Population Increase of *Quadrula metanevra* in Southeast Kansas

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Abstract. While many unionid species have declined markedly in the last century, the monkeyface, *Quadrula metanevra*, has become one of the most abundant in the Neosho, Verdigris, and Fall rivers of southeast Kansas, despite commercial harvest pressure. Comparisons of past surveys with sampling conducted in the 1990s from 48 sites in these streams reveal a substantial surge in the relative abundance of *Q. metanevra* during the past two decades. However, this increase is limited to shallow habitats downstream from three major impoundments located in these streams; in fact, *Q. metanevra* is apparently extirpated upstream from these impoundments. We postulate that *Q. metanevra*'s increase downstream from these impoundments may be related to improved water quality, the increase of two suitable fish hosts (bluegill and green sunfish), and regulated stream flows during droughts. Regulated releases, however, have also degraded habitats due to excessive scouring, thus tempering the apparent benefits. The absence of *Q. metanevra* upstream from these impoundments may be the result of isolation from downstream populations, thus eliminating the possibility for recolonization following mortality from drought and effluence. We are unable to explain the decrease of other unionid species despite their habitat and host similarities to *Q. metanevra*.

Introduction

In the past century, Kansas has experienced reductions and extirpations of unionid mussels, with the presumed extirpation of three species once native to the state: *Ligumia recta* (black sandshell), *Epioblasma triquetra* (snuffbox), and *Obovaria olivaria* (hickorynut) (Murray and Leonard 1962; Cope 1979). For example, *L. recta* was considered abundant in southeast Kansas streams in the early 1900s (Scammon 1906), but is now considered extirpated (Obermeyer et al. 1994). Other species have experienced range reductions as indicated by weathered valves, including *Cyprogenia aberti* (Western fanshell), *Lampsilis rafinesqueana* (Neosho mucket), *Quadrula cylindrica* (rabbitsfoot), and *Ptychobranchus occidentalis* (Ouachita kidneyshell) (see Obermeyer et al., this volume). Therefore, it seems an anomaly that one unionid, *Quadrula metanevra* (monkeyface), has increased to become one of the most abundant unionids in two unconnected river basins (Neosho and Verdigris) in southeast Kansas (Figure 1).

Quadrula metanevra is characterized as a riverine unionid found in swift currents with gravel substratum (Isely 1925; Oesch 1984). *Quadrula metanevra* is generally considered uncommon yet stable (Williams et al. 1993), though it is sometimes locally abundant (Cummings and Mayer 1992).

The Neosho, Verdigris/Fall rivers originate in the tallgrass prairie ecoregion known as the Flint Hills. Further downstream, cultivation is more extensive, especially on the river bottoms. The Neosho River has an average flow that is 51% greater than the Verdigris River (U.S. Geological Survey 1979), though both are subject to periodic droughts and floods. Federal reservoirs and numerous lowhead dams are situated on both of these basins.

Information concerning the population status of *Q. metanevra* in Kansas is of particular interest because it is important in evaluating commercial mussel harvest regulations. Three species of unionids are legally taken in Kansas by licensed mussel harvesters and sold to brokers buying shells for the cultured pearl industry. These are *Amblema plicata* (threeridge), *Quadrula quadrula* (mapleleaf), and *Q. metanevra*. Of the three, *Q. metanevra* has the smallest size limit (2.75 versus a 3-inch minimum shell-height limit).

Reported harvest of Kansas unionids from 1989 through 1994 was 453 tons (Mosher 1995). Of this total, *A. plicata* was the most harvested species (63.7%), followed by *Q. quadrula* (19.4%) and *Q. metanevra* (16.9%). By using the average weight of *Q. metanevra* from previous surveys (Miller 1992), we estimate that approximately 268,000 individuals were harvested during the past 6 years from the Neosho and Verdigris/Fall rivers. Despite this harvest, *Q. metanevra* was the most abundant unionid found in shallow riffle and run habitats during our stream surveys (Miller 1992; Obermeyer et al. 1995).

We hypothesize that the increase in *Q. metanevra* is due to its life history adaptations, augmented flow from impoundments, and the lack of long-term drought episodes in the last 40 years.

Methods

Site selection in the Neosho and Verdigris/Fall river basins was based on the presence of stable riffle and run habitats or areas with a history of sampling. Forty-three sites were sampled qualitatively, and consisted of timed groping, snorkel, or SCUBA searches. To supplement qualitative searches, the substrate was shoveled into a floating sieve (6 mm mesh screen) and searched for small unionids. Species richness, relative abundance, and size-classes were generated at each site. In addition, exposed gravel bars and banks were searched at each site for weathered shells in an attempt to document historic species richness. Weathered valves were classified as rare (1-2 valves), few (3-6 valves), common (7-16 valves), or abundant (>16 valves) at each site searched.

To evaluate commercial mussel refuges on the Verdigris and Neosho rivers, 17 sites were sampled quantitatively using 40 randomly placed 1-m^2 quadrats at each site. Each unionid caught during quantitative sampling was measured. These data were used to compare shell height size-classes to minimize size bias more prevalent in qualitative sampling. Size-classes (height) were generated from nine quantitative sites on the Neosho River and compared with size-classes from eight sites surveyed on the Verdigris River in 1991 (Miller 1992).

Results

Quadrula metanevra was the most abundant mussel species in the Neosho, Verdigris/Fall rivers. It was the most abundant species found from 19 sites surveyed on the Neosho River, representing 34% of 5,503 mussels examined (Figure 2). However, it was not found alive at three sites upstream from John Redmond Reservoir. The next most abundant species from the Neosho River survey were *A. plicata* and *Quadrula pustulosa* (pimpleback), comprising 18% and 9% of the total catch, respectively. *Quadrula metanevra* was the second most common species (22% of total catch) caught from 4,260

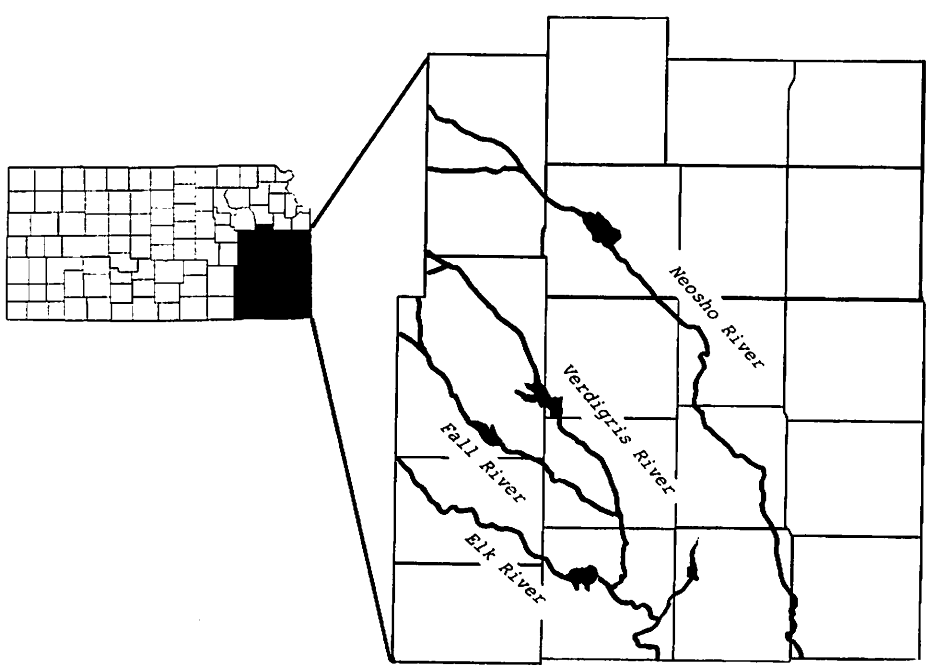

Figure 1. Map showing location of Neosho, Verdigris, and Fall rivers in southeast Kansas.

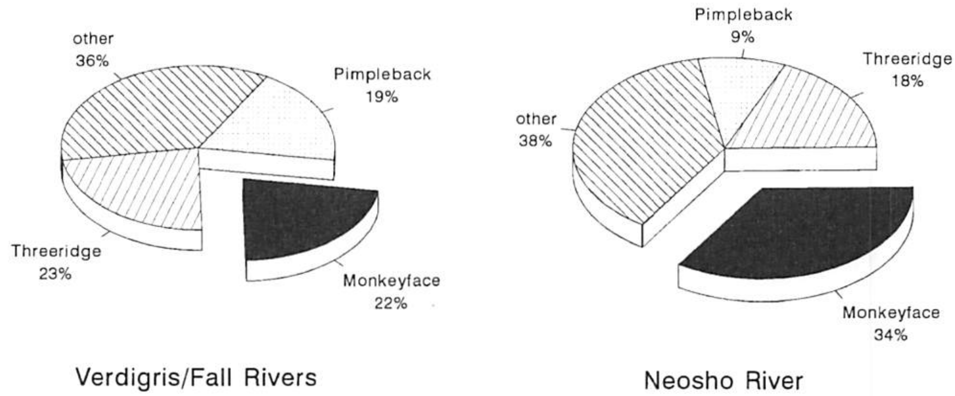

Figure 2. Relative abundance of top three species caught at 17 sites on the Verdigris/Fall rivers and 19 sites on the Neosho River. The most abundant species were *Quadrula metanevra* (monkeyface), *Amblema plicata* (threeridge), and *Quadrula pustulosa* (pimpleback).

unionids examined from 17 sites surveyed on the Verdigris/Fall rivers (Figure 2). The other two most abundant species found at Verdigris/Fall river sites were *A. plicata* and *Q. pustulosa,* making up 23% and 19%, respectively, of the total catch.

Examination of *Q. metanevra* size classes from quantitative sampling sites revealed young recruits in both the Neosho and Verdigris rivers (Figure 3). *Quadrula metanevra* shell heights from Neosho River sites ranged from 21 to 94 mm ($\bar{x}$ = 70.3, SD = 14.7, N = 408), whereas those from the Verdigris River ranged from 11 to 93 mm ($\bar{x}$ = 62.7, SD = 17.7, N = 502). Most *Q. metanevra* specimens smaller than 50 mm in height were typically less than 4 years old, and individuals measuring 50 to 69 mm were aged at 5 to 8 years (Cope 1983). In the Neosho and Verdigris rivers study areas, 11% and 20%, respectively, of the *Q. metanevra* specimens were less than 50 mm in height (Figure 3). Similar numbers of young age-class mussels were not noted for any other unionid species.

Out of 36 sites surveyed in the Neosho and Verdigris rivers, *Q. metanevra* was ranked first in relative abundance at 15 sites, second at 10 sites, and third at 4 sites. However, extant representatives of *Q. metanevra* were not found at 10 sites located upstream from federal impoundments located on the Neosho, Verdigris, and Fall rivers, although weathered valves of *Q. metanevra* were found at 6 of these 10 sites. Weathered valves of *Q. metanevra* were seldom classified as abundant at any sites searched, and were estimated as abundant at only 2 of 19 sites in the Neosho River, and at none of 17 sites examined in the Verdigris/Fall rivers.

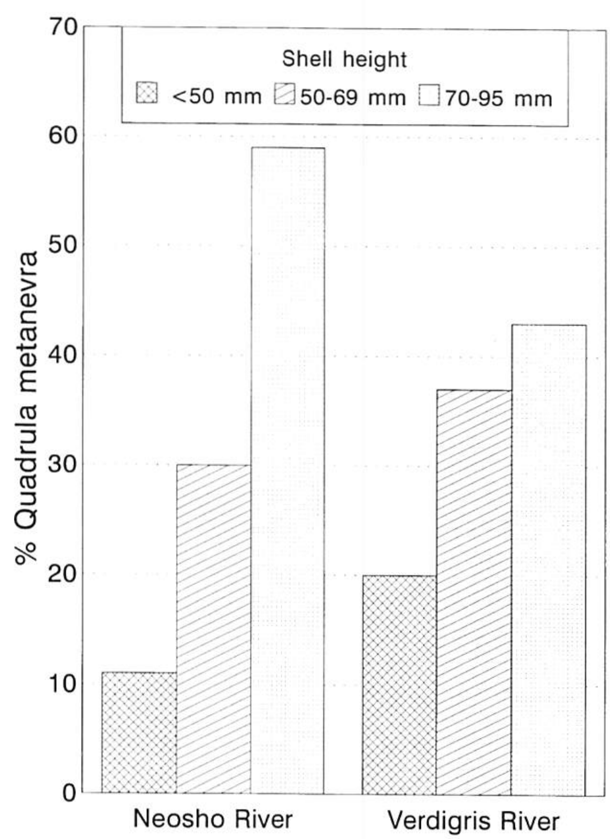

Figure 3. Size classes of *Quadrula metanevra* (monkeyface) measured during quantitative sampling at nine sites on the Neosho River and eight sites on the Verdigris River.

Discussion

Change in Population Status of Quadrula metanevra

Quadrula metanevra was reported from the basins of the Verdigris and Neosho rivers in the late 1880s, although relative abundance was not given (Popenoe 1885; Call 1885, 1886). In the early 1900s, Scammon (1906) reported, "Although well-distributed it is never very common." Isely (1925) found in 1912 that *Q. metanevra* made up only 3% of 713 unionids examined at one Neosho River site. Murray and Leonard (1962) did not report any recent records of *Q. metanevra* from the Verdigris River. These literature reports are supported by the few number of sites where *Q. metanevra* weathered valves were considered abundant.

In the 1970s, *Q. metanevra* apparently had not reached the population levels existing today. It was ranked eighth in relative abundance by Frazier (1977), making up only 1.8% of 2,300 individuals examined at eight Neosho River sites. However, Schuster (1979) considered it the most common species at other sites on the Neosho River. Cope (1979) and Schuster (1979) classified *Q. metanevra* as uncommon to rare in the Verdigris drainage. However, by the early 1980s Cope (1983) found that the 2-4 year age class made up the greatest percentage of *Q. metanevra* individuals in the Verdigris River below established mainstem reservoirs. The rise of *Q. metanevra* to the top of species abundance lists has occurred despite significant harvest of individuals in these waters over the past decade.

Population changes like that of *Q. metanevra* can be attributed to either stochastic or deterministic events (Gilpin and Soule 1986). Stochastic events are normal random changes in the environment that are localized (e.g., weather, disease). Deterministic events occur when essential elements for the survival of the animal are changed, or something has been introduced that affects the population (e.g., habitat manipulation, exotic species). Water contamination and changes in river hydrology due to impoundments, channelization, dredging, and removal of riparian timber are all examples of deterministic events that could affect mussel habitat. We feel that the apparent success of *Q. metanevra* in southeast Kansas is due to its life history adaptations that allow it to avoid or take advantage of anthropogenic alterations as well as the recent absence of prolonged droughts. However, because historical data on mussel density is sparse, we are unable to determine to what extent this apparent success is due to relative reduction of other species rather than an absolute increase in the relative abundance of *Q. metanevra*.

Water Quality Concerns in Southeast Kansas

The Neosho and Verdigris rivers frequently exceed two pollution criteria, fecal coliform bacteria and total suspended solids (Kansas Department of Health and Environment 1994). Principal fecal coliform bacteria sources are animal confinement facilities, livestock in the stream or riparian zones, and discharges from municipal wastewater treatment plants and aerated lagoons. Elevated fecal coliform bacteria levels often exceed contact recreational criteria of >200 colonies per 100 ml. These criteria were exceeded (> 25% of time) at all five stations in the lower Verdigris basin and six of seven stations in the Neosho basin during water sampling efforts from 1990 to 1993. The average fecal coliform bacteria count from the lower Verdigris River in Kansas was 2,336 colonies/100 ml, with maximum values of 48,000 colonies/100 ml (Kansas Department of Health and Environment 1993). These data represent probable nutrient loading that increases biochemical oxygen demand (BOD), and may lead to anoxic conditions at the substrate-water interface in deeper pool habitats.

The other primary pollution parameter that is frequently exceeded is total suspended solids, which is exacerbated by cropland and streambank erosion, removal of riparian forests, road construction and maintenance, channelization, and gravel dredging. The effect of suspended solids and sedimentation is known to be detrimental to unionids and their habitat (Ellis 1936; Aldridge et al. 1986). Recent data from the Kansas Department of Health and Environment (1993) show that total suspended solids frequently exceed their aquatic life support criteria (100 mg/l) at all four sites on the Neosho River and one of five sites on the Verdigris River.

Apparently, *Quadrula metanevra* avoids the most deleterious effects of silt deposition and nutrient loading by using habitats less impacted by these pollutants. The most-used habitats for all size classes of *Q. metanevra* in Kansas were fast-flowing riffles and runs in which silt is less likely to deposit. Likewise, these habitats are well oxygenated and less affected by dissolved oxygen (DO) deficits resulting from nutrient loading. Yet, *Q. metanevra* was apparently not an abundant part of the unionid assemblage in Kansas at the turn of the century when these contaminants were presumably at lower levels prior to intense cultivation, livestock grazing, and urbanization.

Fish Hosts

Lepomis cyanellus (green sunfish) and *Lepomis macrochirus* (bluegill) are the known host fishes (Howard 1914; Wilson 1916) available to *Q. metanevra* in southeast Kansas streams. Both species are considered common. *Lepomis cyanellus* is a habitat generalist species, and Tomelleri and Eberle (1990) call it a "ubiquitous" fish that is abundant and adaptable. They stated that it is the last fish to disappear during a drought and the first to return.

Lepomis macrochirus is a species that probably has increased with the operation of impoundments. Kansas surveys have documented *L. macrochirus* at more sites and higher abundances in mainstem rivers after reservoirs became operational (Cross and Braasch 1968; Cross and Moss 1987), which may have enhanced the probability of fish host contact with *Q. metanevra*.

Periodic Drought Episodes

The Neosho and Verdigris/Fall rivers have experienced periodic droughts during the last century. We have separated these into minor drought events that stopped stream flows for days to weeks, and major drought events that stopped stream flows for months.

Because shallow riffles and runs are most affected by droughts, no-flow events are probably more detrimental to riffle species such as *Q. metanevra*. Periodic droughts may have limited this species from becoming an abundant member of the unionid mussel assemblage of southeast Kansas until large impoundments became operational, such as John Redmond Reservoir (Neosho River) in 1963 and Toronto Lake (Verdigris River) in 1960. Therefore, the noted increase of *Q. metanevra* in these two river systems leads us to believe that regulated releases from federal impoundments are favoring this species. In essence, the augmented flows may mimic a larger river system during periods of low rainfall. The result of these augmented flows has alleviated some of the no-flow and very low-flow events that would have occurred without operation of mainstem impoundments. Augmented flow increases the amount of riffle and run habitat that is available for recolonization and may minimize mortality during short-term droughts.

U.S. Army Corps of Engineers (1980) flow data for the Neosho and Verdigris basins document that the operation of impoundments has changed flow regimes, with the virtual elimination of minor drought events below impoundments. For example, records show that summer 1980 was one of the lowest flow periods in the Neosho and Verdigris river basins since reservoir operation. In September 1980, the Neosho at John Redmond Reservoir had an average daily inflow of 16 cfs, whereas downstream releases averaged 70 cfs during this same period. Monthly inflow from July through November of 1980 at Toronto Lake (Verdigris River) was 1, 13, 1, 5, and 1 average daily cfs, whereas the corresponding releases were 22, 16, 5, 6, and 6 cfs; in September 1980, this reservoir had 24 days of no recorded inflow (Figure 4).

Although mainstem impoundments have tempered low-flow and no-flow events during minor drought episodes, there have been no major drought episodes recorded since the operation of these two reservoirs. Records of water gauging stations report that major drought events (U.S. Geological Survey 1979) have occurred in 1934, 1936, 1939, and 1955-57 in the Neosho River (Parsons gauging station) and in 1932, 1934, 1936, 1939-40, and 1953-55 on the Verdigris River (Independence gauging station).

U. S. Army Corps of Engineers (1987) data show a lack of flow in the Verdigris River (Wilson County) during 1939-1940 (5 months) and 1956-57 (8 months). Flow data for the Neosho River (Coffey County) reveal a prolonged no-flow event in 1956-1957 (6 months); this was the last severe drought to cause such an extended no-flow event. Harold Murray (Trinity University, pers. comm.) who witnessed this drought, stated that when he visited the Neosho River in 1956 it was almost "bone dry" with isolated pools loaded with stranded mussels. These past drought events may be an important factor contributing to the lack of *Q. metanevra* upstream of existing reservoirs in this study. Upstream habitats probably were periodically invaded and became inhospitable during drought episodes. However, this ebb and flow pattern has been disrupted by the construction of impoundments that act as a barrier to upstream recolonization.

Regardless of the downstream tempering effect of impoundments on flow, a major drought event would likely cause a severe population depletion of *Q. metanevra* as it now stands. If a major drought occurs, *Q. metanevra* is set up for a population crash because deepwater refugia are compromised by silt deposition and nutrient loading.

Summary

Possible factors responsible for *Quadrula metanevra's* inferred increase in the Neosho and Verdigris river basins in Kansas include:

1) Operation of mainstem impoundments have likely reduced the magnitude of low- and no-flow events.
2) No major drought episodes have occurred in Kansas since 1957.

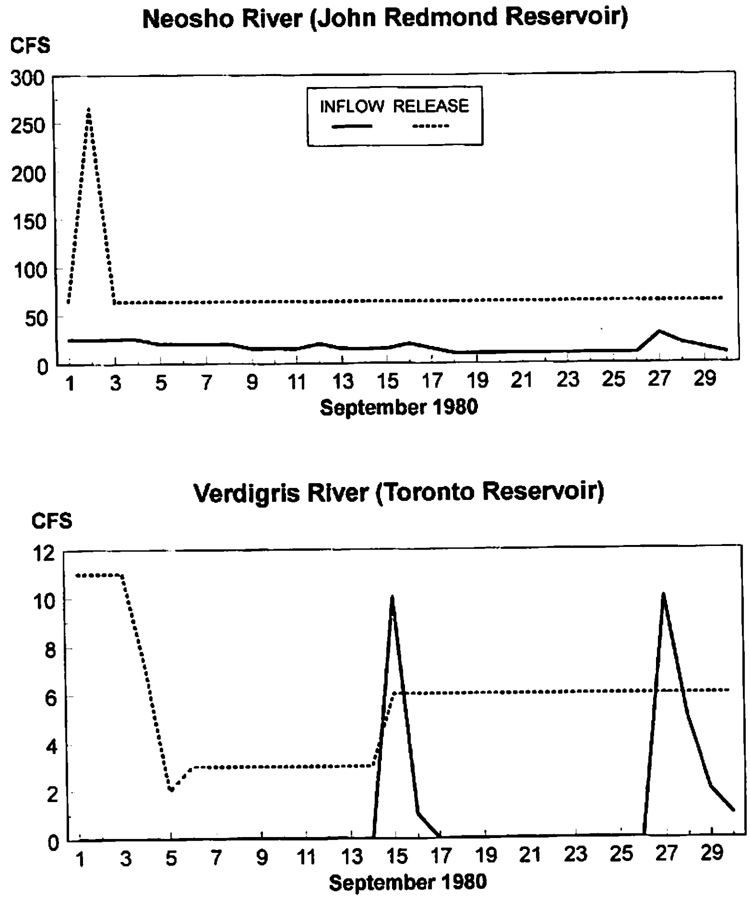

Figure 4. Water inflows and releases during drought month of September 1980 from John Redmond Reservoir on the Neosho River and Toronto Reservoir on the Verdigris River (U.S. Army Corps of Engineers 1980). A water release at the beginning of the month on the Neosho River was requested by Kansas Fish and Game to "freshen the river."

3) *Quadrula metanevra's* fish hosts may be more abundant.
4) Regulated flows over riffle and run habitat may minimize silt deposition and the inferred deleterious effects of nutrient loading.

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