data from these two streamgages to represent the Neosho River hydrograph above the reservoir and below the confluence streamgage the Neosho and Cottonwood Rivers.

Statistical Analyses

We analyzed the fish population and physical data to assess differences between locations above and below John Redmond Reservoir, as well as differences across years. Arithmetic means were calculated for depth and velocity. We calculated location densities for four categories of fish: Neosho madtoms, channel catfish, stonecats, and all non-Neosho madtom ictalurids combined. The last grouping was established because some species of ictalurids were not collected often enough to allow separate species-level analyses. We calculated fish densities by dividing the total number of Neosho madtoms, all other catfishes combined, channel catfish, and stonecats collected at a given location by the total area sampled by kickseining to arrive at fish density per square meter. Because differences were examined at the gravel-bar scale, we scaled the fish density up to that of the smallest bar sampled, which was 36 m^2; consequently, all fish densities are reported from an area of 36 m^2.
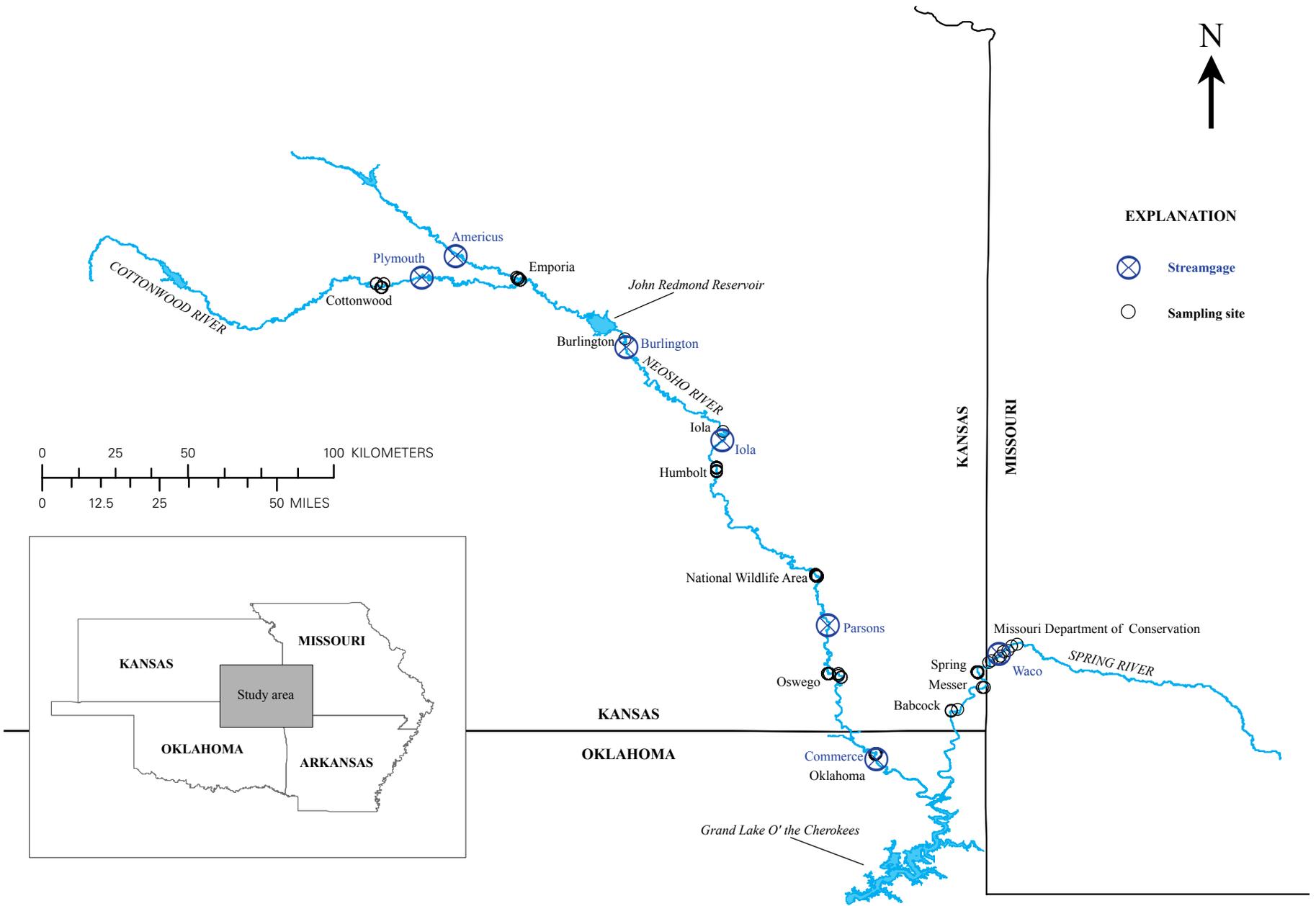
Figure 1. The position of the Neosho madtom sampling locations and U.S. Geological Survey streamgages used in this study. These locations are on the Neosho, Cottonwood, and Spring Rivers in Kansas, Missouri, and Oklahoma.

Mean daily flow data were summarized before analysis using IHA parameter estimates produced with the Indicators of Hydrologic Alteration software, version 7.0.0 (Nature Conservancy, 1996–2006). All IHA parameters were calculated using nonparametric statistics; that is, by assuming the discharge data had a non-normal distribution. IHA nonparametric statistics use the median value except for the 1- to 90-day minima and maxima. We used nonparametric statistics instead of parametric statistics as in Wildhaber and others (2000), because of the non-normal distribution of the hydrologic data. As is standard in the IHA software, the four parameters relating to frequency and duration of high and low pulses were calculated relative to all years (1991–2008).

Because the primary interest in this analysis is whether the John Redmond Reservoir affects catfishes in the Neosho and Cottonwood Rivers, we conducted separate two-way Analyses of Variance (ANOVA) with year and position above or below the reservoir as factors. The ANOVAs were performed on values per sampling location, for fish densities, depth, and velocity. The ability to normalize variables through transformations and equal sample sizes allowed the use of the power and robustness of ANOVA to test for fish densities, depth, and velocity differences among hydrologic parameter mean values relative to the position above or below the reservoir despite the differences in variance that may have existed (Milliken and Johnson, 1984).

Pearson's correlation coefficients were used to assess relations between the densities of Neosho madtoms, all other catfishes combined, channel catfish, stonecats, depth, and velocity. A regression analysis was used to examine the slope of the relation between location-level Neosho madtom density and sampling year.

Separate two-way Analyses of Covariance (ANCOVA) were performed on Neosho madtom densities for each IHA parameter to assess the relations between densities and IHA parameters after adjusting for effects attributable to year and position relative to the reservoir. The above-the-reservoir versus below-the-reservoir association in the ANCOVA models accounted for relations that were the result of upstream to downstream patterns deriving from potentially important factors such as stream size and the presence of the reservoir. The goal of the ANCOVAs was to determine if Neosho madtom population trends were related to IHA parameters independent of the two main factors within the design of the study (that is, year and presence of the reservoir). For the ANCOVAs, we conducted separate analyses using the current (same water year the fish were sampled) and preceding water year (water year prior to when the fish were sampled) from the streamgage closest to the gravel bar sampled. Because there were fewer streamgages than there were gravel bars sampled, we grouped the gravel bars, referred to as locations, by nearest streamgage (that is, Plymouth, Americus, Plymouth and Americus combined, Burlington, Iola, Parsons, Commerce, or Waco; fig. 1). Using this grouped structure, the Neosho madtom location densities in each year were averaged by streamgage structure before any ANCOVAs were conducted. These averaged values

are referred to as streamgage-level averages. Because there is only one streamgage on the Spring River, the analysis of that streamgage-level was simplified to a simple linear regression of IHA verses year. The associations between streamgage-level Neosho madtom density averages and IHA parameters were examined using Pearson correlation coefficients.

Because of the annual nature of the life cycle of the Neosho madtom, it is possible to compare density relations with IHA parameters in the current and preceding water years to assess whether or not population trends were the result of survival to reproductive age (or reproductive success) and/or survival of young-of-year to recruitment to the population, respectively. To confirm this assumption, we tested whether the yearly density of Neosho madtoms were independent by calculating the Durbin-Watson statistic for any ANOVA that did not have year as a discrete factor, and the Hoeffding dependence coefficient for all Pearson correlation coefficient analyses. These statistics were only calculated for tests where the number of observations was greater than five.

All statistical tests were conducted using SAS software version 9.1.3 (SAS, 2004). Means were checked for normality and tested for homogeneity of variance by using a Levene's test. Most non-normal variables were $\log_{10}+1$ transformed. All relations for which $P \le 0.05$ were considered significant.

Results

Neosho Madtom Monitoring

During the 16 years of data collection, most of the monitoring locations have remained in similar areas (fig. 1). The number of locations sampled above and below John Redmond Reservoir were similar but varied somewhat owing to high-water conditions, shifting gravel bars, and budget and time constraints (table 1). In 1993, sampling was not possible because of extreme flooding. For this analysis, 195 locations were used (Cottonwood River, 20; Neosho River, 93; Spring River, 34; Spring River by MDC, 48). An additional 9 locations were sampled using non-standard procedures and they were not used in this analysis (table 1, Neosho River, 8; Spring River, 1). Two locations did not have depth and velocity data recorded, consequently 193 locations were used in the habitat analyses.

Species Associations

In the Cottonwood and Neosho Rivers, Neosho madtoms had a significant, positive association with all catfish species (table 2). The only difference between Neosho madtom density in the Cottonwood/Neosho and Spring Rivers was that Neosho madtom density had a significant positive association with velocity in the Cottonwood/Neosho Rivers and not in the Spring River. The Hoeffding coefficient, which measures independence, ranged from -0.01 to 0.05. This range is not close

Table 1. Summary of the yearly mean value for Neosho madtom density per 36 square meters at each location and respective hydrologic streamgage used in this study.

[Locations are ordered downstream, top to bottom. --, location was not sampled; a, standard protocol was not used and data were not included in analysis; NWA, National Wildlife Area; MDC, Missouri Department of Conservation]

River	Site	Location	Streamgage	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Mean value
								Upstream from John Redmond Reservoir														
Cottonwood	Cottonwood	1	Plymouth	9.7	8.6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	9.2
		2	Plymouth	8.8	10.7	--	1.4	--	1.3	4.0	6.3	3.1	0.7	--	--	--	1.4	--	--	--	--	4.2
		3	Plymouth	19.3	25.9	--	21.3	--	1.3	7.0	13.0	16.7	7.0	--	--	--	3.1	--	--	--	--	12.7
Neosho	Emporia	1	Americus	0	2.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.2
		2	Americus	4.6	14.0	--	24.9	7.5	5.3	0	2.5	0	--	--	--	--	--	--	--	--	--	7.4
		3	Americus	6.4	.3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3.4
		4	Plymouth/Americus	--	--	--	72.7	19.8	2.9	20.9	45.7	--	--	--	--	--	--	--	--	--	--	32.4
								Downstream from John Redmond Reservoir														
Neosho	Burlington	1	Burlington	--	--	--	0.6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.6
	Iola	1	Iola	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	a	7.4	7.4
	Humbolt	1	Iola	4.9	40.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	22.4
		2	Iola	2.9	29.1	--	4.5	--	--	--	--	--	0.3	--	--	--	1.6	2.2	--	--	--	6.8
		3	Iola	5.9	38.0	--	3.7	--	--	--	21.1	39.7	5.1	--	--	1.0	6.4	1.3	--	a	22.0	14.4
	NWA	1	Parsons	--	--	--	4.3	14.9	--	4.2	5.8	16.4	5.8	3.8	--	0	4.2	1.0	0	--	11.2	6.0
		2	Parsons	--	--	--	0	1.0	--	.3	4.2	1.3	0	--	--	0	1.3	.3	--	--	--	.9
	Oswego	1	Parsons	2.2	2.7	--	1.3	1.6	--	--	--	--	--	--	--	--	--	--	--	a	--	1.9
		2	Parsons	0	.5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.3
		3	Parsons	0	--	--	.6	1.0	--	.3	.6	0	0	0	1.0	0	.3	0	a	a	--	.3
		4	Parsons	--	--	--	--	--	--	.3	1.7	1.5	--	--	--	--	--	--	--	--	--	1.2
	Oklahoma	1	Commerce	--	--	--	--	--	--	0	--	--	--	--	--	--	--	--	--	--	--	0
		2	Commerce	--	--	--	--	--	--	.4	1.3	1.0	.3	0	a	--	--	--	--	--	--	.6
		3	Commerce	--	--	--	--	--	--	--	1.0	5.1	1.3	0	0	0	1.9	0	a	a	--	1.2
Spring	MDC	20	Waco	--	--	--	1.1	--	--	--	--	--	--	--	--	.7	.7	1.0	0	0.3	3.0	1.0
		30	Waco	--	--	--	4.8	--	--	--	--	--	--	--	--	1.3	0	0	0	0	.7	1.0
		40	Waco	--	--	--	--	--	--	--	--	--	--	--	--	0	0	0	0	0	.3	.1
		50	Waco	--	--	--	--	--	--	--	--	--	--	--	--	2.0	1.7	0	0	0	1.3	.8
		60	Waco	--	--	--	--	--	--	--	--	--	--	--	--	1.3	1.0	1.7	.7	0	3.0	1.3
		70	Waco	--	--	--	--	--	--	--	--	--	--	--	--	1.0	1.7	0	.7	0	1.0	.7
		80	Waco	--	--	--	--	--	--	--	--	--	--	--	--	0	0	0	0	0	0	0
		90	Waco	--	--	--	--	0	--	--	--	--	--	--	--	0	0	.3	0	0	.3	.1
	Spring	1	Waco	--	--	--	.5	5.3	--	0	0	1.7	0	0	0	0	.4	0	0	--	--	.7
		2	Waco	--	--	--	.8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.8
		3	Waco	--	--	--	0	--	--	0	0	0	0	0	.6	0	.3	.3	0	--	--	.1
	Messer	1	Waco	--	--	--	--	1.0	--	--	--	--	--	--	--	--	--	--	--	--	--	1.0
		2	Waco	--	--	--	0	--	--	--	--	--	--	--	--	--	--	--	0	a	--	0
	Babcock	1	Waco	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	--	--	0
		2	Waco	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	0	--	0
		3	Waco	--	--	--	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0

Table 2.   Statistics about the relations between Neosho madtoms, other ictalurids, depth, and velocity. Statistics include: number of locations, mean, standard deviation, Pearson's correlation coefficients and their respective P-values.

[m, meter; m/sec, meter per second; n, number of locations; na, not applicable; <, less than]

	Neosho madtoms	Catfishes other than Neosho madtoms	Channel catfishes	Stonecats	Depth (m)	Velocity (m/sec)
		Cottonwood/Neosho Rivers				
n	113	113	113	113	111	111
Mean	2.7796	9.8713	7.8767	1.0376	1.5676	1.0926
Pearson correlation coefficient	na	.4116	.3754	.3079	-.0559	.2288
Pearson coefficient p-value	na	[a]<.0001	[a]<.0001	[a].0009	.5602	[a].0157
Hoeffding coefficient	na	.05	.03	.03	< -.01	.02
		Spring River				
n	82	82	82	82	82	82
Mean	.3436	3.8207	.9153	.4535	1.1569	1.5417
Pearson correlation coefficient	na	.3990	.2415	.2727	-.0246	.0198
Pearson coefficient p-value	na	[a].0002	[a].0288	[a].0132	.8267	.8600
Hoeffding coefficient	na	.03	< -.01	< -.01	-.01	-.01

[a] Indicates significance at the 0.05 level.

to 1 (the statistic can range from -0.05 to 1); consequently, the data are considered independent and the correlations valid (SAS, 2004).

Reservoir Associations

After 1998, only seven locations were sampled in 3 years upstream from John Redmond Reservoir; consequently, there were only 3 additional years in this analysis since the previous report (Wildhaber and others, 2000). Testing for reservoir associations limited the data to only those years where locations above and below the reservoir were sampled (n = 88). The position of the location above or below the reservoir explained a significant amount of the variation only in the Neosho madtom density after accounting for the yearly variation (table 3). None of the variation in either habitat variable was significantly explained by year or position relative to the reservoir.

Indicators of Hydrologic Alteration Associations

After averaging up to the streamgage level, there were 71 observations available with which to examine the association between hydrology and Neosho madtom density (Cottonwood/Neosho River, 57; Spring River, 14). The streamgage-level densities immediately below the reservoir were the second lowest compared to the other densities (fig. 2). The locations near the Commerce streamgage had the lowest average density of Neosho madtoms and are the farthest downstream in the Neosho River (fig 1).

After removing the variation due to year and reservoir associations, the density of Neosho madtoms in the Cottonwood/Neosho Rivers was positively associated with the average June and October discharge, annual minimum, and 1-, 3-, and 7-day minima from the preceding water year (water year prior to when the fish were sampled; table 4). During the current water year (same water year the fish were sampled), the density of Neosho madtoms was positively associated with low-pulse count, 1-day maximum, and 1-, 3-, 7-, and 30-day minima. The range of the Durbin-Watson statistics for these 62 tests was 2.43 to 2.93, with a mean of 2.67. This would indicate independence of the observations for each test because they are close to 2 (range of statistic is 0 to 4; SAS, 2004).

After removing the variation due to year and reservoir associations, the density of Neosho madtoms in the Spring River was positively associated with the previous water year's average May and September discharge, and 7-day maximum (table 4). During the current water year, the density of Neosho madtoms was positively associated with average October and May discharge and rise rate. The range of the Durbin-Watson statistics for these 62 tests was 1.52 to 2.32, with a mean of 1.90. This would indicate independence of the observations for each test because they are close to 2 (range of statistic is 0 to 4; SAS, 2004).

Site-Level Trends

The most years sampled at one location was 12, which occurred at three different locations (table 1). Neosho

Table 3.   Two-way analysis of variance using Type III sums of squares and the associated p-value, and F statistics for evaluating the variation in fish density and habitat variables due to year, position of the location relative to the John Redmond Reservoir, and their interaction.

[Back-transformed mean values for the two locations also are summarized by species group and habitat variable. m², square meter; m, meter; m/sec, meter per second; F, F-distribution]

Variable		Density (fish per 36 m²)				Depth (m)	Velocity (m/sec)
		Neosho madtoms	Catfishes other than Neosho madtoms	Channel catfishes	Stonecats		
Type III sums of squares P-value (F)							
Year	[a]8	0.1342	[b]0.0113	[b]0.0057	0.3195	0.4778	0.1696
		(1.62)	(2.72)	(3.02)	(1.19)	(.96)	(1.51)
Location	[a]1	[b].0043	.2977	.2495	.4324	.1878	.9026
		(8.69)	(1.1)	(1.35)	(.62)	(1.77)	(.02)
Year/location interaction	[a]8	.2492	[b].0200	[b].0176	.4108	.4281	.9330
		(1.32)	(2.48)	(2.53)	(1.05)	(1.02)	(.37)
Means							
Cottonwood and Neosho River sites above John Redmond Reservoir	[c]33	6.39	13.97	10.95	1.61	0.38	0.33
Neosho River sites below John Redmond Reservoir	[c]55	2.30	9.12	7.06	1.05	.42	.32

[a] Indicates the degrees of freedom.

[b] Indicates significance at the 0.05 level.

[c] Indicates the number of observations.
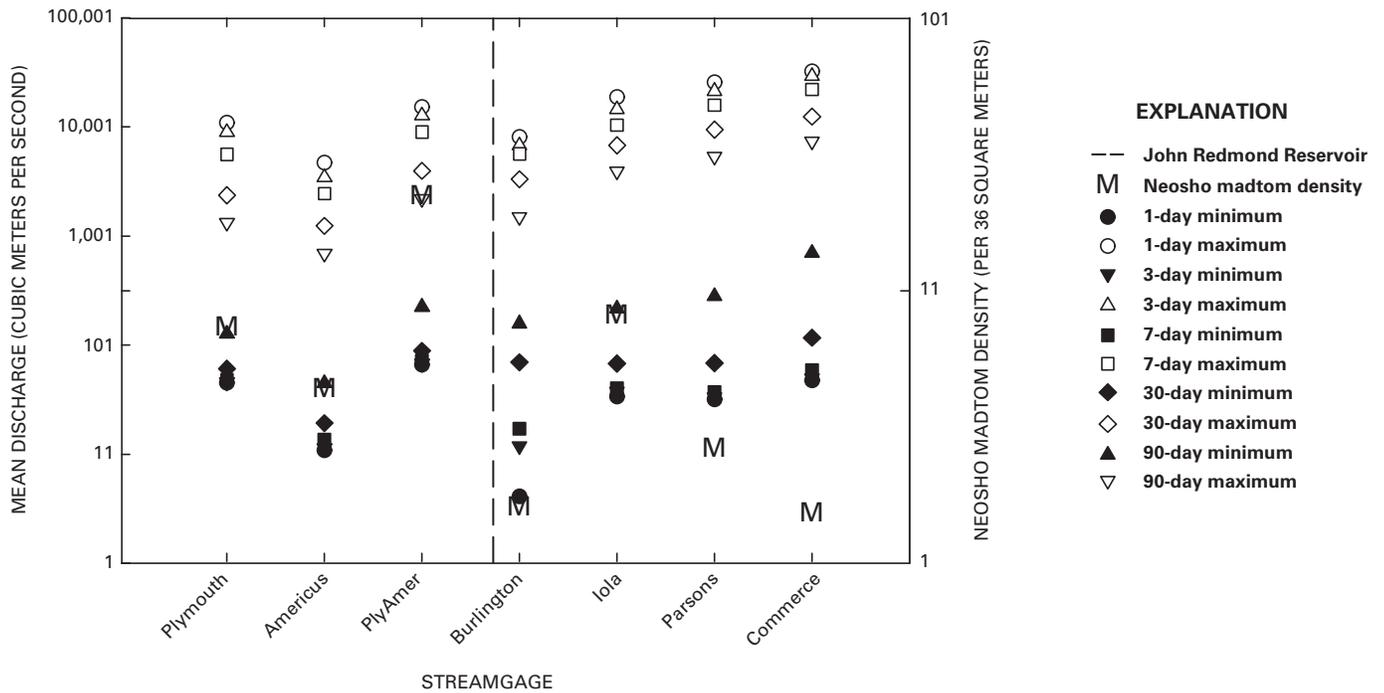

Figure 2.   The pattern of the Indicators of Hydrologic Alteration parameters and Neosho madtom density at the U.S. Geological Survey streamgages on the Cottonwood/Neosho Rivers. The streamgages are ordered downstream, left to right; the dashed line indicates the location of the John Redmond Reservoir; and the letter 'M' indicates streamgage-level Neosho madtom density.

Table 4.   Coefficients and P-values from the two-way analysis of covariance of Neosho madtom densities and Indicators of Hydrologic Alteration parameters, summarized by river, preceding water year (water year prior to when the fish were sampled), and current water year (same year the fish were sampled). Neosho madtom densities were grouped and averaged for each year by the nearest U.S. Geological Survey streamgage.

[The transformation in parentheses was performed on the indicated variables. n, number of observations; m³/sec, cubic meter per second; $\log_{10}$, logarithm with base 10; <, less than]

	Cottonwood/Neosho Rivers (n = 57)		Spring River (n = 14)	
	Coefficient from preceding water year (P-value)	Coefficient from current water year (P-value)	Coefficient from preceding water year (P-value)	Coefficient from current water year (P-value)
Monthly discharge (m³/sec)				
October ($\log_{10}$ + 1)	0.5577 [a](0.0198)	0.6013 [b](0.0511)	0.0736 (0.5048)	0.1974 [a](0.0494)
November ($\log_{10}$ + 1)	.4671 [b](.0534)	.1131 (.7109)	.0238 (.7514)	.0965 (.1991)
December ($\log_{10}$ + 1)	.3485 (.1849)	.1817 (.5037)	.0790 (.4031)	.1052 (.3236)
January ($\log_{10}$ + 1)	.4062 (.1111)	.3281 (.2597)	.0828 (.3706)	.0991 (.3267)
Feburary ($\log_{10}$ + 1)	.3656 (.1373)	.3262 (.2531)	.0945 (.3042)	.0772 (.4139)
March ($\log_{10}$ + 1)	.3250 (.2105)	.3116 (.2691)	.1106 (.2329)	.0512 (.6375)
April ($\log_{10}$ + 1)	.6418 [b](.0688)	.4934 (.1250)	.1967 [a](.0395)	.1884 [a](.0500)
May ($\log_{10}$ + 1)	.3424 (.3040)	.5135 (.1139)	.2062 (.1289)	.2830 [a](.0021)
June ($\log_{10}$ + 1)	.5124 [a](.0411)	.3424 (.1589)	.1870 (.1557)	.1823 [b](.0838)
July ($\log_{10}$ + 1)	.3849 (.1042)	.4524 [b](.0840)	.1016 (.3624)	.1143 (.3335)
August ($\log_{10}$ + 1)	.3697 (.1566)	.3773 (.1531)	.1982 (.1556)	.1453 (.3175)
September ($\log_{10}$ + 1)	.2769 (.2694)	.3367 (.1552)	.2874 [a](.0129)	.1205 (.4052)
Magnitude and duration of annual extremes (m³/sec)				
1-day minimum ($\log_{10}$ + 1)	0.4680 [a](0.0226)	0.6223 [a](0.0031)	0.1489 (0.3677)	0.2263 (0.2015)
1-day maximum ($\log_{10}$ + 1)	.2436 (.4517)	.6170 [a](.0379)	.1720 [b](.0660)	.1093 (.3111)
3-day minimum ($\log_{10}$ + 1)	.6003 [a](.0089)	.7527 [a](.0011)	.1521 (.3704)	.2392 (.1868)
3-day maximum ($\log_{10}$ + 1)	.0818 (.7794)	.4721 [b](.0923)	.1695 [b](.0670)	.1185 (.2615)
7-day minimum ($\log_{10}$ + 1)	.5997 [a](.0118)	.7819 [a](.0011)	.1630 (.3507)	.2570 (.1675)
7-day maximum ($\log_{10}$ + 1)	-.0004 (.9988)	.3975 (.1647)	.1954 [a](.0469)	.1204 (.2925)
30-day minimum ($\log_{10}$ + 1)	.4015 [b](.0992)	.6930 [a](.0097)	.1689 (.3542)	.2949 (.1307)
30-day maximum ($\log_{10}$ + 1)	.2467 (.4856)	.5732 [b](.0922)	.2120 [b](.0645)	.1653 (.1537)
90-day minimum ($\log_{10}$ + 1)	.2178 (.3796)	.1858 (.4925)	.0611 (.5661)	.1626 (.1732)
90-day maximum ($\log_{10}$ + 1)	.3063 (.3969)	.5472 (.1127)	.2266 [b](.0799)	.2084 [b](.0803)
Timing of annual extremes (day of the year)				
Annual minimum	0.0063 [a](0.0082)	<0.0001 (0.9929)	-0.0012 (0.4965)	0.0005 (0.7659)
Annual maximum	.0028 (.1322)	.0011 (.5412)	.0001 (.8209)	.0006 (.3741)
Rate and frequency of change in conditions				
Fall rate (m³/sec, $\log_{10}$ + 1)	0.1916 (0.5946)	0.3962 (0.2262)	0.1668 (0.1228)	0.1656 (0.2185)
Rise rate (m³/sec, $\log_{10}$ + 1)	-.0171 (.9486)	.1116 (.6738)	.1010 (.1576)	.1396 [a](.0453)
Number of reversals between rising and falling discharges	.0076 (.1895)	-.0018 (.8101)	-.0057 (.2948)	-.0027 (.6241)
Frequency and duration of low and high pulses				
Low-pulse length in days ($\log_{10}$ + 1)	-0.4880 [b](0.0548)	-0.3639 (0.1185)	-0.1161 (0.1642)	0.0943 (0.3379)
Low-pulse count ($\log_{10}$ + 1)	-.5490 (.2904)	-.9032 [a](.0344)	-.2126 (.3268)	-.3745 (.1835)
High-pulse length in days	.0144 (.6447)	-.0366 (.3477)	.0371 [b](.0599)	.0483 (.1655)
High-pulse count	-.0408 (.3156)	.0044 (.9074)	.0079 (.4762)	-.0028 (.8099)

[a] Indicates significance at the 0.05 level.

[b] Indicates significance at the 0.10 level.

madtoms never were detected in five locations on the Spring River. The greatest density of Neosho madtoms at one sampling location was 32.4 per 36 m^2 from Emporia, Kans., location number 4 (table 1). Sampling locations in all three rivers indicated a decrease in Neosho madtom density from 1991 to 2006, with a slight increase in density occurring in 2008 (table 1). After averaging up to the site level, all sites had a negative slope over the years, although this trend was significant at only the Oswego site on the Neosho River (table 5). The range of the Durbin-Watson statistics for these nine tests was 1.89 to 2.72. This would indicate independence of the observations for each test because they are close to 2 (range of statistic is 0 to 4; SAS, 2004).

After averaging the sampling locations up to the site level (mean IHA parameters are given in the appendix;

Cottonwood/Neosho Rivers, 66 total observations from 7 sites; Spring River, 23 total observations from 3 sites), there were many negative associations between average Neosho madtom densities and the IHA parameters, but only 30 of 620 comparisons were statistically significant (tables 6–8). The Hoeffding coefficient for the Cottonwood/Neosho River sites ranged from -0.16 to 0.40, with a mean of -0.01, and -0.18 to 0.18 with a mean of -0.04, for the current and previous water years analysis, respectively. For the Spring River sites, it ranged from -0.13 to 0.33, with a mean of -0.0003 and -0.20 to 0.39, with a mean of -0.02 for the current and previous water years analysis, respectively. These ranges are not close to 1 (the statistic can range from -0.05 to 1), consequently the data are considered independent and the correlations valid (SAS, 2004).

Table 5. Slope of regression analysis and the P-value of the Durbin-Watson T-statistic for each site.

[--, not enough data to perform analysis; NWA, National Wildlife Area; MDC, Missouri Department of Conservation; *, due to no variation in density, no P-value can be calculated]

River	Site	Total years	Slope	P-value	Durbin-Watson T-statistic
Cottonwood	Cottonwood	9	-0.0447	[a]0.0782	1.90
Neosho	Emporia	8	-.0972	.1337	1.86
	Emporia location 4	5	-.0375	.8455	1.60
	Burlington	1	--	--	--
	Iola	1	--	--	--
	Humbolt	10	-.0182	.5528	2.08
	NWA	12	-.0222	.3884	2.17
	Oswego	13	-.0231	[b].0095	2.69
	Oklahoma	9	-.0232	.4764	1.92
Spring	MDC	8	-.0124	.4195	2.41
	Spring	12	-.0281	.1187	2.72
	Messer	3	-.0121	.7191	2.64
	Babcock	3	0	*	*

[a] Indicates significance at the 0.10 level.

[b] Indicates significance at the 0.05 level.

Table 6. Site-level Pearson's correlation coefficients of Neosho madtom densities with the Indicators of Hydrologic Alteration parameters for the Cottonwood, Emporia, and Humbolt sites. Pearson's correlation coefficients and P-values are summarized for each site.

[The transformation in parentheses was performed on the indicated variables. n, number of years; m^3/sec, cubic meter per second; $\log_{10}$, logarithm with base 10]

Parameter	Cottonwood (n = 9)				Emporia (n = 8)			
	Coefficient from preceding water year (P-value)		Coefficient from current water year (P-value)		Coefficient from preceding water year (P-value)		Coefficient from current water year (P-value)	
Monthly discharge (m^3/sec)								
October ($\log_{10}$ + 1)	0.2353	(0.5422)	-0.2348	(0.543)	-0.0793	(0.8519)	-0.5727	(0.1379)
November ($\log_{10}$ + 1)	.2496	(.5172)	-.0959	(.8061)	.3211	(.4381)	-.7887	[a](.0200)
December ($\log_{10}$ + 1)	.2536	(.5103)	-.1786	(.6456)	.2191	(.6022)	-.5883	(.1250)
January ($\log_{10}$ + 1)	.3776	(.3164)	-.0429	(.9127)	.1906	(.6511)	-.4848	(.2234)
Feburary ($\log_{10}$ + 1)	.3492	(.3570)	-.0459	(.9066)	.2501	(.5503)	-.6619	[b](.0738)
March ($\log_{10}$ + 1)	.2472	(.5213)	-.1649	(.6716)	.1858	(.6596)	-.4089	(.3145)
April ($\log_{10}$ + 1)	.0321	(.9346)	.1750	(.6524)	.5265	(.1801)	-.5470	(.1606)
May ($\log_{10}$ + 1)	-.4547	(.2188)	-.0653	(.8674)	.4316	(.2856)	-.1637	(.6985)
June ($\log_{10}$ + 1)	-.4371	(.2394)	-.3105	(.4162)	.3680	(.3698)	-.0555	(.8961)
July ($\log_{10}$ + 1)	.0249	(.9494)	-.0719	(.8541)	.3499	(.3956)	.0046	(.9913)
August ($\log_{10}$ + 1)	-.1594	(.6821)	-.3031	(.4279)	.2652	(.5256)	.0663	(.8761)
September ($\log_{10}$ + 1)	-.5758	(.1047)	-.5149	(.1560)	.3376	(.4135)	.1739	(.6805)
Magnitude and duration of annual extremes (m^3/sec)								
1-day minimum ($\log_{10}$ + 1)	0.2467	(0.5222)	-0.4971	(0.1733)	0.0998	(0.8141)	-0.4669	(0.2435)
1-day maximum ($\log_{10}$ + 1)	-.3410	(.3691)	-.0482	(.9021)	.0923	(.8279)	-.4967	(.2105)
3-day minimum ($\log_{10}$ + 1)	.2159	(.5768)	-.4954	(.1750)	.1731	(.6819)	-.4613	(.2499)
3-day maximum ($\log_{10}$ + 1)	-.3860	(.3048)	-.1207	(.7570)	.1257	(.7668)	-.4442	(.2701)
7-day minimum ($\log_{10}$ + 1)	.2296	(.5524)	-.4822	(.1886)	.2650	(.5260)	-.6161	(.1038)
7-day maximum ($\log_{10}$ + 1)	-.4400	(.2359)	-.0769	(.8442)	.1157	(.7850)	-.3173	(.4437)
30-day minimum ($\log_{10}$ + 1)	.2650	(.4908)	-.4765	(.1947)	.0856	(.8403)	-.4457	(.2684)
30-day maximum ($\log_{10}$ + 1)	-.4557	(.2176)	-.0961	(.8058)	.2009	(.6333)	-.2721	(.5144)
90-day minimum ($\log_{10}$ + 1)	.3722	(.3239)	-.1887	(.6268)	.2744	(.5108)	-.5447	(.1627)
90-day maximum ($\log_{10}$ + 1)	-.3232	(.3963)	-.0847	(.8285)	.2918	(.4831)	-.3544	(.3890)
Timing of annual extremes (day of the year)								
Annual minimum	-0.0246	(0.9499)	0.5883	[b](0.0956)	0.5828	(0.1295)	-0.0546	(0.8979)
Annual maximum	-.2884	(.4517)	.1618	(.6775)	.6478	[b](.0824)	-.3459	(.4013)
Rate and frequency of change in conditions								
Fall rate (m^3/sec, $\log_{10}$ + 1)	0.0178	(0.9637)	0.1234	(0.7517)	0.4554	(0.2568)	-0.7069	[a](0.0499)
Rise rate (m^3/sec, $\log_{10}$ + 1)	.1751	(.6523)	.0857	(.8264)	.3860	(.3450)	-.5901	(.1236)
Number of reversals between rising and falling discharges	.0801	(.8377)	.1060	(.7861)	.3873	(.3431)	-.3679	(.3699)
Frequency and duration of low and high pulses								
Low-pulse length in days ($\log_{10}$ + 1)	-0.3184	(0.4037)	0.1909	(0.6227)	-0.1730	(0.6820)	0.3674	(0.3706)
Low-pulse count ($\log_{10}$ + 1)	.0950	(.8078)	.1101	(.7780)	-.3980	(.3289)	.6639	[b](.0726)
High-pulse length in days	.3916	(.2972)	-.6976	[a](.0367)	.5016	(.2054)	-.5893	(.1242)
High-pulse count	-.1113	(.7756)	.0524	(.8935)	-.4574	(.2545)	-.3997	(.3266)

Table 6. Site-level Pearson's correlation coefficients of Neosho madtom densities with the Indicators of Hydrologic Alteration parameters for the Cottonwood, Emporia, and Humbolt sites. Pearson's correlation coefficients and P-values are summarized for each site.—Continued

[The transformation in parentheses was performed on the indicated variables. n, number of years; m³/sec, cubic meter per second; $\log_{10}$, logarithm with base 10]

Parameter	Emporia location 4 (n = 5)				Humbolt (n = 10)			
	Coefficient from preceding water year (P-value)		Coefficient from current water year (P-value)		Coefficient from preceding water year (P-value)		Coefficient from current water year (P-value)	
Monthly discharge (m³/sec)								
October ($\log_{10}$ + 1)	0.7058	(0.1829)	0.3477	(0.5664)	-0.1798	(0.6191)	0.2982	(0.4026)
November ($\log_{10}$ + 1)	.9378	[a](.0185)	.2088	(.7361)	-.2212	(.5391)	.2892	(.4177)
December ($\log_{10}$ + 1)	.8946	[a](.0404)	.4316	(.4681)	.0121	(.9736)	.2784	(.4361)
January ($\log_{10}$ + 1)	.8689	[b](.0559)	.4582	(.4377)	.1817	(.6154)	.2780	(.4368)
Feburary ($\log_{10}$ + 1)	.8183	[b](.0904)	.4696	(.4249)	-.0899	(.8050)	.2930	(.4112)
March ($\log_{10}$ + 1)	.3098	(.6120)	.4964	(.3949)	-.0795	(.8271)	.3267	(.3568)
April ($\log_{10}$ + 1)	.5188	(.3704)	.6958	(.1920)	.0821	(.8217)	.5407	(.1065)
May ($\log_{10}$ + 1)	-.1935	(.7552)	-.0197	(.9750)	-.2356	(.5123)	.1776	(.6235)
June ($\log_{10}$ + 1)	-.4232	(.4777)	-.3469	(.5673)	-.5139	(.1287)	.1103	(.7615)
July ($\log_{10}$ + 1)	.4250	(.4757)	.3713	(.5384)	-.0505	(.8898)	.5261	(.1183)
August ($\log_{10}$ + 1)	.3215	(.5978)	-.7844	(.1162)	.1130	(.7559)	.5627	[b](.0904)
September ($\log_{10}$ + 1)	.2741	(.6554)	-.9307	[a](.0217)	-.0855	(.8144)	-.0972	(.7893)
Magnitude and duration of annual extremes (m³/sec)								
1-day minimum ($\log_{10}$ + 1)	0.8417	[b](0.0738)	-0.1729	(0.7810)	0.1526	(0.6738)	-0.0486	(0.8939)
1-day maximum ($\log_{10}$ + 1)	.1922	(.7569)	-.5232	(.3656)	-.0788	(.8287)	.3663	(.2978)
3-day minimum ($\log_{10}$ + 1)	.8419	[b](.0736)	-.1743	(.7792)	.2369	(.5099)	-.0466	(.8982)
3-day maximum ($\log_{10}$ + 1)	.1830	(.7683)	-.3819	(.5258)	-.1671	(.6446)	.2859	(.4233)
7-day minimum ($\log_{10}$ + 1)	.8350	[b](.0784)	-.1866	(.7637)	.3084	(.3859)	-.0386	(.9156)
7-day maximum ($\log_{10}$ + 1)	.0219	(.9722)	-.2510	(.6838)	-.2738	(.4440)	.2087	(.5628)
30-day minimum ($\log_{10}$ + 1)	.8696	[b](.0554)	-.1366	(.8266)	.1710	(.6367)	.1017	(.7798)
30-day maximum ($\log_{10}$ + 1)	-.1447	(.8164)	-.2338	(.7050)	-.3376	(.3401)	.3584	(.3092)
90-day minimum ($\log_{10}$ + 1)	.8551	[b](.0648)	.4091	(.4941)	-.0225	(.9508)	.4067	(.2435)
90-day maximum ($\log_{10}$ + 1)	.0086	(.9891)	-.1732	(.7806)	-.2959	(.4064)	.4675	(.1730)
Timing of annual extremes (day of the year)								
Annual minimum	-0.0077	(0.9901)	0.2750	(0.6544)	-0.0072	(0.9841)	-0.3540	(0.3156)
Annual maximum	-.2395	(.6980)	-.8643	[b](.0588)	-.2258	(.5306)	.5425	(.1052)
Rate and frequency of change in conditions								
Fall rate (m³/sec, $\log_{10}$ + 1)	0.5178	(0.3715)	0.4174	(0.4844)	-0.0755	(0.8358)	0.4759	(0.1644)
Rise rate (m³/sec, $\log_{10}$ + 1)	.7153	(.1744)	.3512	(.5622)	-.1413	(.6970)	.4712	(.1692)
Number of reversals between rising and falling discharges	-.0529	(.9326)	-.2115	(.7328)	-.2637	(.4616)	.2761	(.4401)
Frequency and duration of low and high pulses								
Low-pulse length in days ($\log_{10}$ + 1)	-0.9123	[a](0.0308)	0.0780	(0.9007)	-0.3148	(0.3756)	-0.1677	(0.6433)
Low-pulse count ($\log_{10}$ + 1)	-.3147	(.6060)	-.3843	(.5230)	-.3222	(.3638)	-.1831	(.6126)
High-pulse length in days	.1458	(.8151)	-.7757	(.1231)	-.4318	(.2128)	.3477	(.3249)
High-pulse count	.3295	(.5882)	.0893	(.8864)	.3451	(.3287)	.3064	(.3892)

[a] Indicates significance at the 0.05 level.

[b] Indicates significance at the 0.10 level.

Table 7. Site-level Pearson's correlation coefficients of Neosho madtom densities with the Indicators of Hydrologic Alteration parameters for the National Wildlife Area, Oswego, and Oklahoma sites. Pearson's correlation coefficients and P-values are summarized for each site.

[The transformation in parentheses was performed on the indicated variables. NWA, National Wildlife Area; n, number of years; m³/sec, cubic meter per second; $\log_{10}$, logarithm with base 10]

Parameter	NWA (n = 12)		Oswego (n = 13)	
	Coefficient from preceding water year (P-value)	Coefficient from current water year (P-value)	Coefficient from preceding water year (P-value)	Coefficient from current water year (P-value)
Monthly discharge (m³/sec)				
October ($\log_{10}$ + 1)	0.1669 (0.6041)	0.3155 (0.3178)	-0.0961 (0.7549)	0.1250 (0.6840)
November ($\log_{10}$ + 1)	-.1020 (.7524)	.2432 (.4463)	.0480 (.8764)	.1321 (.6671)
December ($\log_{10}$ + 1)	.1582 (.6234)	.3047 (.3356)	-.0285 (.9263)	.0822 (.7895)
January ($\log_{10}$ + 1)	-.0069 (.9829)	.4291 (.1640)	.1418 (.6440)	-.0171 (.9558)
Feburary ($\log_{10}$ + 1)	-.0899 (.7811)	.4128 (.1823)	.0414 (.8932)	-.2616 (.3880)
March ($\log_{10}$ + 1)	.1410 (.6620)	.5464 [a](.0661)	-.0353 (.9089)	-.3256 (.2777)
April ($\log_{10}$ + 1)	.4502 (.1420)	.7013 [b](.0110)	.1045 (.7341)	.0551 (.8580)
May ($\log_{10}$ + 1)	.0382 (.9063)	.1784 (.5791)	.0208 (.9461)	.2956 (.3268)
June ($\log_{10}$ + 1)	-.5364 [a](.0722)	.4670 (.1259)	-.3340 (.2646)	-.1697 (.5794)
July ($\log_{10}$ + 1)	-.0811 (.8022)	.5993 [b](.0394)	-.1400 (.6482)	.2818 (.3509)
August ($\log_{10}$ + 1)	.1784 (.5791)	.7045 [b](.0105)	.1903 (.5335)	.3711 (.2118)
September ($\log_{10}$ + 1)	-.1223 (.7049)	.0525 (.8714)	.0873 (.7768)	-.3763 (.2050)
Magnitude and duration of annual extremes (m³/sec)				
1-day minimum ($\log_{10}$ + 1)	0.0625 (0.8471)	0.0694 (0.8303)	0.1696 (0.5796)	-0.1705 (0.5777)
1-day maximum ($\log_{10}$ + 1)	.3523 (.2614)	.5750 [a](.0505)	.0412 (.8936)	.4580 (.1155)
3-day minimum ($\log_{10}$ + 1)	.0558 (.8632)	.0604 (.8520)	.1562 (.6104)	-.1598 (.6019)
3-day maximum ($\log_{10}$ + 1)	.2307 (.4706)	.5093 [a](.0908)	.0225 (.9418)	.4192 (.1540)
7-day minimum ($\log_{10}$ + 1)	.0071 (.9824)	.0531 (.8699)	.1245 (.6852)	-.1564 (.6098)
7-day maximum ($\log_{10}$ + 1)	.1894 (.5555)	.4432 (.1490)	-.0610 (.8430)	.4007 (.1748)
30-day minimum ($\log_{10}$ + 1)	-.0256 (.9370)	-.0004 (.9990)	.2205 (.4692)	-.1321 (.6671)
30-day maximum ($\log_{10}$ + 1)	.0775 (.8108)	.4682 (.1247)	-.1178 (.7015)	.3630 (.2229)
90-day minimum ($\log_{10}$ + 1)	-.0714 (.8256)	.3204 (.3099)	.0452 (.8833)	.1087 (.7237)
90-day maximum ($\log_{10}$ + 1)	.0584 (.8568)	.6036 (.0377)	-.1325 (.6662)	.3653 (.2197)
Timing of annual extremes (day of the year)				
Annual minimum	-0.2186 (0.4950)	0.2335 (0.4651)	0.0207 (0.9465)	-0.0224 (0.9422)
Annual maximum	.1661 (.6059)	.2874 (.3651)	-.2388 (.4321)	.2462 (.4174)
Rate and frequency of change in conditions				
Fall rate (m³/sec, $\log_{10}$ + 1)	0.1156 (0.7206)	0.6522 [b](0.0215)	0.0125 (0.9677)	0.0131 (0.9661)
Rise rate (m³/sec, $\log_{10}$ + 1)	.2018 (.5294)	.7677 [b](.0035)	.1217 (.6921)	.2017 (.5088)
Number of reversals between rising and falling discharges	.0811 (.8022)	.3559 (.2562)	.1913 (.5312)	-.1316 (.6681)
Frequency and duration of low and high pulses				
Low-pulse length in days ($\log_{10}$ + 1)	0.0092 (0.9774)	-0.3973 (0.2009)	0.1219 (0.6916)	-0.0997 (0.7459)
Low-pulse count ($\log_{10}$ + 1)	-.2327 (.4668)	-.2954 (.3513)	-.5302 [a](.0623)	-.2243 (.4613)
High-pulse length in days	-.4434 (.1488)	-.1131 (.7264)	-.2605 (.3901)	.2015 (.5092)
High-pulse count	.1967 (.5401)	.5700 [a](.0530)	-.0236 (.9390)	-.2792 (.3556)

Table 7.   Site-level Pearson's correlation coefficients of Neosho madtom densities with the Indicators of Hydrologic Alteration parameters for the National Wildlife Area, Oswego, and Oklahoma sites. Pearson's correlation coefficients and P-values are summarized for each site.—Continued

[The transformation in parentheses was performed on the indicated variables. NWA, National Wildlife Area; n, number of years; m³/sec, cubic meter per second; $\log_{10}$, logarithm with base 10]

Parameter	Oklahoma (n = 9)			
	Coefficient from preceding water year (P-value)		Coefficient from current water year (P-value)	
Monthly discharge (m³/sec)				
October ($\log_{10} + 1$)	0.3558	(0.3474)	0.7573	[b](0.0181)
November ($\log_{10} + 1$)	.3148	(.4093)	.3872	(.3032)
December ($\log_{10} + 1$)	.3319	(.3830)	.7004	[b](.0356)
January ($\log_{10} + 1$)	.4124	(.2700)	.5110	(.1598)
Feburary ($\log_{10} + 1$)	-.0077	(.9843)	.3724	(.3236)
March ($\log_{10} + 1$)	.1679	(.6658)	.4406	(.2352)
April ($\log_{10} + 1$)	.4593	(.2136)	.6214	[a](.0740)
May ($\log_{10} + 1$)	.3435	(.3654)	.2111	(.5855)
June ($\log_{10} + 1$)	-.7271	[b](.0264)	.1131	(.7721)
July ($\log_{10} + 1$)	.0681	(.8618)	.4909	(.1796)
August ($\log_{10} + 1$)	.1763	(.6501)	.2881	(.4522)
September ($\log_{10} + 1$)	.6136	[a](.0788)	-.4338	(.2434)
Magnitude and duration of annual extremes (m³/sec)				
1-day minimum ($\log_{10} + 1$)	0.4485	(0.2260)	0.2484	(0.5192)
1-day maximum ($\log_{10} + 1$)	-.1401	(.7191)	.5372	(.1358)
3-day minimum ($\log_{10} + 1$)	.4359	(.2408)	.2583	(.5023)
3-day maximum ($\log_{10} + 1$)	-.1320	(.7349)	.4638	(.2086)
7-day minimum ($\log_{10} + 1$)	.3800	(.3131)	.2510	(.5147)
7-day maximum ($\log_{10} + 1$)	.0003	(.9993)	.5007	(.1697)
30-day minimum ($\log_{10} + 1$)	.4466	(.2281)	.2144	(.5795)
30-day maximum ($\log_{10} + 1$)	.0529	(.8925)	.4059	(.2784)
90-day minimum ($\log_{10} + 1$)	.3080	(.4201)	.4958	(.1746)
90-day maximum ($\log_{10} + 1$)	.1555	(.6895)	.4974	(.1731)
Timing of annual extremes (day of the year)				
Annual minimum	-0.6112	[a](0.0803)	-0.1079	(0.7822)
Annual maximum	.0268	(.9454)	.5692	(.1097)
Rate and frequency of change in conditions				
Fall rate (m³/sec, $\log_{10} + 1$)	0.2555	(0.5070)	0.5565	(0.1196)
Rise rate (m³/sec, $\log_{10} + 1$)	.2907	(.4479)	.5837	[a](.0989)
Number of reversals between rising and falling discharges	.6618	[a](.0522)	.2424	(.5298)
Frequency and duration of low and high pulses				
Low-pulse length in days ($\log_{10} + 1$)	0.0786	(0.8407)	-0.3857	(0.3052)
Low-pulse count ($\log_{10} + 1$)	-.8172	[b](.0072)	-.0424	(.9137)
High-pulse length in days	.1237	(.7512)	.6024	[a](.0860)
High-pulse count	.2312	(.5494)	.1350	(.7291)

[a] Indicates significance at the 0.10 level.

[b] Indicates significance at the 0.05 level.

Table 8. Site-level Pearson's correlation coefficients of Neosho madtom densities with the Indicators of Hydrologic Alteration parameters for the Spring River sites. Pearson's correlation coefficients and P-values are summarized for each site.

[The transformation in parentheses was performed on the indicated variables. MDC, Missouri Department of Conservation; n, number of years; m^3/sec, cubic meter per second; $\log_{10}$, logarithm with base 10]

Parameter	MDC (n = 8)		Spring (n = 12)	
	Coefficient from preceding water year (P-value)	Coefficient from current water year (P-value)	Coefficient from preceding water year (P-value)	Coefficient from current water year (P-value)
Monthly discharge (m^3/sec)				
October ($\log_{10} + 1$)	-0.0289 (0.9459)	0.6696 [a](0.0693)	0.4370 (0.1555)	0.4297 (0.1632)
November ($\log_{10} + 1$)	.1844 (.6620)	.1181 (.7807)	.1652 (.6079)	.4973 [b](.0100)
December ($\log_{10} + 1$)	.2471 (.5552)	.3217 (.4371)	.2007 (.5317)	.3028 (.3388)
January ($\log_{10} + 1$)	.3623 (.3778)	-.0448 (.9161)	.0799 (.8050)	.4492 (.1429)
Feburary ($\log_{10} + 1$)	.3899 (.3397)	.1407 (.7396)	.0550 (.8651)	.2949 (.3521)
March ($\log_{10} + 1$)	.4363 (.2798)	.4432 (.2714)	.2176 (.4970)	.0798 (.8052)
April ($\log_{10} + 1$)	.4284 (.2896)	.4303 (.2872)	.4218 (.1720)	.3920 (.2076)
May ($\log_{10} + 1$)	.4520 (.2609)	-.0785 (.8535)	.1373 (.6706)	.8137 [b](.0013)
June ($\log_{10} + 1$)	.8240 [b](.0119)	-.0584 (.8907)	-.0087 (.9785)	.7390 [b](.0060)
July ($\log_{10} + 1$)	.7483 [b](.0327)	-.0176 (.9671)	-.0860 (.7905)	.4300 (.1630)
August ($\log_{10} + 1$)	.6814 [a](.0627)	-.0559 (.8953)	.0600 (.8530)	.5556 [a](.0607)
September ($\log_{10} + 1$)	.8069 [b](.0155)	.1210 (.7754)	.3116 (.3242)	.3560 (.2561)
Magnitude and duration of annual extremes (m^3/sec)				
1-day minimum ($\log_{10} + 1$)	0.4903 (0.2174)	0.4054 (0.3191)	0.2661 (0.4032)	0.4401 (0.1522)
1-day maximum ($\log_{10} + 1$)	.5319 (.1748)	.1904 (.6516)	.2742 (.3885)	.4422 (.1500)
3-day minimum ($\log_{10} + 1$)	.4874 (.2206)	.4119 (.3106)	.2686 (.3987)	.4474 (.1447)
3-day maximum ($\log_{10} + 1$)	.5136 (.1929)	.1634 (.6990)	.2734 (.3899)	.4794 (.1148)
7-day minimum ($\log_{10} + 1$)	.4672 (.2432)	.4462 (.2678)	.2914 (.3581)	.4446 (.1476)
7-day maximum ($\log_{10} + 1$)	.5138 (.1928)	.1845 (.6618)	.3017 (.3405)	.4560 (.1363)
30-day minimum ($\log_{10} + 1$)	.4751 (.2341)	.4446 (.2697)	.3219 (.3075)	.4867 (.1086)
30-day maximum ($\log_{10} + 1$)	.4718 (.2379)	.1601 (.7049)	.2894 (.3616)	.5505 [a](.0636)
90-day minimum ($\log_{10} + 1$)	.5812 (.1308)	.3571 (.3852)	.1101 (.7335)	.4118 (.1835)
90-day maximum ($\log_{10} + 1$)	.4492 (.2642)	.1313 (.7566)	.2496 (.4339)	.6079 [b](.0360)
Timing of annual extremes (day of the year)				
Annual minimum	0.6124 (0.1065)	-0.0831 (0.8449)	-0.4004 (0.1972)	0.1031 (0.7498)
Annual maximum	.8109 [b](.0146)	-.2668 (.5230)	-.0837 (.7960)	.3415 (.2773)
Rate and frequency of change in conditions				
Fall rate (m^3/sec, $\log_{10} + 1$)	0.6420 [a](0.0861)	0.1283 (0.7621)	0.1310 (0.6849)	0.4232 (0.1705)
Rise rate (m^3/sec, $\log_{10} + 1$)	.6418 [a](.0862)	.2036 (.6288)	.2067 (.5191)	.6129 [b](.0341)
Number of reversals between rising and falling discharges	.3231 (.4350)	-.5113 (.1953)	-.4644 (.1282)	-.2322 (.4676)
Frequency and duration of low and high pulses				
Low-pulse length in days ($\log_{10} + 1$)	-0.6853 [a](0.0607)	-0.4290 (0.2889)	-0.2614 (0.4118)	0.3668 (0.2408)
Low-pulse count ($\log_{10} + 1$)	-.9645 [b](.0001)	.4977 (.2094)	.1664 (.6053)	-.6704 [b](.0170)
High-pulse length in days	.6703 [a](.0689)	.4429 (.2718)	.2835 (.3718)	.3063 (.3328)
High-pulse count	.4456 (.2686)	.1255 (.7671)	-.0312 (.9233)	-.0255 (.9373)

Table 8.   Site-level Pearson's correlation coefficients of Neosho madtom densities with the Indicators of Hydrologic Alteration parameters for the Spring River sites. Pearson's correlation coefficients and P-values are summarized for each site.—Continued

[The transformation in parentheses was performed on the indicated variables. MDC, Missouri Department of Conservation; n, number of years; m³/sec, cubic meter per second; $\log_{10}$, logarithm with base 10]

Parameter	Messer (n = 3)			
	Coefficient from preceding water year (P-value)		Coefficient from current water year (P-value)	
Monthly discharge (m³/sec)				
October ($\log_{10}$ + 1)	0.8731	(0.3242)	-0.0194	(0.9877)
November ($\log_{10}$ + 1)	.2514	(.8382)	.3931	(.7428)
December ($\log_{10}$ + 1)	-.4904	(.6737)	-.8956	(.2934)
January ($\log_{10}$ + 1)	-.8635	(.3365)	.2128	(.8635)
Feburary ($\log_{10}$ + 1)	-.7494	(.4607)	-.2502	(.8390)
March ($\log_{10}$ + 1)	-.7558	(.4545)	-.6476	(.5515)
April ($\log_{10}$ + 1)	.3695	(.7590)	-.0195	(.9876)
May ($\log_{10}$ + 1)	-.2497	(.8393)	.9123	(.2687)
June ($\log_{10}$ + 1)	-.6615	(.5398)	.9322	(.2359)
July ($\log_{10}$ + 1)	-.9583	(.1846)	.8492	(.3542)
August ($\log_{10}$ + 1)	-.8891	(.3026)	.9055	(.2790)
September ($\log_{10}$ + 1)	-.4692	(.6891)	.4052	(.7344)
Magnitude and duration of annual extremes (m³/sec)				
1-day minimum ($\log_{10}$ + 1)	0.0284	(0.9819)	0.5231	(0.6495)
1-day maximum ($\log_{10}$ + 1)	.0677	(.9569)	-.1869	(.8803)
3-day minimum ($\log_{10}$ + 1)	.0353	(.9775)	.5280	(.6459)
3-day maximum ($\log_{10}$ + 1)	.0556	(.9646)	.0453	(.9712)
7-day minimum ($\log_{10}$ + 1)	.0984	(.9373)	.4810	(.6806)
7-day maximum ($\log_{10}$ + 1)	.1354	(.9136)	-.0265	(.9831)
30-day minimum ($\log_{10}$ + 1)	.0979	(.9376)	.5958	(.5937)
30-day maximum ($\log_{10}$ + 1)	.2988	(.8068)	.5901	(.5981)
90-day minimum ($\log_{10}$ + 1)	-.6799	(.5241)	.6920	(.5135)
90-day maximum ($\log_{10}$ + 1)	.1134	(.9277)	.9712	(.1531)
Timing of annual extremes (day of the year)				
Annual minimum	-0.9974	[b](0.0455)	0.9200	(0.2563)
Annual maximum	-.3406	(.7787)	.7907	(.4194)
Rate and frequency of change in conditions				
Fall rate (m³/sec, $\log_{10}$ + 1)	-0.7547	(0.4556)	0.9966	[a](0.0529)
Rise rate (m³/sec, $\log_{10}$ + 1)	-.5069	(.6616)	.8935	(.2965)
Number of reversals between rising and falling discharges	-.9762	(.1391)	-.2250	(.8555)
Frequency and duration of low and high pulses				
Low-pulse length in days ($\log_{10}$ + 1)	0.3389	(0.7799)	0.8523	(0.3504)
Low-pulse count ($\log_{10}$ + 1)	.7442	(.4656)	-1.0000	[b](<.0001)
High-pulse length in days	-.1628	(.8959)	-.8660	(.3333)
High-pulse count	-.8660	(.3333)	-1.0000	[b](<.0001)

[a] Indicates significance at the 0.10 level.

[b] Indicates significance at the 0.05 level.

Summary

At the locations monitored by the U.S. Fish and Wildlife Service, the density of Neosho madtoms has steadily declined until 2008; however, the associations of Neosho madtom densities with respect to the John Redmond Reservoir and other catfish species remains consistent with Wildhaber and others (2000). In the Neosho and Spring Rivers, Neosho madtoms had a significant positive association with all catfish species. The position of the site relative to the reservoir explained a significant amount of the variation only in the Neosho madtom density after accounting for the yearly variation. The average density of Neosho madtoms at the streamgage immediately below the reservoir had the second lowest compared to the other streamgages. The positive IHA associations with Neosho madtoms that remained consistent from the previous report of Wildhaber and others (2000) included the 1-, 3-, and 7-day minima and the annual minimum from the previous water year and the 1-, 3-, 7-, and 30-day minima from the current water year.

Acknowledgments

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Appendix

Table 1. Yearly median Indicators of Hydrologic Alteration parameters averaged over the years for the Cottonwood/Neosho River sites.

[n, number of years; NWA, National Wildlife Area; m³/sec, cubic meter per second]

Parameter	Emporia (n = 8)		Emporia location 4 (n = 5)		Humbolt (n = 10)	
	Preceeding water year	Current water year	Preceeding water year	Current water year	Preceeding water year	Current water year
Monthly discharge (m³/sec)						
October	32.19	54.14	168.17	201.08	198.01	173.93
November	60.98	77.13	364.26	245.30	285.21	181.56
December	57.84	54.53	324.26	275.93	312.40	276.48
January	45.43	46.13	249.34	226.48	295.08	431.50
Feburary	46.40	48.60	258.97	210.00	430.84	544.07
March	95.14	80.80	410.22	402.31	720.35	1,108.55
April	158.97	153.63	552.93	462.08	1,304.06	1,235.75
May	458.39	332.61	1,964.64	1,470.06	3,006.31	1,892.89
June	170.56	175.87	1,072.30	824.91	2,891.64	1,562.53
July	75.64	91.08	639.19	389.21	891.71	1,000.69
August	63.77	55.10	417.65	280.90	347.46	321.36
September	35.14	28.43	232.36	163.93	145.74	300.44
Magnitude and duration of annual extremes (m³/sec)						
1-day minimum	8.43	9.90	70.01	64.90	31.69	32.89
1-day maximum	4,734.31	4,687.96	19,558.14	15,158.95	19,564.61	18,691.73
3-day minimum	10.27	10.39	72.12	66.70	35.25	36.47
3-day maximum	3,370.96	3,427.49	16,358.28	12,628.94	14,395.82	14,417.32
7-day minimum	12.07	12.59	77.86	71.30	38.81	39.37
7-day maximum	2,429.74	2,437.07	11,307.25	8,947.87	10,681.09	10,372.45
30-day minimum	17.68	18.30	98.41	87.49	65.86	66.68
30-day maximum	1,200.03	1,236.12	4,885.10	3,938.18	6,984.55	6,755.03
90-day minimum	49.36	43.61	285.28	222.54	239.85	214.30
90-day maximum	684.59	688.61	2,799.13	2,183.48	4,307.81	3,912.84
Timing of annual extremes (day of the year)						
Annual minimum	247.00	249.38	255.00	250.00	292.70	278.50
Annual maximum	137.25	156.50	148.00	137.60	176.30	175.50
Rate and frequency of change in conditions						
Fall rate (m³/sec)	7.63	6.70	30.43	21.70	48.59	49.93
Rise rate (m³/sec)	12.02	11.49	37.45	30.05	75.54	85.34
Number of reversals between rising and falling discharges	108.63	106.50	105.60	100.60	116.50	109.30
Frequency and duration of low and high pulses						
Low-pulse length in days	6.19	5.99	4.45	6.97	4.97	6.65
Low-pulse count	4.44	4.86	2.47	2.47	3.75	3.88
High-pulse length in days	3.94	4.25	5.30	4.90	5.50	4.05
High-pulse count	11.00	10.38	9.20	10.40	10.40	9.70

Table 1. Yearly median Indicators of Hydrologic Alteration parameters averaged over the years for the Cottonwood/Neosho River sites.—Continued

[n, number of years; NWA, National Wildlife Area; m³/sec, cubic meter per second]

Parameter	NWA (n = 12)		Oswego (n = 13)		Oklahoma (n = 9)	
	Preceeding water year	Current water year	Preceeding water year	Current water year	Preceeding water year	Current water year
Monthly discharge (m³/sec)						
October	233.56	217.81	223.03	160.75	290.56	280.36
November	309.94	307.39	237.65	256.89	262.67	427.87
December	629.10	487.99	437.47	390.91	547.26	763.86
January	513.20	496.84	409.71	367.24	462.50	643.90
Feburary	691.66	849.80	610.18	565.43	717.19	1,073.12
March	1,209.07	1,889.49	1,353.92	1,357.08	2,063.01	2,864.93
April	1,663.87	1,924.16	1,292.30	1,368.54	1,458.01	1,991.75
May	3,846.54	3,185.23	2,943.11	2,513.74	3,311.38	3,463.61
June	3,377.17	2,816.26	2,955.25	2,982.97	4,142.43	4,643.51
July	1,407.36	1,191.46	737.97	1,158.14	1,158.88	1,577.99
August	372.97	351.66	259.71	309.59	257.17	305.36
September	356.54	405.30	243.99	264.79	388.70	435.97
Magnitude and duration of annual extremes (m³/sec)						
1-day minimum	39.85	43.22	35.79	31.32	42.54	46.42
1-day maximum	31,598.66	26,697.08	25,837.65	26,367.16	29,354.24	32,309.23
3-day minimum	42.37	45.67	37.53	33.25	44.40	48.60
3-day maximum	25,924.96	22,371.97	21,170.99	21,850.22	26,185.35	29,034.32
7-day minimum	47.90	50.24	42.09	37.26	52.48	57.84
7-day maximum	19,325.74	16,968.41	15,354.16	15,958.28	19,655.98	21,975.09
30-day minimum	92.81	91.37	80.46	72.62	93.69	115.86
30-day maximum	10,687.98	10,134.23	8,842.86	9,713.38	10,828.65	12,387.71
90-day minimum	411.79	369.09	327.01	326.76	460.46	696.13
90-day maximum	6,283.51	5,824.69	5,039.99	5,520.31	6,442.82	7,322.51
Timing of annual extremes (day of the year)						
Annual minimum	280.83	270.08	278.85	277.62	271.22	264.67
Annual maximum	177.25	166.08	163.69	160.54	122.33	105.33
Rate and frequency of change in conditions						
Fall rate (m³/sec)	82.07	82.62	63.04	64.76	82.51	107.81
Rise rate (m³/sec)	151.12	157.57	118.02	130.17	191.18	246.40
Number of reversals between rising and falling discharges	98.42	100.25	98.00	96.00	98.33	97.44
Frequency and duration of low and high pulses						
Low-pulse length in days	8.58	7.56	10.10	7.81	7.11	7.82
Low-pulse count	2.94	2.38	3.31	2.64	4.66	3.90
High-pulse length in days	3.75	4.04	3.58	3.62	4.28	4.39
High-pulse count	11.17	11.25	10.38	10.15	11.44	11.78

Table 2. Yearly median Indicators of Hydrologic Alteration parameters averaged over the years for the Spring River sites.

[Values were back-transformed if transformation was required for the analysis. MDC, Missouri Department of Conservation; n, number of years; m³/sec, cubic meter per second]

Parameter	MDC (n = 8)		Spring (n = 12)		Messer (n = 3)	
	Preceeding water year	Current water year	Preceeding water year	Current water year	Preceeding water year	Current water year
Monthly discharge (m³/sec)						
October	106.74	112.32	153.58	268.88	211.28	147.54
November	226.93	207.64	279.97	1,342.99	466.43	267.82
December	331.27	306.33	374.88	755.67	942.66	332.03
January	337.78	356.49	368.80	869.57	750.81	337.82
Feburary	360.35	389.80	420.95	671.10	631.70	373.91
March	463.37	466.33	659.30	618.43	1,030.28	579.36
April	523.54	641.78	529.29	871.35	1,094.63	485.07
May	873.59	979.88	720.27	1,306.32	1,145.61	757.11
June	531.19	654.00	504.70	573.42	882.21	475.53
July	263.00	262.84	277.35	196.65	590.45	235.95
August	117.26	123.00	121.45	128.31	217.76	110.59
September	140.16	142.91	113.71	106.16	245.24	96.87
Magnitude and duration of annual extremes (m³/sec)						
1-day minimum	44.84	44.07	59.30	66.21	89.97	53.94
1-day maximum	20,325.69	17,735.08	19,728.91	32,748.74	45,174.74	15,465.45
3-day minimum	46.59	45.84	61.19	68.56	91.82	55.85
3-day maximum	15,394.38	13,737.79	14,717.90	27,078.45	34,096.48	11,983.55
7-day minimum	49.98	48.98	65.10	75.24	95.26	59.31
7-day maximum	9,292.88	8,154.82	8,875.81	15,243.65	18,688.64	7,399.98
30-day minimum	63.94	62.64	84.11	98.39	114.78	77.27
30-day maximum	3,622.62	3,671.54	3,696.22	6,530.44	6,222.79	3,236.96
90-day minimum	158.07	152.43	230.57	204.39	537.47	194.57
90-day maximum	1,992.59	2,251.90	1,990.66	3,689.38	3,211.96	1,822.68
Timing of annual extremes (day of the year)						
Annual minimum	269.63	275.75	272.92	259.67	282.33	271.08
Annual maximum	125.75	109.00	125.42	90.67	145.67	117.50
Rate and frequency of change in conditions						
Fall rate (m³/sec)	22.75	21.01	21.71	19.17	47.62	27.04
Rise rate (m³/sec)	52.71	66.85	63.61	116.44	212.20	56.20
Number of reversals between rising and falling discharges	84.25	83.38	81.58	76.67	81.00	81.25
Frequency and duration of low and high pulses						
Low-pulse length in days	16.48	23.70	13.67	33.14	4.34	22.52
Low-pulse count	2.12	2.40	2.67	2.68	1.47	2.97
High-pulse length in days	4.75	4.19	4.21	5.00	6.67	3.63
High-pulse count	10.75	9.63	11.42	9.00	14.00	10.58