# The Role of Reproductive Behavior in the Conservation of Fishes: Examples from the Great Plains Riverine Fishes

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Recovery efforts for threatened and endangered fish species are hampered by lack of knowledge of their reproductive ecology. Habitat requirements and environmental stimuli necessary for reproduction are often unknown and vary widely among species. For Great Plains riverine fishes, this is often complicated by the high turbidity of the system in which the species occur, which precludes direct visual observation of behavior. Innovative methods for collecting behavioral data are required to better understand the conditions necessary for successful reproduction. To this goal, I will discuss four fish species on which I have worked in collaboration with university and agency researchers, graduate students, state and federal resource managers, and private landowners.

The species are: Topeka Shiner, *Notropis topeka* (Gilbert 1884), a headwater and low-order stream species; Neosho Madtom, *Noturus placidus* Taylor 1969, a middle-size river species; and Pallid Sturgeon, *Scaphirhynchus albus* (Forbes & Richardson 1905) and Shovelnose Sturgeon, *S. platorynchus* (Rafinesque 1820), both large river species. These species demonstrate the variety of physical requirements necessary for successful reproduction in Great Plains riverine fishes. The recovery plans for these species indicate that information on behavior and habitat requirements for spawning is lacking.[1,2,3]

## Topeka Shiner

The Topeka Shiner (Fig. 1) was listed as an endangered species in 1998.[3] The Topeka Shiner is a small, stout minnow (<75 mm total length - TL) characteristic of small, low order (headwater) prairie streams. Topeka Shiner occur in pool and run areas of streams, seldom being found in riffles. They are pelagic, occurring in mid-water and surface areas, and are primarily considered a schooling fish.[4] Clean gravel, cobble and sand are the predominant substrate types within Topeka Shiner streams. Kerns[5] found that this species primarily feeds on insects while Hatch[6] found it be omnivorous (flowering-plant seeds are common in the diet). Topeka Shiner are broadcast spawners (i.e., eggs are released over open substrate) in pool habitats, over Green Sunfish (*Lepomis cyanellus*) and Orangespotted Sunfish (*L. humilis*) nests, with males establishing small territories on the edges of these nests.[4,5]

The Topeka Shiner is affected by habitat destruction, degradation, modification, and fragmentation resulting from siltation, reduced water quality, tributary impoundment, stream channelization, in-stream gravel mining, and changes in stream hydrology, and introduced predaceous fishes.[3] The historic distribution of Topeka Shiner included low order tributary streams throughout the central prairie regions of the United States. Topeka Shiner occurrences have declined by 80% (50% within the last 40 years); isolated and fragmented

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*Fig. 1.*
Topeka Shiner, *Notropis topeka*. Photo © Konrad Schmidt.

populations now exist in less than 10% of its original range. Limited reproductive success is considered one potential cause for the decline of the species.[3] My research focuses on the the effects of temperature and photoperiod on reproductive development and behavior, as well as substrate particle size preference.

***Approach*** The small size of adult Topeka Shiner makes laboratory studies a relatively easy task. Under controlled conditions, adults are exposed to various combinations of photoperiod, temperature, and substrate to determine which combination is most effective at stimulating reproduction. For these studies, adult fish came from hatchery ponds run by state and federal resource managers.

The experiments included individually controlled and monitored experimental chambers, and simulated winter conditions to assess stimulation of reproductive development. Six females and one male were placed in a tank (Fig. 2) under specific temperature and photoperiod combinations. Each tank was monitored with video cameras to minimize experimenter's disturbance and to record courting and spawning behaviors, defined as presence and successful hatching of eggs.

***Information gained*** Preliminary results suggest that the combination of photoperiod and temperature are important factors influencing reproduction. Longer photoperiods and temperatures between 22-28°C enhance reproductive development, while 31°C hinder the process. The next step in this research will be to determine substrate preferences under photoperiod and temperature combinations in which spawning behavior and success are highest.

This research should provide the U.S. Fish and Wildlife Service (USFWS) with information on the spawning requirements of the Topeka Shiner; it will also help identify suitable habitats for reintroductions and plan large-scale production for reintroductions, which ultimately will contribute to recover the species.[3]

## Neosho Madtom

The Neosho Madtom (Fig. 3) was listed as threatened in 1991.[1] It is a small (<75 mm TL) ictalurid fish endemic to the mainstems of the Neosho and Cottonwood rivers in Kansas and Oklahoma and the Spring River in Kansas and Missouri.[7,8,9] This species occupies portions of riffles with mean flows of 79 cm/sec, mean depths of 0.23 m, and unconsolidated pebble and gravel (2-64 mm in diameter).[10] Neosho Madtom feed at night on larval insects found among the gravel.[8] High abundance of this species has been documented in riffles in late summer and early fall, after young-of-year (YOY) are

*Fig. 2.*
Topeka Shiner experiment tank. Photo © Christopher C. Witte.

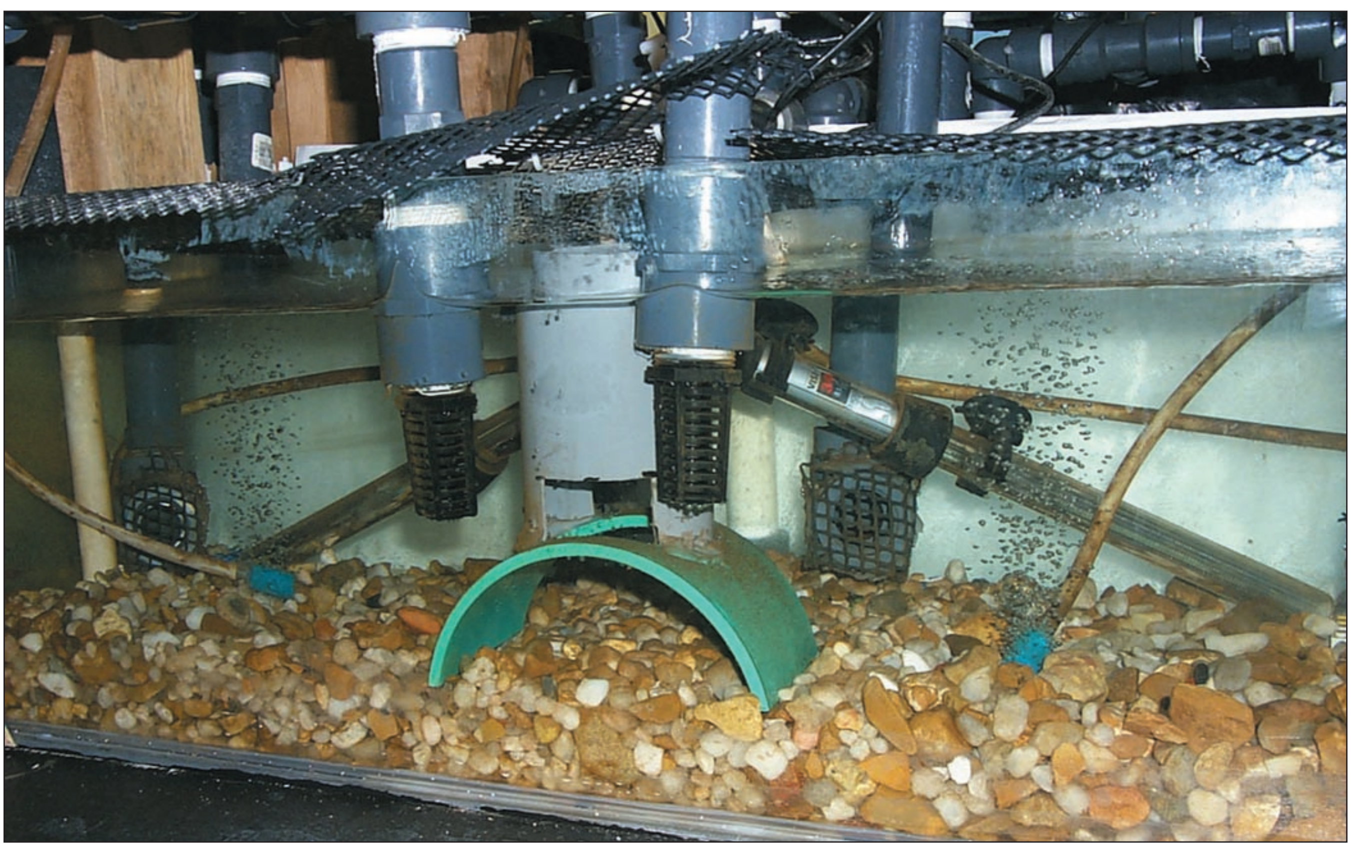
*Fig. 3.*
Neosho Madtom, *Noturus placidus*. Photo © Janice L. Bryan.

estimated to have recruited to the population.[7,10,11] Previous research suggests that Neosho Madtom have an annual life-cycle with recruitment of YOY into adult collection gear about the time the adults begin to disappear from collections.[11]

Once distributed throughout the Spring-Neosho (Grand) River system, this species is now restricted to portions of the Neosho and Cottonwood Rivers in Kansas and Oklahoma, with one remnant population in the Spring River in Kansas. Much of the Neosho Madtom's historic habitat has been inundated by impoundments.[1] Additional habitats have been degraded by in-stream gravel mining, feedlot operations, and lead-zinc mining.[12] Reservoir operations have affected reproduction and survival.[13]

Nesoho Madtom spawn in nests constructed under large objects in gravel.[12] Spawning occurs from May through July as temperatures approach 25°C.[11,15,16] Male parental care

*Fig. 4.*
Neosho Madtom experiment tank. Photo © Janice L. Bryan.



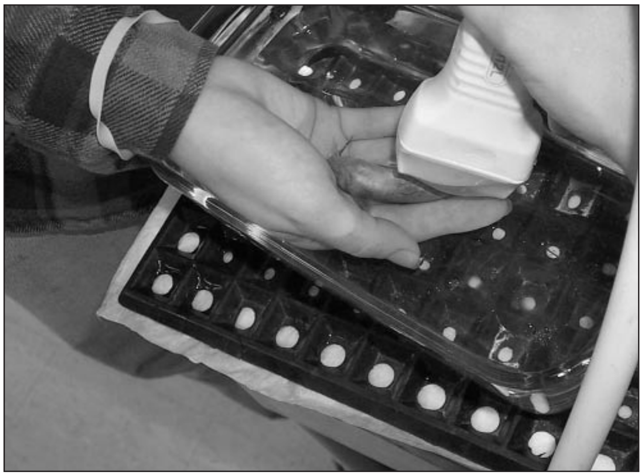


*Fig. 5.*
Ultrasound use on Neosho Madtom. Photo © Mark L. Wildhaber.

*Fig. 6.*
Neosho Madtom spawning event. Photo © Janice L. Bryan.

lasts for 8-9 days following spawning.[17] Its short life span restricts reproduction to one or two spawning seasons.[11,17]

Similar methods to those described for Topeka Shiner (above)[14,15,17,19] have been used to examine the effects of photoperiod, temperature, and water flow on the reproductive behavior of Neosho Madtom. In this specific study, the main goal was to determine the temperature range and light period within which spawning occurs, and if excessive water flow limits spawning.

***Approach*** The small size of the Neosho Madtom allowed for laboratory study under controlled conditions. Adults were exposed to various combinations of photoperiod, temperature, and water flow to determine the most effective at stimulating reproduction. Since production of offspring in the laboratory has been limited, for these studies individuals had to be obtained from the wild.

The collection of data employed time-lapsed videography for monitoring behavior, individual controlled and monitored experimental chambers, and simulated winter conditions to stimulate reproductive development. One female and one male were placed in a tank under a specific combination of temperature, photoperiod, and flow, and supplied with a gravel substrate and a PVC nesting structure (Fig. 4). Each tank was monitored with video cameras to minimize human disturbance and to document courting, spawning, and rearing behaviors.[14,19] The nest-building habits of Neosho Madtom facilitated the collection of up-close documentation of their spawning behavior using an additional camera placed inside each nest.[20] In initial studies, sex was determined through secondary sexual characteristics and internal examination upon completion of the study. In later studies designed to document changes in reproductive state under varying temperature and photoperiod, we used a medical ultrasound unit (Fig. 5) to confirm sex and to estimate fecundity of the same individuals over several annual cycles.[18] Presence and successful hatching of eggs indicated successful spawning.

***Information gained*** The studies demonstrated that Neosho Madtoms' proportion of time spent performing cavity enhancement was higher, cavities were deeper, and gravel size in cavities was smaller for those fish given a longer photoperiod.[14] Courtship behaviors were observed in male-female pairs held in longer photoperiods, but not in shorter photoperiods. Under flowing-water conditions, there was a decreased average frequency, proportion of time, and event duration of male nest-building behavior.[19] Water flow decreased the overall frequency of occurrence of reproductive behavior sequences. We observed spawning (Fig. 6) between 21-28°C with most occurring at 25°C. Temperature and photoperiod influenced the reproductive cycle and increased river flows during spawning could have affected reproductive success negatively.

Knowing how photoperiod, temperature, and water flow affect Neosho Madtom reproductive success provides information to the USFWS and the U.S. Army Corps of Engineers on how flow regulation in concert with natural photothermal changes can be used to improve species recovery plans.

## Pallid and Shovelnose Sturgeon

The Pallid Sturgeon (Fig. 7) was listed as endangered by USFWS in 1990.[2] Though the Shovelnose Sturgeon (Fig. 8) is not listed by the USFWS as either threatened or endangered, it has been listed as vulnerable by the World Conservation

▲ *Fig. 7.*
Pallid Sturgeon, *Scaphirhynchus albus*. Photo © Steven Krentz.

▼ *Fig. 8.*
Shovelnose Sturgeon, *Scaphirhynchus platorynchus*. Photo © Aaron J. DeLonay.

Commission.[21] The Pallid is a mid-sized sturgeon reaching up to 30 kg in weight, while the Shovelnose is smaller (<3 kg);[4] both are native to the Missouri and Mississippi Rivers.[22,23] The Shovelnose Sturgeon feeds primarily on invertebrates, while the larger Pallid Sturgeon starts out feeding on invertebrates but later shifts to a fish diet.[24,25,26] Pallid Sturgeon are adapted to large, turbid, riverine environments and do not frequent tributaries or clear-water riverine habitats often used by Shovelnose Sturgeon.[27] Spawning habitat preferences of Pallid and Shovelnose Sturgeon are not known; both species are assumed to spawn in current over coarse substrate.[27,28] Like most sturgeon species, Pallid and Shovelnose Sturgeon are suspected to be broadcast spawners where the eggs become adhesive soon after release and attach to the substrate until hatch.[29] Biologists speculate that spawning runs are dependent on river flow.[28,30,31] Spawning behavior, habitat, and environmental cues necessary to elicit spawning have not been documented. Morphological, physiological and genetic similarities indicate that Pallid and Shovelnose Sturgeon are closely related.[22,32,33,34] Therefore, research on Shovelnose Sturgeon may also be applicable to the conservation of Pallid Sturgeon.

As with many sturgeon species, habitat alteration and destruction are limiting factors for Pallid and Shovelnose Sturgeon.[35,36] Shovelnose Sturgeon may also be threatened by commercial over-harvest for the caviar industry and has been extirpated from portions of its range.[2] The USFWS recovery plan for Pallid Sturgeon lists rehabilitation of habitat as necessary for reproduction and recruitment.[2] The Shovelnose Sturgeon is more common and widespread than the Pallid Sturgeon.[28] Past distribution of the species included the Mississippi, Missouri, Ohio, and Rio Grande Rivers and their tributaries. There has been a 30% reduction in the Shovelnose Sturgeon range with an additional 30% reduction in population anticipated within the next 10 years (three generations).[21] If the Shovelnose and Pallid Sturgeon are to be conserved and recovered, their limited reproduction will be the primary obstacle to overcome.[2]

The goal of this research is to determine the ecological requirements for successful Pallid and Shovelnose Sturgeon reproduction in the Missouri River. The specific objectives are to: (1) determine the direction, magnitude, and habitat used during spawning migrations, (2) describe the reproductive physiology prior to and after successful and unsuccessful spawning, and (3) evaluate the effect that a semi-natural increase in flow has on the reproductive status, movements, and habitat use.

***Approach*** The approach of this study is interdisciplinary and integrates physiology, behavior, habitat use, and physical habitat assessment to document sturgeon spawning and assess the effects of environmental variables on spawning success. In the field, as many as 100 sturgeon were collected and assessed for reproductive state, fecundity of females, and gonadosomatic index using ultrasonic and endoscopic methods.[37] Blood samples were taken for hormone analyses. Female sturgeon that were ready to spawn were tagged both with ultrasonic telemetry tags (for relocating fish) and data storage tags (DSTs) that continuously monitor depth and temperature from within the fish's body cavity. This study took place in two different (ca. 640 km each) segments of the 1280 km Lower Missouri River. One of the river segments is highly influenced by regulated flows while the other segment has more natural flows, which allowed a comparison of the effects of natural and artificial flows on reproductive behavior.

The tagged fish were located repeatedly throughout the spawning season. Using mapping equipment, a 3 km stretch of the river centered on a fish location was mapped for depth, velocity, and substrate to provide not only fish habitat use but also local habitat availability. Continuous temperature loggers were placed in the Missouri River and tributaries where fish were collected. Gravel and rock deposits were located within the thalweg of the Missouri River, from the mouth at St. Louis to Sioux City, Iowa (during low water conditions). After spawning season, the fish were recaptured to assess spawning success and to retrieve the DST tags.

Fish movement and habitat use data, along with the physical habitat data, are to be analyzed as they are in wildlife telemetry studies using a combination of discrete-choice and utilization distribution modeling.[38] Multivariate statistical analyses were conducted to determine predictor and explanatory variables (both environmental and physiological) indicative of spawning success.

***Information gained*** The majority of Shovelnose Sturgeon recaptured did spawn successfully, suggesting that the methodology did not compromise spawning behavior. Furthermore, data indicate that Shovelnose Sturgeon may travel over 640 km from point of tagging during their spawning migration.

The measurements of water conditions and habitat characteristics will be important in qualitative and quantitative description of habitat used by sturgeon during pre-spawn and spawning periods. Fish internal temperature (from DSTs), compared with the temperature measured by the continuous temperature loggers, will indicate whether fish are selecting seasonal habitats based on thermal preferences and the role of temperature as a spawning cue. This comparison will also indicate whether fish ascended river tributaries. The discrete-choice and utilization distribution modeling approaches will help determine if fish are selecting one habitat over another among those habitats on a local level, particularly during spawning.

Blood chemistry data will be used to assess spawning or failure to spawn. A combined analysis of the hormone data with environmental data may point to potential spawning cues. Tracking reproductively mature fish will provide data on the timing and magnitude of spawning movements, and the potential locations of spawning habitats. Environmental and physical habitat data, obtained together with tracking gravid and post-spawn females, will be critical to understanding where and under what conditions sturgeon spawn. Results will be used to quantify existing spawning habitat and to develop management strategies to create suitable and sufficient spawning habitat.

Knowing the location and type of substrate preferred by spawning Pallid and Shovelnose Sturgeon will allow biologists to locate adult fish during the spawning season, estimate the population of reproductive adults, monitor spawning activity and relative success, and assess habitat suitability during the spawning period. This information is critical to design adequate habitat alterations and experimental flow manipulations intended to promote reproduction. Telemetry locations of implanted fish and the associated habitat and water quality measurements will be placed into a GIS format and made available to the U.S. Army Corps of Engineers (USACE), the USFWS, and others for use in the redirection of sturgeon assessment and monitoring efforts.

The USACE, USFWS, numerous Tribes, state agencies, and stakeholders are involved in efforts to define operational changes that will remove jeopardy and contribute to survival of Pallid Sturgeon. Management actions to alter the flow regime or morphology of the Missouri River and provide benefits to Pallid Sturgeon need to be designed with a comprehensive and detailed predictive understanding of how sturgeon might respond.

### Final Comment

It is important to realize the crucial role that behavior plays in the conservation of Great Plains fishes. I hope this article provides an overview of the exciting approaches being used in the conservation of native fishes. This research could inspire similar conservation projects on other fish species where analogous questions and logistical problems arise.

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