Evaluation of a Spring Rise for the Missouri River

By Donald G. Jorgensen

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Cover Photo: Spillway of Gavins Point Dam, South Dakota-Nebraska, courtesy of U.S. Army Corps of Engineers.

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EXECUTIVE SUMMARY

EVALUATION OF A SPRING RISE FOR THE MISSOURI RIVER

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A spring rise for the Missouri River has been advocated in the U.S. Fish and Wildlife Service's (USFWS') biological opinion (2000) and in a review by the National Research Council (2002). The USFWS has made modification of flows at Gavins Point, including a spring rise; the first element of a management plan termed a reasonable and prudent alternative (RPA), which is included in the biological opinion. This study evaluates the effects of the RPA proposed spring rise on the Missouri River, especially on the lower Missouri River (below Gavins Point Dam).

The biological opinion states that a spring rise is needed to provide a spawning cue for the fish species of the Missouri River including the endangered pallid sturgeon. A survey of spawning information for 85 species of Missouri River fish was made to evaluate if a spring rise would provide a spawning cue for the fishes of the Missouri River. The results indicate that a spring rise is not essential to cue spawning of the Missouri River fish species. Increased flow could be a supplementary spawning cue for a few non-native fish carp species. Temperature was reported to be a cue for all fish species. The assertion in the biological opinion that a spring flow is essential to cue the fishes in the Missouri River is arbitrary and is not supported by information gathered for this investigation.

Because temperature is the essential cue for spawning of the fishes of the Missouri River and because releases of water through the dams are typically colder, temperature disturbances are likely having an effect on the spawning of the fishes of the Missouri River. Development of a program to regulate water temperature by release of waters deserves consideration. A temperature regulation system that allows water to be withdrawn at a specific temperature from the reservoirs would likely allow control of the temperature of the water releases and eliminate the need for over the spillway discharges.

In reference to spawning of the endangered pallid sturgeon, information collected for the study also indicates that temperature is the essential cue for spawning. The biological opinion states that current research indicates temperature cues sturgeon spawning. The U.S. Army Corps of Engineers (USACE) states in the Summary of the Revised Draft Environmental Impact Statement for the Missouri Rivers that both the USFWS and USACE biologists agree there are no data to support definition of a spawning cue that would result in spawning below Gavins Point Dam (lower Missouri River). A most compelling observation on the irrelevance of a spring rise to cue spawning of the pallid sturgeon is that the Missouri River between St. Joseph and St. Louis typically has a spring rise and many of the tributaries of the lower Missouri River also have spring rises, yet this reach and these tributaries are not known to contain young of the year pallid sturgeon.

One likely reason that the pallid sturgeons are not successfully spawning in the lower Missouri River is the lack of gravel substrate. USFWS biologists have suggested that degradation of the streambed below Gavins Point Dam is creating a gravel stream bottom. However, studies of bottom conditions below the dam and the remainder of the lower Missouri River have not found gravel habitat suitable for sturgeon spawning.

It is likely that sturgeons in the Missouri River, especially the lower Missouri River, are dominantly spawning in the tributaries. This is consistent with information found in literature references concerning spawning of pallid sturgeons, shovelnose sturgeons and lake sturgeons. Because it is likely that most sturgeon spawn in tributaries, the importance of a spring rise on the lower Missouri River is likely to be minimal.

The biological opinion reports that a spring rise would result in a significant increase in connecting the river to backwater areas, chutes, and abandoned oxbows adjacent to the river, which is likely to be beneficial to many Missouri River fish species. However, large-scale changes in the shape and geomorphology of the lower Missouri River have reduced the number of chutes and backwaters. There are few chutes and backwaters to connect with irrespective of the size of a spring rise. The USACE's studies show that a spring rise would increase the size of the connected area by about 600 acres. Thus, a spring rise will not significantly increase the connectivity of the river. Improved connectivity can be achieved by habitat creation and or restoration.

The biological opinion states that a spring rise should increase the productivity of the river. This would be done by increased interchange of organisms, nutrients, sediment and debris in the aquatic/terrestrial zone. However, the Missouri River dams have reduced high discharges to the extent that larger discharges of released water do not normally result in overbank floods. In general, channeling of the river and bank stabilization has reduced the area of the littoral zone. Further, bank stabilization has reduced cut and fill alluviation. Thus, the size of the aquatic/terrestrial zone has been reduced and connectivity is limited. Accordingly, a spring rise would not significantly increase interchange of material or increase productivity. In the lower Missouri River, most of the nutrient, sediment, debris, and much of the water itself come from the tributary streams. In comparison, the increase of the amount of nutrient exchange resulting from a spring rise below Gavins Point Dam is likely to be trivial as compared to natural nutrient exchange attributed to the tributaries.

The biological opinion states that a spring rise would significantly increase the amount of islands and sandbars in the unchannelized reach between Gavins Point and Ponca, Nebraska. After the three high-flow years of 1995, 1996, and 1997, the area of islands and sandbars was increased temporarily. The biologic opinion uses these three years as examples to indicate geomorphologic changes that result from spring raises. Even a casual examination of the hydrographs for these three years, shows that these were not spring rises as discussed in the RPA, they were in essence high-flow periods of long duration that lasted from spring into fall. In reference to volume of flow, 1995 represented the 102nd highest volume of flow in 104 years, 1996 represented the 98th highest volume of flow in 104 years, and 1997 represented the highest volume in the entire 104 years of record. To compare the geomorphic change resulting from three successive extreme flow events for long durations to the effects of the spring rises as described in the biological opinion is not valid and is misleading.

Discharges from Gavins Point Dam are sediment deficient; thus, degradation of the streambed will occur. Records of streambed degradation show that during years with high discharges, streambed degradation is active; however, during more normal discharges, streambed degradation is minimal. These observations are consistent with the tenets of alluvial geomorphology. Streambed degradation ultimately results in the stream being more incised. Minimum degradation will occur if flood pulses are minimized. A spring rise, as any other pulse, will cause degradation and stream incisement, and ultimately, the area of islands and sandbars will be reduced.

Additionally, a spring rise would initiate a series of undesirable environmental and economic effects: One serious negative environmental impact from degradation relates to the loss of wetlands. Streambed degradation will lead to lowering of water levels in the river from Gavins Point to Omaha. Lower river water levels will even further reduce the connectivity of the river to the limited chutes and backwaters. However, much more significant is that lowering of the stream levels will result in lowering of ground-water levels in the floodplain from Gavins Point to Omaha. Ground-water levels in floodplains support wetlands and lakes. Additionally, a spring rise would not only require changes in releases at Gavins Point Dam but from other main-stem dams. These releases will cause degradation below each dam. The sediment removed below each upstream dam by a spring rise will be deposited in the next lower reservoir.

A spring rise would retard drainage from farmland during the planting season. A spring rise would increase degradation and erosion below all the dams. A spring rise, because of degradation, would lower still further river-water levels and ground-water levels resulting in increased power consumption and cost associated with pumping water for municipalities, industries, and farms. A spring rise would increase the likelihood of spring flooding from Omaha to Saint Louis.

Below are some items that relate to jeopardy and river management:

* The range of the piping plover has increased over the Missouri River Basin since 1917. Accordingly, it is not logical to state that the management of the Missouri River is causing jeopardy to the piping plover.

* The tributary streams of the lower Missouri River are important spawning areas for most fishes of the Missouri River. The tributary streams are likely to be the main nursery

area of the Missouri River Basin (and for large rivers in general). The tributary streams supply the dominant quantity of nutrients, sediment, and organic debris generally considered useful in relation to the productivity of the river. Thus, the assumption in the RPA of the biological opinion that the low populations of the fish in the Missouri River are predominantly due to changes on the main-stem needs careful reconsideration.

* The biological opinion does not call for any action relating to predation and competition between predator fishes and most native fishes. The continual large-scale stocking of predator fish by the various States in the tributaries and in the reservoirs is having serious effects on native fishes. Not including an element in the RPA to alleviate predation and competition between stocked and native fish species is a shortcoming of the document.

*Changes in the tributaries are having numerous large-scale effects on the main-stem environment. Small dams are ubiquitous on the tributaries. The impoundments have resulted in reduction of the sediment loads delivered to the Missouri River.

* Small low head dams without fish bypasses near the mouth of the tributaries have likely reduced upstream migration and spawning of many Missouri River fish species, such as pallid sturgeons. In general, tributary conditions, except for the Kansas River were not considered except for a cursory manner in the biological opinion nor were they included in the RPA. Any plan to improve fish populations of the Missouri River should consider the tributary streams.

* Information from this study suggests that improvement of habitat in the lower Missouri Rivers and its tributaries would be the most beneficial action that would increase populations of the fishes of the Missouri River. The RPA should be revised to take advantage of results from this and other new investigations.

New information from new studies and additional analyses of Missouri River conditions since the biological opinion of 2000 are now available. This information has led to a much-improved understanding of the conditions of the Missouri River, especially in relation to the validity of the biological opinion and the RPA. The biological opinion must be updated to include new science and to develop a new RPA.

CONTENTS

FIGURES

I) INTRODUCTION

The management of the Missouri River and its main-stem reservoirs is important to the country and deserves careful attention. Management of the Missouri River should meet the Congressional authorized purposes as well as the environmental laws of the country. The Missouri River Basin, the River, and the main-stem dams are shown in **figure 1**.

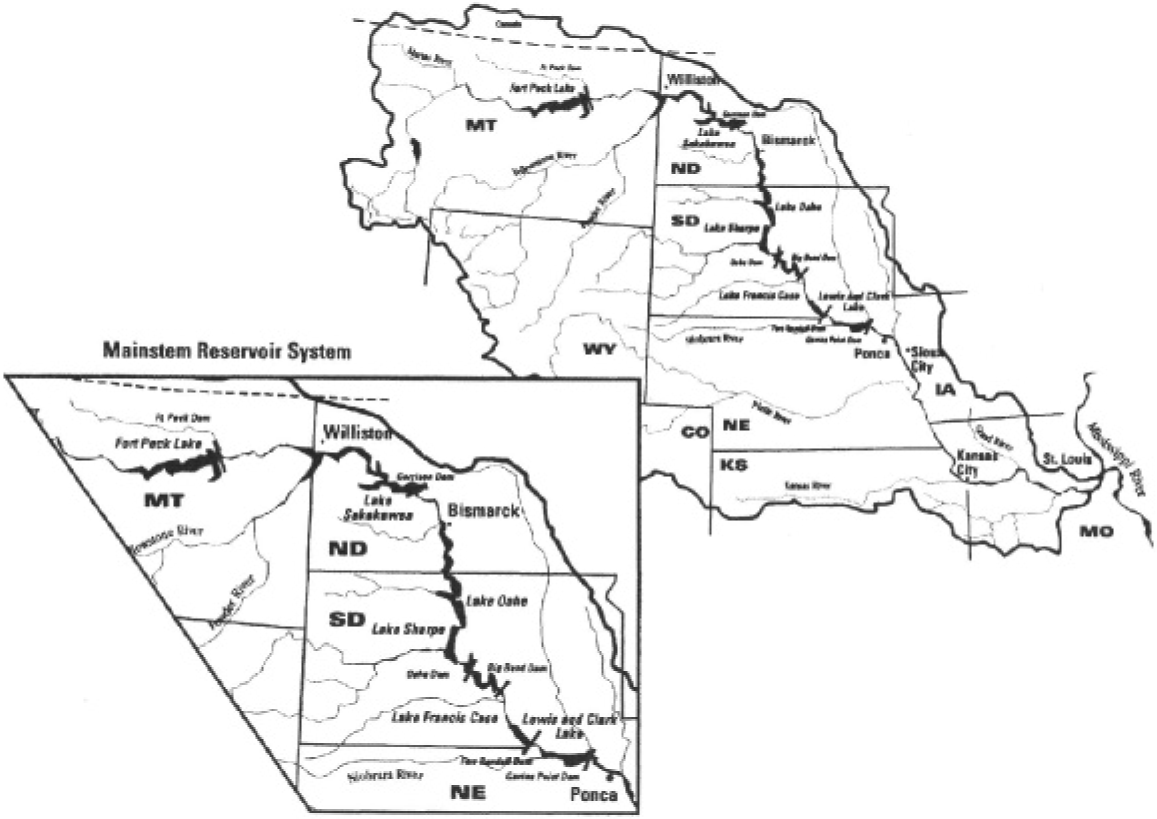


Figure 1. Missouri River Basin (from USACE, 2001b).

The U. S. Fish and Wildlife Service (USFWS) believes the present operation of the Missouri River jeopardizes the least tern, piping plover, and pallid sturgeon. The USFWS (USFWS, 2000, p. 233) has made flow modification a critical element in its Reasonable and Prudent Alternative (RPA), which is part of the biological opinion. The National Research Council (NRC) of the National Academy of Sciences (NAS) has explored conditions on the Missouri River ecosystem and suggests a more natural flow system. The NRC report (2002, p. 95) suggests a spring flood pulse on some stretches of the river to improve the ecosystem more favorable to recovery.

The application of a modified flow system that better emulates the natural-flow system is widely recommended for "recovery" (Poff and others, 1997; Junk and others, 1989). However, some scientists, such as Tyus and Saunders (1996) and Saunders and Tyus (1998, p. 427-428, after reviewing the flood-pulse concept, caution that universal application of a "more natural" flow regime does not constitute a panacea for ecological restoration, especially in greatly altered systems.

The logic to the "natural hydrograph" being a hydrograph that favors "restoration" of a stream is, of course, beneficial by definition if restoration or recovery means to restore conditions to their original conditions. However, restoring the stream in all aspects, including flow, is required. It must be remembered that the flood hydrograph is only one element of the environment of the fish species of the Missouri River. Even if flow were reverted back to the natural hydrograph that would not ensure that other elements, such as water quality and tributary conditions, would not seriously impair or make impossible the "restoration" of a stream. In reference to the Missouri River, construction of major dams and impoundments of large sections of the river and its tributaries, are just some of the changes that cannot be removed by simply altering flows at Gavins Point Dam. Junk and others (1989, pp. 110 and 122) warn that applying the 'flood-pulse concept can not be expected to be successful in all situations:

> In temperate regions, light and/or temperature variations may modify the effects of the pulse, and anthropogenic influences on the flood pulse or floodplain frequently limit production.

The primary purpose of this investigation is to ascertain the probable effects of a spring rise as outlined in the biological opinion on the Missouri River with added emphasis on the lower Missouri River below Gavins Point Dam. The effects to be evaluated include cueing of Missouri River fishes for spawning, change of river "connectivity", change of river "productivity", changes of sandbar geomorphology in reference to habitat for least tern and piping plover nesting, changes in degradation, change in flood plain wetlands, change in drainage to the river, and change in volume of sedimentation in reservoirs.

The author wishes to acknowledge the review of this article and suggestions for improvement from Dr. Harold Tyus, Mr. Roderic Tondreau, Dr. Vince Travnichek, Dr. David Galat, and Mr. Bill Beacom.

II) SPRING RISE AS A MISSOURI RIVER MANAGEMENT TOOL

The USFWS in its Biological opinion has prepared a "Reasonable and Prudent Alternative" (RPA) for the management of the Missouri River. The RPA asks for six management elements. The first element listed is "flow enhancement" at Gavins Point Dam. Specifically, USFWS (2000, p. 2) states:

> Flow enhancement: The Service has determined that a spring rise and summer drawdown must be implemented from Gavins Point Dam to restore, in part, spawning cues for fish, maintain and develop sandbar habitat for birds and fish, enhance aquatic habitat through connection of the main channel to backwaters and side channels, and improve habitat conditions for summer nesting terns and plovers, forage availability, and fish productivity. A spring release from Fort Peck Dam will provide spawning cues and increase the amount of warm water habitat available to pallid sturgeon and native fishes. This is to be accomplished by creating a spring rise (flood pulse) followed by a summer drawdown (lowflow).

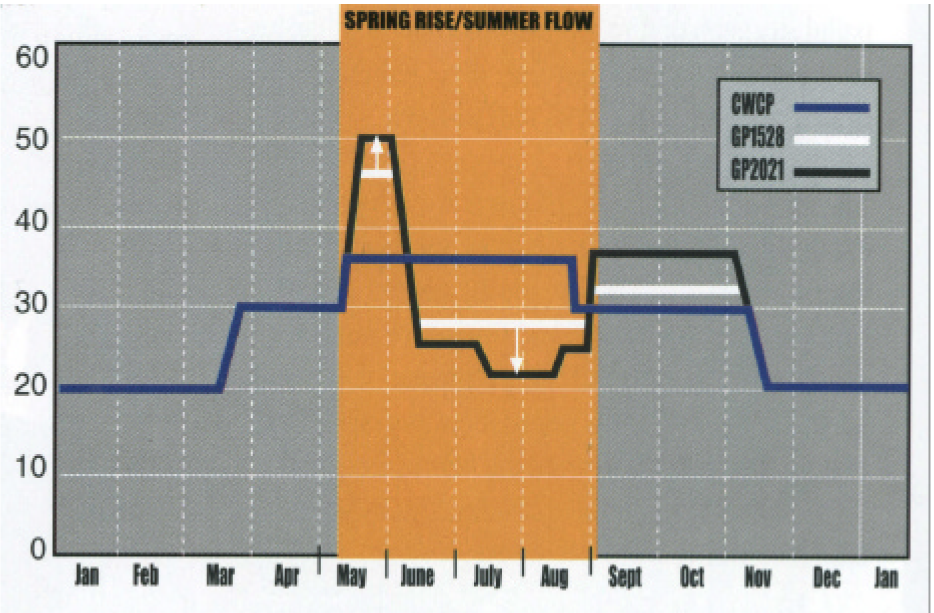
Thus, the USFWS is asking that the spring rise (flood pulse) and summer low flow be used as the primary Missouri River management tool. The primary purpose of this report is to evaluate and or assess the likely consequences of applying the spring rise to the Missouri River, especially below Gavins Point Dam.

The USACE analyzed four options of Gavins Point flow modification. The results are succinctly presented in Summary of the Revised Draft of the Missouri River Environmental Impact Statement (USACE, 2001b, p.11):

> The GP options include a range of changes from Gavins Point Dam. According to the BiOp (Biological opinion), an increase in spring releases (the spring rise) and a decrease in summer releases to those of the CWCP (Current Water Control Plan) are necessary.
>
> The spring rise would occur once every 3 years between May 1 and June 15, as conditions allow…..The rise is intended to provide a spawning cue for the pallid sturgeon.
>
> Summer flows would be lower every year as conditions allow under GP options. The lower summer flows would expose more sandbar acres for tern and plover nesting and create shallow water habitat for young pallid sturgeon… Spring rise releases would initially be stepped down to provide minimum service to navigation (6 kcfs less than full service) by June 21. Lower releases would be held steady until September 21…

> The four GP (Gavins Point) options that are described in the USACE's RDEIS (2001a) are GP1521, GP1528, GP2021, and GP2028. The first two digits refer to the size of the flood pulse in thousands of cubic feet per second (kcfs) above a minimum service discharge rate of approximately 28,500 cubic feet per second (28 kcf). The last two digits refer to the

summer low flow and represent the discharge in thousands of cubic feet per minute (kcfs). The chronology of the spring rise and summer low flow for GP1528, GP2021 and the Current Water Control Plan (CWCP) are shown in **figure 2**. The expected maximum stage changes (height of water) resulting from the two-spring-rise options are shown in tabular form in figure 2.



Maximum Stage Changes for the GP Options for Selected Lower River Locations (feet)

	Spring Rise Stage Changes		Summer Low-Flow Stage Changes	
	GP1528/GP1521	GP2021/GP2028	GP1528/GP2028	GP1521/GP2021
Sioux City	3.8	5.0	-1.5	-3.4
Omaha	3.3	4.4	-1.3	-3.0
Nebraska City	3.3	4.3	-1.3	-2.9
St. Joseph	3.3	4.4	-1.3	-3.0
Kansas City	3.0	4.0	-1.2	-2.7
Boonville	3.0	4.0	-1.2	-2.7
Hermann	2.0	2.7	-0.8	-1.8

Figure 2. Spring rise hydrograph and stage changes (from USACE, 2001a).

II. A) EVALUATING THE SPRING RISE AS A SPAWNING CUE FOR MISSOURI RIVER FISHES

The major reason for the proposed flood pulses as reported in the biological opinion is that the flood pulse (spring rise) would result in the fishes of the Missouri River, including the pallid sturgeon to spawn. This important statement needs evaluation. Tyus and Karp (1989, p.7) report that there are many potential stimuli related to reproduction of fish, and that, in general, these may be synergistic. There are endogenous stimuli, such as stage of maturity, physiological stage of the fish itself, and there are exogenous stimuli, such as substrate, temperature, discharge, and photoperiod. This investigation largely evaluates exogenous factors of temperature and flow. An analysis is made to ascertain the dominant or essential factor needed to cue spawning. In the Missouri River Basin, it is especially difficult to evaluate spawning cues in the spring, because commonly, photoperiod, temperature, and flow changes seemingly correlate or are otherwise contemporaneous of each other. Typically in much of the Missouri River Basin, the spring rise is a flow change related to snowmelt. Under these conditions, spawning of some fish species seemingly correlate with both temperature and discharge. However, temperature and snowmelt that causes the spring rise are not independent of each other in much of the Missouri River Basin. In general, snowmelt is directly dependent on temperature. Additionally, the amount of the discharge is related to the amount of snow that can be melted. Thus evaluation is difficult. Some insight can generally be gained from examination of series of annual hydrographs that include temperature, discharge, and initiation of spawning. If there is variability in the spring rise for the years of record, it is often possible to better evaluate the relative importance of temperature or flow. Unfortunately, this comprehensive data is not available for most fish species. Thus, other types of observations are needed to evaluate spawning.

As stated above, one of the objectives is to investigate the likely effects of the proposed spring rises on spawning of the fishes of the Missouri River. The exact number of fish species in the Missouri River is not definitely known. Berry and Young (2001) listed 109 species collected for a benthic fish study of the Missouri and Lower Yellowstone Rivers. Galat and Clark (2002) reported 99 fish species reside in the main-stem Missouri River.

Exogenous spawning information was collected for Missouri River fish species for this investigation. Table 1 lists spawning information for 85 species of the approximately 99 species that live in the main-stem Missouri River. The fish species selected are the same as those selected by Galat and Clark (2002), except that the pallid sturgeon and shovelnose sturgeon spawning conditions are combined. The pallid sturgeon was included because it has been identified as an endangered species. It is generally noted that the more common shovelnose sturgeon is a surrogate for the pallid sturgeon. In reference to spawning this is in part supported by the observation that there are numerous hybrids of the species. In general, most sturgeon species have similar spawning characteristics. Recently a study by Bramblett and White (2001) showed differences in habitat preference for the two species, however, there was also significant overlap of habitat. Their study was in the Yellowstone and Missouri Rivers of Montana and North Dakota, which gemorphically are relatively unchanged by man. (It is stated that hybridization is not as common in these reaches as compared to modified reaches. Hybridization is encouraged when two closely related species share the same spawning grounds and when the population of one of the species is much larger than the other (Travnachek, 2003, pers. comm.).)

The spawning data collected for this investigation are presented in the table "Spawning Characteristics of Missouri River Fishes" in Appendix A. This table has its own list of references cited. Although, numerous references were used to construct the table, the table should not be considered complete. A survey or sampling approach was used. In the table, the term "river" or "large river" refers, in general, to mainstream rivers, such as the Missouri or Mississippi Rivers. The term "tributary" refers to river or other stream that is tributary to a mainstream river or a lake or a reservoir. For example, the Big Sioux River would be a tributary. "Tributary" streams, may also refer to streams that are tributary to reservoirs and or lakes. " Lake" refers to natural lakes, such as oxbow lakes or reservoirs behind dams.

Information from the table indicates that most species are able to spawn in divergent environments. Only 6 of the 85 species exhibited a dominant preference to spawning in the river. Nine of the 85 species had a strong preference for spawning in tributary streams. Twenty-five of the 85 species typically spawn in either rivers or tributaries. Twenty-one of the 85 species typically spawn in lakes and tributaries. Twenty-two of the 85 species typically spawn in rivers, lakes, and tributaries. Nine of the 85 species typically spawn in lakes and rivers. Cumulatively, 77 of the 85 species considered spawn in tributaries. Cumulatively, 45 of the 85 species are known to spawn in lakes. Cumulatively, 79 of the 85 species spawn in tributaries and or lakes. A spring rise in the Missouri River per se is not the essential cue to initiate spawning for fish species that spawn in lakes. Fish that spawn in the tributary streams and mouths of tributary streams do not per se need a spring rise in the lower Missouri River to spawn.

Temperature was identified as a major spawning cue for all species, which is to be expected, as fish are poikilthermous. Increased flow was specifically identified as an important cue for a limited number of fish species. However, several of those species, which spawn in shallow tributary streams, apparently respond to flood pulses if the water temperature is within that species spawning temperature range. The flood pulse apparently provides enough water such that the eggs are able to hatch before being exposed by lowering stream water levels. This seems to be especially important to fish species who broadcast eggs that must drift for several days before hatching; these conditions are not typical of the lower Missouri River. A spring rise may initiate migration preparatory to spawning. However, for many species, such as the shovelnose sturgeon, initiation of migrations may be from a photic cue or a temperature cue. Additionally, for most species it has not been established if migration is an essential preliminary cue to spawning or if migration is an integral part of the cue to spawn. In general, it is unclear how great the spawning distance must be to "satisfy" the urge of many fish species to migrate. Fish, such as sturgeons, may migrate to spawning grounds and not spawn. Flood pulses are typically associated with oxygenated water, which may be important to successful hatching of some species. Thus, oxygenated water may be a cue to some species to spawn and not a flood pulse per se. This may be important to several carp species, which are reported to spawn in relation to increased flow. Carp species, such as the exotic silver carp and bighead carp and others, can typically live in water with low dissolved oxygen. In this situation, it may be possible that these fish will spawn if the water is oxygenated and if temperature and conditions are suitable. However, low oxygen levels are not typical for the lower Missouri River.

Specifically in reference to the shovelnose and pallid sturgeons (**fig. 3**), data collected for the Tongue River (tributary stream of the Yellowstone River) by Elser and others, (1977, figs. 12 and 13) could suggest a correlation of shovelnose sturgeon spawning in 1975 and 1976 with the spring rises; however, these two figures also show that spawning started at about 18° C. Similar hydrographs prepared by Berg (1981) for the shovelnose sturgeon in the Marias River (a Missouri River tributary) for the years 1976, 1977, 1978, and 1979 show that the essential cue to spawning was temperature and not the typically nearly contemporaneous spring rise. This definitive conclusion was possible because the flow and temperature changes were not coincident during all the years investigated. This result confirms the USFWS (2000, p. 103) statement: "Current research, however, indicates that pallid sturgeon spawning is directly linked to water temperatures.

Figure 3. Pallid sturgeons. (USACE image.)

Further, no definitive record was found of shovelnose and or pallid sturgeon spawning in the main-stem of the Missouri River. Most pallid sturgeon researchers assume that pallid sturgeon use tributary streams for foraging and spawning (USFWS, 2000, p. 159). This is consistent with observations dating back more than 100 years that sturgeons spawn in small streams. For example, it was reported by the U.S. Fish Commission in 1884 (Goode, 1884,p. 663) that " It (shovelnose and/or pallid sturgeon) spawns early in May, ascending smaller streams for that purpose (spawn)". Moos (1978) collected "spent" shovelnose sturgeon in the Missouri River below Gavins Point Dam. It could not be determined if the sturgeon spawned in the river or the tributaries. If the sturgeon were spawning in the river, it would be conclusive information that shovelnose sturgeon can spawn without a spring rise. If the sturgeons are spawning in the tributaries as believed, there is no need per se for a spring rise in the river to cue spawning.

The information from the table (Appendix) strongly asserts that a spring rise is not the essential exogenous spawning cue for the predominance of the fishes including the pallid surgeon in the lower Missouri River as is asserted in the in the biological opinion (USFWS, 2000). The information from the table strongly suggests that temperature is the dominant and likely the essential cue for spawning of fishes of the lower Missouri River.

II.B) SPRING-RISE EFFECTS ON CONNECTIVITY AND PRODUCTIVITY

Large unmodified streams with abundant sediment that flow over soft strata typically have moving meanders. The Missouri River before modification, in general, met these criteria. The moving meanders will typically produce meander loop cutoffs and the formation of oxbow lakes and or cut off chutes. Such conditions are believed to have resulted in a river that had more biologic productivity than the present river.

Modification of the Missouri River has been significant. The physical geometric changes that relate to the aquatic/terrestrial zone reported in appendix III of the Biological opinion (USFWS, 2000; Galat and others, 1994) include:

8 percent reduction in channel length

27 percent reduction in bank-to-bank channel area

50 percent reduction in original surface area of the river

98 percent reduction in surface area of islands

89 percent reduction in the number of islands

97 percent reduction in the area of the sandbars

The net result of the geometric changes is that presently there are only a limited amount of chutes and oxbows for the river to connect to. Therefore, the proposed spring rises will not appreciably increase connectivity as is shown in **figure 4**. Additionally, the increase in spawning habitat will be small.

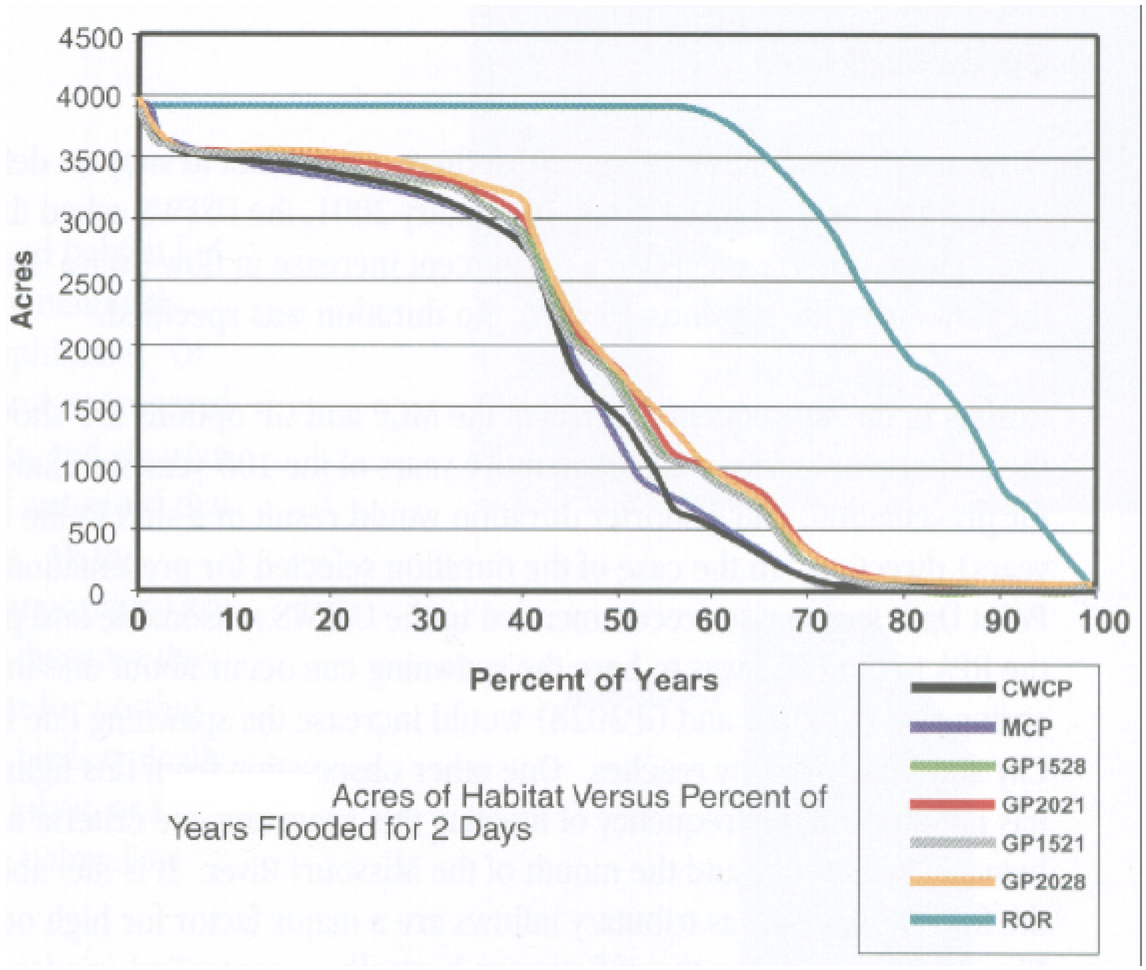


Figure 4. Connectivity for spring rise alternatives (from USACE, 2001a).

Because the areas of backwaters are reduced and because the area of the littoral zone has been reduced, and because bank stabilization has reduced river meandering, the size of the aquatic/terrestrial zone does not significantly change during a flood pulses. (However, in relation to productivity, the reduced turbidity allows more light which in turn increases the productivity at least to some degree.) In general, the increase of material, such as nutrients (including carbon), sediment, detritus, and debris resulting from a spring rise would be small. The unchannelized reach might be expected to be a “reservoir” of nutrients as this reach has more shallow areas. However, because Lewis and Clark Lake is a trap for sediments as well as nutrients, the water in that reach is likely deficient in nutrients although cut and fill alluviation would supply some nutrients in this reach. A single small tributary stream is likely to carry more nutrients and material into the Missouri than would result from the minimal increased connectivity that the proposed alternatives might produce. For example, the 25th percentile range of increased connectivity for a two day event in May and June that would result from the proposed spring rise would be 3, 380 to 3,456 acres as compared 3,282 acres without a spring rise (USACE, 2001b, pp. 7-57 through 7-61).

Because a spring rise would not significantly increase the connection of the river to adjacent water bodies and because the increase in terrestrial/aquatic zone will be minimal, it is very unlikely that the proposed spring rise would significantly increase either connectivity or productivity as postulated in the biological opinion.

II.C) SPRING-RISE EFFECTS FOR THE LEAST TERN AND PIPING PLOVER

It is stated in the biological opinion that a spring rise out of Gavins Point would create sandbars and would scour vegetation from existing sandbars. The "clean" sandbars, especially those on islands, form good habitat for the piping plover and least tern nesting. Reference is made in the biological opinion to the increased acreage of low lying sandbars that were present after 1997 in the mostly unchannelized reach between Gavins Point Dam and Ponca, Nebraska, as compared to acreage prior to 1995. The extreme flood pulses of 1995, 1996, and 1997, did not result in an increase in acres of sandbars from Ponca to St. Louis. Thus, this discussion of increasing sandbar area deals largely with the reach from Gavins Point Dam to Ponca. It should be noted that neither the high discharges nor the low discharges from Gavins Point Dam carry significant sand, and thus, sand bars are not being created per se.

The discharges out of all the main-stem reservoirs including Gavins Point Dam are deficient in sediment. Thus, degradation will occur, which reduces sandbars (USFWS, 200, p. 87). Degradation will continue the entire life of the reservoirs unless other sources of substitute sediment are made available. The rate of degradation, however, will be variable, and is dominantly a function of water velocity. The shear stress on the wetted perimeter of the stream increases as the square of the velocity. The sediment carrying capacity of the stream increases at even a greater rate (Shelton, 1966, p. 130). The amount of degradation is largely an exponential function of water velocity and duration Accordingly, a flood pulse, such as a spring rise, would dramatically increase the amount of streambed degradation.

The biological opinion points out that streambed degradation and the resulting incising of the river below Gavins Point is increasing the sandbar elevations above the normal water level of the stream. If the sandbars are not scoured (cleaned), vegetation typically increases on the sandbars, which is undesirable in relation to habitat for the term and plover. It is stated in the biological opinion that higher flood pulses will be required to scour these higher sandbars if vegetation is to be removed. The biological opinion, in general, does not consider the fact that any flood pulse that is strong enough to change the geometry of the streambed or scour the sandbars would also result in additional streambed degradation, and the river would become more incised. For example, the high flows of 1995, 1996, and 1997 resulted in about lowering of river water stage at 30,000 cubic feet per second of 2.5 feet of streambed degradation at Sioux City, Iowa, and about 1 foot in the tailwaters below Gavins Point Dam (Sando and Neitzert, 1999). The lowering of stage is a useful surrogate of streambed degradation. Degradation records based on water stage declines show that streambed degradation is rapid during flood pulses, such as a spring rise, and minimal during normal flow conditions. Streambed degradation causes the stream to incise, which over a period of time reduces the area of islands and sandbars. Thus, the proposed spring rise would incise the streambed deeper and would result in the height of the sandbars being even higher in reference to the typical stream level. Further, a flood pulse that occurs during the mating and nesting period of the least terns and piping plovers would seriously reduce the probability of successful recruitment for that year.

II.D) OTHER EFFECTS OF A SPRING RISE

II.D.1) Formation of Sturgeon Spawning Substrate Downstream of Gavins Point Dam: It is commonly stated that the streambed degradation below Gavins Point resulting from a spring rise would result in "paving" of the streambed. It is stated that streambed paving would result when a gravel layer would be formed by washing away sands and leaving gravel and cobble. The gravel and cobble would reportedly be the substrate on which sturgeons spawn. Data presented by Sando and Neitzert (1999, fig. 7) show that the average diameter of bed material in the first 5 miles below Gavins Point Dam was typically below 7 mm diameter in 1986, and after the high discharges of 1995, 1996, and 1997, the average diameter decreased to less than 2 mm diameter. (See **figure 5**.) Thus, large flood pulses disperse gravel and other coarse grained sediment from the streambed. Further, information on the materials below the Missouri River streambed near Vermillion, South Dakota, shows that the material in which the river is eroding does not contain significant gravel (Jorgensen and others, 2002, pp.51-58). Thus, significant substrate of gravel and rock suitable for sturgeon spawning in the Missouri River from Gavins Point to Ponca, Nebraska, does not exist and would not likely be created in the future by a spring rise.

II.D.2) Streambed Degradation and Wetlands: Degradation of the streambed bottom is causing lowering of ground-water levels in the floodplain lakes and wetlands of the Missouri River floodplain from Gavins Point to Omaha. The water levels in the wetlands and lakes of the floodplain are partially or completely supported by the groundwater levels in the alluvial materials of the floodplain. The river water levels are hydraulically connected ground-water levels in the alluvium. Degradation of the streambed of the Missouri River lowers the altitude of the river water levels, which in turn lowers the ground-water levels in the alluvium. The ground-water levels are, in general, connected to the water levels in the lakes and wetlands. Degradation has resulted in thousands of acres of wetlands and lake surfaces disappearing. Streambed degradation is at a maximum during flood pulses. During periods of normal or low flow degradation is minimal or sometimes reversed. A program of spring rises would result in a reduction of lakes and wetlands.

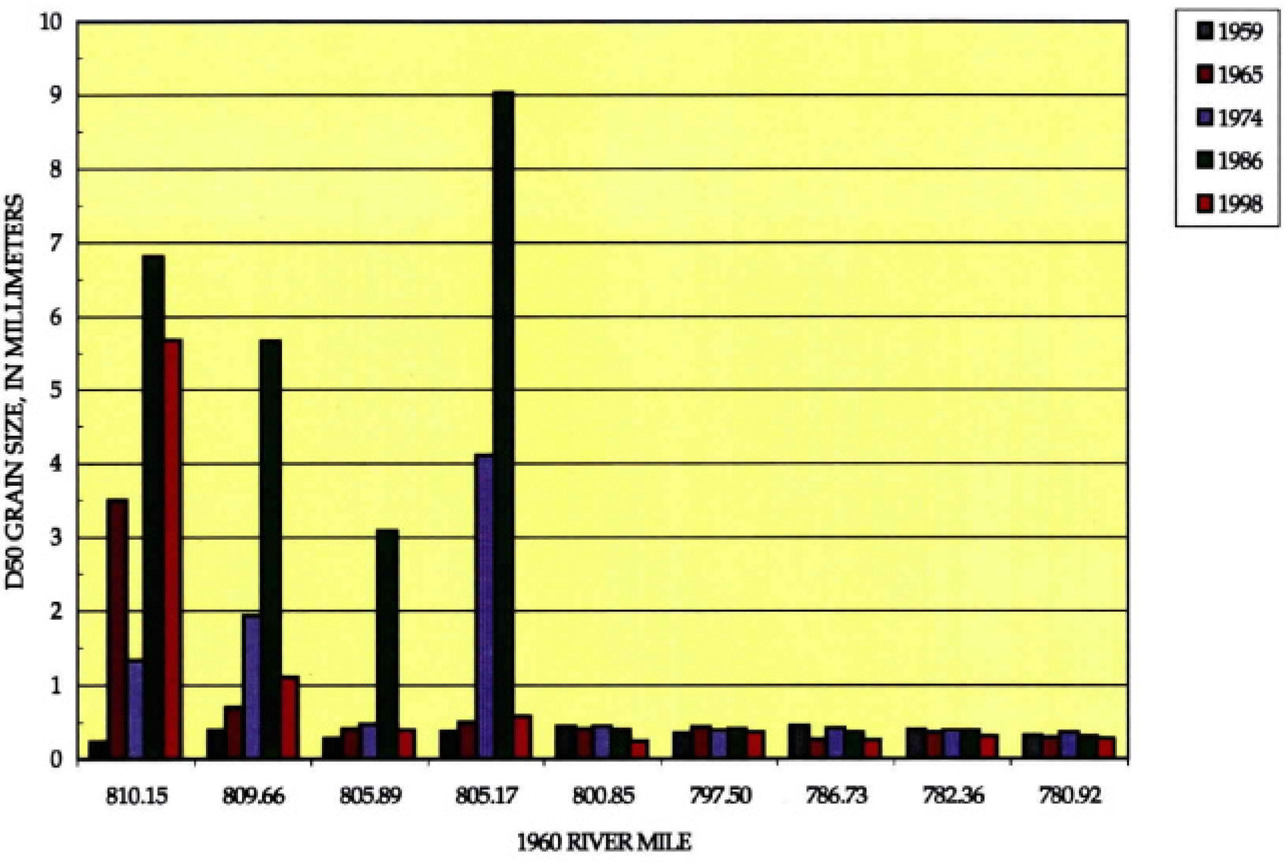


Figure 5. Bed material below Gavins Point Dam (from Sandos and Neitzert, 1999, figure 7.).

II.D.3) Drainage of Agricultural Land: Following Jorgensen and others (2002, p. 26):

> Higher river stages associated with a spring rise have been observed to retard drainage from agricultural land in the spring. The MCP and the CWCP have the least damages resulting from retarded drainage and from excessively high ground water levels (USACE, 2001a, p. 14 -15.) The proposed Gavins Point alternatives would increase spring stream levels 2.8 to 5.0 feet at Sioux City and from 2.0 to 2.7 feet at Hermann near St. Louis (USACE, 2001a, p. 11). The increased river level would decrease the entrance water-surface gradients of the drainage ditches and also reverse the normal ground-water gradient to the river, which would result in raising the ground-water levels near the river, and retard or "dam" the normal ground-water drainage more distant to the river at crop planting times.

II.D.4) Sedimentation Into the Reservoirs. Following Jorgensen and others (2002, p. 26):

> To create the spring rise below Gavins Point would require high releases from all upstream main-stem dams. Most degradation occurs during periods of high flows. Specifically, degradation is largely a function of fluid drag on the streambed. All factors being equal the drag increases as the square of velocity. Thus, the rate of degradation increases proportional to the velocity squared. The sediment removed during degradation is washed into the next downstream reservoir. This is a problem to all the reservoirs but more so to Lewis and Clark Lake, which also is the depository for the sediment from the Niobrara River. Sediment from tributary streams can be reduced by minimizing high releases and sediment loads to the reservoirs. Sediment from streams can be reduced by dams or by soil conservation practices.

II.D.5) Spring Flooding in the St. Joseph to St. Louis Reach. Following Jorgensen and others (2002, p. 27):

> The stream below St. Joseph is especially susceptible to spring flooding. The USFWS proposed RPA would exacerbate at least to some degree the already bad situation. Significant overbank flooding could result if runoff from local large rainfall events reaches the river concurrently with the "spring rise". The SRDEIS (USACE, 2001a, p.14) states, "Overall, impacts to flood control benefits resulting from any of the alternatives are considered insignificant" (USACE, 2001b, p.14). Most people would disagree with the statement, especially if you are one of the farmers flooded (potentially more than one million acres of farmland are subject to flooding) or if you live in a home that is flooded (potentially more than 30,000 homes could be flooded), or if you own a nonresidential building that is flooded (potentially more than 5,000 nonresidential buildings are subject to flooding.

II.D.6) Spreading of Purple Loosestrife. A non-native plant, purple loosestrife, has been introduced into the Missouri River Basin ecosystem (Tondreau, pers. com., 2002; Jorgensen and others, 2002, p. 27). Skinner (1996, p. 43) states:

> Purple loosestrife, *Lythrum salicaria L.,* is a perennial plant of European origin that is invading and degrading wetland habitats all across North America. Purple loosestrife forms dense monotonic stands that replace native plant species in wetland and lakeshore habitats, degrading food, shelter, and nesting sites for native wildlife… The negative effects on aquatic ecosystems caused by purple loosestrife far outweigh its attributes as an attractive ornamental or honey plant. Unlike in Europe, the growth of purple loosestrife in North America is so vigorous that native wetland species are displaced. Purple loosestrife's high-speed production produces large seed banks that can remain viable for years.

The plant is established in some locations, such as along the Missouri River in Dixon County, Nebraska. Dixon County officials believe that the weed is spread as the result of flooding. Further study is needed to evaluate if a spring rise would result in further spreading of this plant.

III) DISCUSSION AND CONCLUSIONS

The biological opinion for the Missouri River is calling for a return to a more natural hydrograph for the Missouri River. USFWS has made flow modification from Gavins Point Dam a critical element in implementing a spring rise and a summer low flow. A study by NRC (National Resources Council) agrees that flow modification is needed. Restoring the natural hydrograph is considered by some as the paradigm for "restoring" river systems. The natural hydrograph paradigm as discussed by Poff and others (1997) includes the flood-pulse concept of Junk and others (1989). However. Junk and others (1989) warn that conditions other than flow may modify the effects of flood pulses. The spring rise called for by USFWS is, of course, a flood pulse. However, others (for example, Saunders and Tyus, 1998) warn that ecological restoration is more complex than just manipulating flows. Conditions other than flow may be the controlling factors in relation to ecological health of the basin and its fishes. For example, the wholesale introduction of non-native fish species is for practical purposes an irrevocable action and is known to damaging to native fishes. Another example is the present and past introduction of numerous contaminants. (*Contaminants are believed to be causing negative environmental and health impacts and, in general, cannot be reversed by flow modification. The USFWS' RPA does not address problems of predation and, competition among fish species nor does the RPA address the problems created by hormonal disruption.)*

The USFWS (2000) has requested a spring rise on the average of once every three years and a summer low flow every year. The USFWS position is that the spring flow will restore spawning cues for fish, maintain and develop sandbar habitats for birds, enhance aquatic habitat by connecting the main channel to backwaters and side channels (connectivity), and enhance fish productivity (productivity). A purpose of this investigation is to determine the likely effects resulting from a spring rise on the Missouri River and to relate the information acquired for this study to management of the Missouri River, especially below Gavins Point Dam.

Data on spawning of Missouri River fish species were collected and tabulated to allow comparisons and evaluations of items that result in cueing of the Missouri River fish species to spawn. Galat and Clark studied spawning temperatures for 84 species of the 99 species that are believed to be present in the Missouri River. This study used the same 84 species plus the pallid sturgeon. Results of the survey include: Fifty-three of the 85 species spawn in tributaries and or other environments. (If the species are spawning in tributaries, it is then moot if the river has a flood pulse or summer low flow in reference to spawning.) Thirty-nine of the 85 species spawn in lakes. *Cumulatively 79 out of the*

85 fish species can spawn in tributaries and or in lakes. If the species are able to spawn in tributaries and or in lakes, the RPA statement that a spring rise is required to cue their spawning in the lower Missouri River is in error and or moot. Thus, the assertion in the biological opinion that a spring rise must be implemented to cue spawning of lower Missouri River fishes is arbitrary.

In reference to spawning of the shovelnose sturgeon and the closely related pallid sturgeon, the USACE (2001b, p. 3-96) reports the following:

> Shovelnose spawn over substrate of rock rubble, or gravel in the main channel and on the major tributaries or on wing dams in larger rivers (Christiansen, 1975; Elser et al., 1977, Moos, 1978; Helms, 1974). In the unchannelized Missouri River near Vermillion, South Dakota, shovelnose sturgeon spawn in late May through June with water temperatures near 18.5°C to 19.5°C (Moos, 1978). Shovelnose spawning also has been documented in the lower Tongue River near Miles City, Montana, from early June until mid-July at temperatures of 17.0°C to 21.6°C (Elser et al., 1977). Initiations of spawning migrations have been associated with seasonal flow differences (Peterman, 1977; Zakharyan, 1972).

Some explanation of the above quote is needed and also some information on the references provided is useful. It is commonly reported that wing dikes are spawning areas for sturgeon. However, the author is unaware of any actual observations or other convincing evidence of sturgeon spawning on wing dikes. The study by Christiansen (1975) dealt with the effect of contamination of catfish on the lower Missouri River. The study Elser and others (1977) dealt with the Yellowstone and Tongue Rivers, which are tributary streams in Montana and do not represent the conditions in the lower Missouri River. The study of Moos (1978) dealt with shovelnose sturgeons in the unchannelized Missouri River below Gavins Point Dam. Moos collected “spent” shovelnose sturgeon; thus, indicating the sturgeon had spawned. However, it could not be ascertained if the shovelnose had spawned in the River or in tributary streams. (If the sturgeons are spawning in the tributaries, it is moot if there is a spring rise on the Missouri. If the sturgeons were spawning in the Missouri River, they were spawning without the benefit of a spring rise.) The Helms study (1974) dealt with shovelnose sturgeon in impoundments on the Mississippi River. The additional information about the referenced studies above is to help the reader not to infer from the RDEIS statements that shovelnose and pallid sturgeons are necessarily spawning in the lower Missouri River. Sturgeons may be spawning in the main-stem of the lower Missouri River, but this cannot be ascertained from the references given in the RDEIS.

The RDEIS lists Peterman (1977) and Zaharyan (1972) as references to support that migration of sturgeons is due to seasonal differences of flow. The Peterman article dealt with spawning on the Lower Yellowstone River, a tributary stream in Montana. The article did not consider temperature but only remarked on flow. As is previously stated in this report, spawning of sturgeons has been shown to be controlled by temperature and not the typically contemporaneous flow change. The Zaharyan article dealt with sturgeon reproduction in a Russian stream. That article reports that more spawning occurred on years with higher water levels because the higher water levels inundated more of the spawning site. This additional information is provided to help the reader not to infer that the Peterman and Zaharyan studies state that spawning is cued by flood pulse. In fact, the Iowa DNR reports that sturgeon-spawning runs were largest during years of low flow in the tributaries (Iowa DNR, 2002).

In reference to the endangered pallid sturgeon and the shovelnose sturgeon, results from this investigation indicate that temperature is the essential cue for sturgeon spawning. This result confirms the USFWS (2000, p. 103) statement: “Current research, however, indicates that pallid sturgeon spawning is directly linked to water temperature”. Notwithstanding the previous statement, USFWS (2000, p. 233) then states, that flow modification (including the spring rise) would “trigger spawning activity in pallid sturgeon and other native fishes”. The question arises which statement is correct. Further confirmation that USFWS knows that the spring rise will not result in cueing the pallid sturgeon comes from the USACE’s Summary of the Revised Draft Environmental Impact Statement (SRDEIS). Specifically the USACE (2001a, p. 22) states:” Corps and USFWS biologists agree that there are no data to support definition of a spawning cue that would successfully result in spawning in the Lower River”. (In the previous sentence, spawning cue refers to the spawning cue for the pallid sturgeon and Lower River refers to the Missouri River below Gavins Point Dam.) The most compelling evidence that a spring rise is not the essential control for successful spawning of pallid sturgeons in the lower Missouri River is that the reach between St. Joseph, Missouri, and St Louis has a spring rise nearly every year. Thus, if the spring rise were the controlling element then this reach would have a relatively high population of pallid sturgeon larvae and young of the year. This is not the case. A similar observation is that the lower Missouri River has many tributary streams that have spring rises. If a spring rise was the control, then larvae and young of the year pallid sturgeon would be found in more than trivial quantities in these tributary streams as well as in the lower Missouri River; however, this is not the case.

The pallid sturgeon and to a lesser degree the shovelnose sturgeon are not successfully spawning in the lower Missouri River, which is probably in part due to the lack of gravel substrate. Galat and others (2001, fig. 13) investigated the bed material in the Missouri River. The typical gravel content of bend sections in the Lower River ranged from 5 to 20 percent, which is inadequate for a substrate suitable for sturgeon spawning. Substrate suitable for spawning must have gravel of such a size that it is stable in reference to the velocity of water in the stream because the eggs adhere to the gravel. Accordingly, a substrate consisting of 80 percent or more of material less than gravel size is likely unstable in fast velocities associated with spawning. The lower Missouri River does have wing dams and revetments made of large rock. However, these rocks are typically covered with algae and are not likely to be suitable sites for sturgeon eggs to adhere (**fig. 6**). Thus, there is little substrate suitable for sturgeon spawning in the main-stem of the lower Missouri River. Further it is questionable if the main-stem of the Missouri River, especially the lower Missouri River, was ever an important spawning area for the pallid sturgeon. Observations of sturgeon spawning in tributary streams have been reported. For example, The U.S. Fish Commission reported in 1884: “This species is found in abundance in all the larger rivers of the West and South. It spawns in early May, ascending smaller streams for that purpose.” “Species” referred to shovelnose and or pallid sturgeon and "purpose" referred to spawning. It is believed that most sturgeon spawn in tributary streams (USFWS, 2000, p. 159). If so, spring rises on the lower Missouri, will have little or no effect on spawning. *The above information and observations do not support the contention that a spring rise would result in sturgeon spawning in the lower Missouri River.*

Large-scale changes in the geomorphology of the Missouri River have occurred. The reservoirs have greatly changed the stream as well as blocked the migration of certain fish species. In the lower Missouri River, bank stabilization has narrowed the stream and greatly reduced the islands and the area of sandbars. The net result is that presently there are only a few chutes and other backwaters that can be connected to the river no matter what size of a spring rise is applied. The USACE (2001b) determined that a spring rise for the lower Missouri River with a two-day duration of connectivity (at the 25th percentile range) would result in 3380 to 3456 acres connected. This compares to 3,282 acres connected for the current water plan. *Thus, the improvement of connectivity due to a spring rise for the lower Missouri River is slight to nearly non-existent.*

Figure 6. Algae covered riprap. This quartzite riprap had been submerged for about 3 months. Rock size ranges from more than 1 foot to about 3 inches. Algae covered rock is unsuitable substrate for spawning sturgeon.

The change of the geometry of the channel for bank stabilization and navigation on the lower river has greatly reduced sandbar islands and sandbars. The change has resulted in a reduction of the aquatic/terrestrial zone. Bank stabilization has reduced the cutting and other erosion of banks. These two changes along with the loss of connectivity have greatly reduced the streams ability to exchange nutrients. Lack of nutrients tends to reduce productivity of aquatic organisms. *Thus, the proposed spring rises will do little to increase the productivity of the river.* It should be noted that the river does not exist alone; that is the river has numerous tributary streams. In general, the drainage area of the Missouri River Basin is nearly the sum of drainage areas of the tributaries. *These tributary streams are the largest source of nutrients, sediment, and debris. To suggest that a spring rise on the main-stem of the lower Missouri R will significantly alter the problems related to productivity and connectivity of the lower Missouri River without considering the tributaries is not realistic.*

It is suggested in the biological opinion that sandbars and new islands will appear after spring flows, which would be suitable habitat for the least tern and piping plover. The GP alternatives would increase the habitat less than 170 acres (USACE, 2001a, p.23). (It is likely that acreage of eliminated wetlands and lakes resulting from streambed degradation will far exceed 170 acres.) As stated previously, the reduction in islands and sandbars has been in the order of 90 percent. However, additional habitat suitable for the least tern and piping plover virtually unused exists on the Missouri River, especially below Garrison Dam. Both the piping plover and the least tern are gregarious birds and tend to nest in colonies; this characteristic is detrimental to their recruitment. For example, the reach downstream from Gavins Point Dam has provided the greatest number of fledged birds even though it has 80 percent less habitat. Further, since 1998, the majority of the tern and plover below Gavins Point Dam occupy just one sandbar island, while other islands are sparsely occupied. *The above information strongly suggests that habitat for nesting is not the critical factor that is controlling the least tern and piping plover populations. Thus, the USFWS hypothesis that the operation of the Missouri River is causing jeopardy to these two birds is questionable and unsubstantiated. The logic of imparting a flood pulse on the sandbars during the nesting period of the terns and plovers is faulty.*

Another purpose of the spring rise is to scour the vegetation from the existing sandbars. In 1998 after the three abnormally high flow years, the acreage of islands and sandbars had increased significantly. The biological opinion states that the results from the three high flow years are confirmation that spring rises will significantly increase the area of vegetation-free sandbar islands of suitable habitat for the least terns and piping plovers. It has been suggested that these three years are "models" of spring rises, or are indicative of the results a spring rise would produce. This is misleading, the high flows (discharges out of Gavins Point) for 1995, 1996, and 1997 cannot be considered comparable to spring rises proposed for Gavins Point flow modification. Presently there are 104 years of flow records available; the 1995 discharges were the 102nd highest, 1996 discharges were the 98th highest, and 1997 discharges were the highest on record. It is a "giant stretch" to consider those three years as models of the results that spring rises as proposed in the biological opinion could be expected to produce. When streams experience higher than average flow years, the width of the streambed tends to widen. However, any flow that can widen the streambed will also cause streambed degradation and over a period of a few years of more normal flow, the streambed will narrow and because the river below Gavins Point is deficient in sediment, some minimal degradation will still occur. The degradation at Sioux City after 1998, after the high-flows of 1995, 1996, and 1997, was about 2.5 feet. Records show that high-flow years have resulted in severe degradation. Records also show that low-flow years, in general, have resulted in minor or negligible degradation. These observations are consistent with the tenets of alluvial geomorphology. Each time a flood pulse occurs, accelerated degradation will occur. The degradation will in effect increase the difference in elevation between the normal river water level and the top of the island or sand bar. Thus, in many cases, it will require even a greater flood pulse to overtop the island and or sand bar to cause cleaning. It seems unfortunate that the process of scouring islands and sand bars by flood pulses is ultimately self-defeating. However, water is not the only agent acting on the geomorphology of the sandbars and sandbar islands. Wind (eolian) processes both scours and builds sand bars and islands, especially during the winter when water levels in the river are low. Eolian effects on sandbars were not considered in other than a cursory manner in the biological opinion. Eolian erosion and deposition can and does provide clean sand habitat. *The logic expressed in the biological opinion that a series of spring rises over the long term will result in more islands and clean sandbars should be carefully reexamine as it is not consistent with the tenets of alluvial geomorphology nor is it consistent with data collected.*

USFWS biologists are of the opinion that degradation of the streambed bottom will result in creation of a gravel substrate that would be suitable for sturgeon spawning (Krentz, 2002). However, data by Sando and Neitzert (1999), and Galat and others (2001) indicate that gravel is absent or in quantities so limited that it is inadequate to form a suitable substrate*. Further, Jorgensen and others (2002) listed subsurface data that indicate there is little or no gravel in the material below the streambed; thus, degradation will not likely result in the "creation" of a gravel substrate suitable for sturgeon spawning.*

Additionally, a spring rise would initiate a series of events that will result in negative environmental and economic impacts. These include:

* A spring rise would cause streambed degradation that would lower water levels in the river, which ultimately would lower the ground-water levels in the flood plain from Gavins Point to Omaha. Lower ground-water levels would cause even more wetlands and lakes to go dry (Jorgensen and other, 2002). (See **figures 7a and 7b.**) Lowered ground-water levels and river levels would result in increased pumping costs for the areas municipalities, rural residents, and irrigators.

*A spring rise would retard drainage from farmland in the spring during planting season. This problem becomes more severe below St. Joseph where a spring rise on the Missouri River occurs nearly every year.

*A spring rise would increase streambed degradation downstream of all the dams. (A spring rise will typically require high discharges from all the reservoirs.) The eroded streambed material would be deposited in the next downstream reservoir.

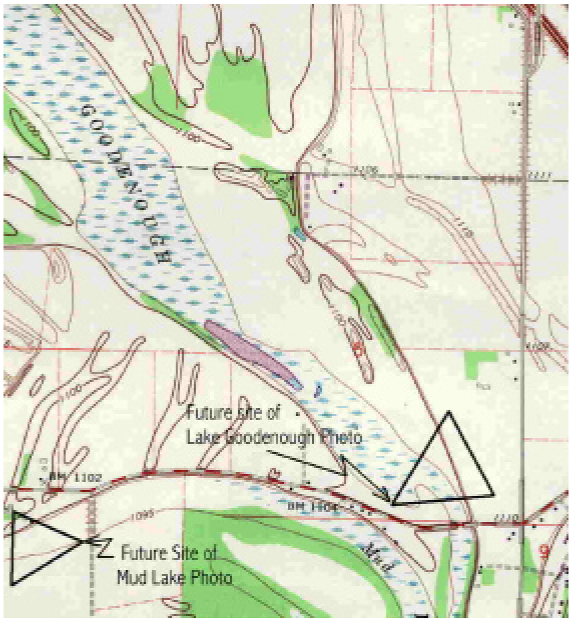


Figure 7a. Lake Goodenough, 1963. Section of a 1963 USGS topographic map. Note the future photo sites.

Figure 7b. Lake Goodenough, 2002. Much of Lake Goodenough is now farmed. Degradation has lowered water levels to the extent that at this location it is not a lake and does not exhibit wetland characteristics. (See last figure for location.)

* A spring rise would increase the risk of spring flooding along the river from Omaha, Nebraska, to St. Louis, Missouri.

*A spring rise could increase the spreading of purple loosestrife.

Holistically, the information available indicates that flow modification from Gavins Point Dam would not significantly help the pallid sturgeon. Flow modification could harm, the least tern, or the piping plover and would result in significant environmental and economic harm. The flow modification element of the RPA of the biological opinion should be removed at this time

Additionally, the premise used to develop the biological opinion needs revisiting. The premise has apparently been made that the changes made on the Missouri River, although dramatic, are the reason that the pallid sturgeon, least tern and piping plover populations are small. Based upon information gathered by this study, the veracity of this assumption is questionable and needs further consideration.

Below are some related thoughts and aspects of Missouri River management that should be further considered:

*The range of the piping plover has increased over time in the Missouri River Basin (Beacom, personal communication, 2002; Jorgensen and others, 2002; Peasron, 1917, p. 264). *Thus, it is illogical to conclude that the operation of the Missouri River by USACE has jeopardized the piping plover.*

* Typically, fish productivity is relatively high at mouths of tributaries of the Missouri River and large rivers in general. The presence or absence of a spring rise on the Missouri River will, in general, not affect the productivity associated with the mouth of the tributaries. *Because tributary mouths are very productive, and because many fish species spawn in the mouths of tributaries, efforts to improve conditions in the mouth of tributaries should be developed and included in any management plan.*

* Because temperature is the essential cue for spawning fish in the lower Missouri River, a means to control or better regulate the temperature of water releases from the reservoirs should be developed and implemented. This would allow the temperature of the water released through the turbines to better match the water temperatures that cue spawning of fish. In general, the water released through the dam turbines is colder than the water would have been if the dams were not there (U.S. News & World Rept., 2002, p. 41). Jordan's investigation (2000) included an analysis of the effect of the water released from Fort Randall Dam on native fish populations including the shovelnose sturgeon. Information and data presented showed that temperature of the water in the river below Fort Randall was directly controlled by the temperature of the water released from the dam in the reach between the dam and the Niobrara River. This cold-water release delayed spawning of the fish by about two weeks.

Mixing the warmer water that typically discharges over a spillway with the typically colder water, which discharges through the turbines, is one method of warming the exit waters. This approach has some shortcomings because it can only be done, under present river management, in years when there is "spare" water in the reservoir. In general, water over the spillways is not used to produce renewable hydroelectric power. A potentially better method would be to construct a water-feed structure for the turbines that allows water at desired temperature to be taken from the reservoir at intake elevations, which are likely to be at different elevations at different times.

*Tributary streams are typically the major source of fish production for large streams. Large rivers are typically highways for fish (Junk and others, 1989). Large rivers act as refuges for fish in tributaries when lack of water, or excess turbidity is in the tributaries (Ruelle and others, 1993, p. 449). Some Missouri River tributaries have a spring rise and should contribute a large proportion of fish to the lower Missouri River. The question arises, why aren't more fish being propagated in the tributaries? *It is not unlikely that under present conditions, the controlling factor on fish populations in the lower Missouri River is the lack of production in the tributaries.* If that is the case, flow modification on the lower Missouri River will not significantly increase Missouri River populations of the different fish species. *Efforts should be made to improve conditions for successful fish reproduction on the tributaries.*

Additionally, changes should be made on the tributary streams that would improve conditions on the Missouri River. Problems on the tributaries include the ubiquitous annual stocking of predator fish in the tributary streams and their reservoirs by the State game and fish agencies often in conjunction with the USFWS. Endocrine disruption is likely seriously affecting the shovelnose sturgeons (and most likely affecting the pallid sturgeon and other Missouri River fishes). In the Mississippi River near Saint Louis, shovelnose sturgeons (and most likely pallid sturgeons and other fish species) are being affected by endocrine disrupters (Harshbarger and others, 2000). Building of dams near the mouths of the tributaries is likely to be significantly reducing fish recruitment from the tributaries to the Missouri River. For example, dams (without any type of fish bypass) may be blocking the migration and spawning of pallid sturgeon on suitable substrate in tributaries (Beacom, pers. communication, 2002). *The RPA, except for the Kansas River, does not address problems on the tributaries that are impacting the fish population in the Missouri River. Habitat restoration or creation on tributary streams and the mouths of tributaries would increase fish populations on the Missouri River and should be part of any program of restoration.*

* Tributary streams could be used to control sedimentation and turbidity to some degree. For example, sediment control on tributary streams that flow to reservoirs would reduce the rate of reservoir filling. Conversely, increasing the sediment and nutrients in tributary streams that flow into the Missouri River below reservoirs could under certain limitations result in improved conditions in the Missouri River.

* Because a spring rise would not likely significantly help the fishes and because a spring rise would have many environmental and economic negatives, emphasis should be on habitat, restoration/ creation/ acquisition, unbalancing the reservoirs, monitoring, and

propagation/ augmentation as discussed in the biological opinion for the Missouri River. Habitat restoration or creation would develop habitat suitable for spawning for many Missouri River fish species. This habitat would include new low water velocity areas. Restoration or building chutes and backwaters should result in increased nutrient exchange needed for increased productivity. For example, increased sand bars and low velocity areas can be achieved by notching wing dikes and other techniques. (See **figures 8a and 8b**.)

* Predation and competition of introduced non-native fish species could be a major reason for the demise of native fish, such as the pallid sturgeon. The National Research Council (NRC, 2002, p. 2) states:

> In many reaches of the river, nonnative sport fish exist in greater number than native species. The nonnative fishes are the most tolerant of altered conditions of temperature, turbidity, and habitat. Although some nonnative fish produce substantial economic benefits, nonnative species may also contribute to the declining abundance of native fish.

A growing number of biologists believe that introduction of non-native fish is the major reason for the decline of native fish in the country. Tyus (2002) stated:

> The native Missouri River fish community has been greatly affected by human induced habitat change. Populations of at least nine native fishes have declined in range and abundance in all or some portion of the river system. These declines have been mostly attributed to physical and chemical alterations of habitat. However, as physical habitats were being altered by water resources development, nonnative fishes were introduced into these modified environments. In newly created reservoirs, turbid riverine conditions were replaced by clear lacustrine-like environments and stocked with hardy, highly aggressive predaceous and/or competitive fishes. Some introduced fishes were "pre-adapted" to the modified environments and thrived in them. But these same conditions were alien to the native fishes, which universally declined. Remaining riverine sections are more suitable to the native fishes. But introduced fishes also have increased in the remaining riverine habitats due to direct stockings, and escapements from reservoirs and tail waters. Physical habitat changes contributed to the declines of some of the native fishes would not have been so precipitous if fish introduction had not occurred. Additional fish introduction and management practices favoring the spread and proliferation of introduced species could hasten native fish declines, result in more threatened or endangered listings, and reduce options for recovering species listed now and in the future. There is a critical need for management agencies to recognize the potential problems of fish introduction, to investigate these problems with well-planned research, and to develop management options for reducing the adverse reactions between introduced and native Missouri River fishes.

The above information strongly suggests that there is a need to evaluate the role of predation and competition of native and nonnative species. The tributary streams are being extensively stocked with predator "game" fish by State agencies. The Missouri River main-stem reservoirs are also being stocked by State agencies with predator "game" fish. Additionally, the reservoirs also are being stocked with non-native fish to feed the predator fish. The stocking is often done in conjunction with USFWS who supplies fish for stocking. *It is not surprising that recruitment of pallid sturgeon and other native fish is low or nearly non-existent if predator fish are eating the eggs, the larvae, and the young of the year as well as in competition for habitat*.

The RPA in the biological opinion should be revised to include measures to eliminate or reduce predation or competition by non-native fish species on native fish species and to take advantage of new information and analyses that are now available.

Figure 8a. Notched wing dike, upstream view. Notch is in front of sandbar behind wing dike.

Figure 8b. Chute and sandbar downstream of notched dike. View is looking downstream from the notch. The notch formed a channel near the shore and a large sandbar island at low stage or a large low velocity shallow area during a higher stage.

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V) APPENDIX A, TABLE 1

Part A, Worksheet 1.

In the following table, the term “river” or “large river” refers to a large or mainstream river, such as the Missouri River. The term “tributary” or “tributary stream” refers to a tributary to a mainstream river, lake, or a reservoir. The term “lake” refers to a natural lake or a reservoir. The order of the presentation of the fish species is the same as used by Galat and Clark (2002). In general, the order is that of increasing spawning temperature.

SPAWNING CHARACTERISTICS OF MISSOURI RIVER FISHES

Common Name	*Scientific Name*	Spawning Characteristics
Mountain Whitefish	*Prosopium williamsoni*	Spawning is in rivers, tributaries and lakes. Spawning is in cool water, typically on gravel riffles and or in lakes on near shore gravel shoals in October and early November (Washington Dept. Fish and Wildlife,1991; Breden and Rosen, 1966,p. 122-123). Spawning is at 0 - 6 deg. C. (Galat and Clark, 2002). Eggs receive no parental care and hatch in about 36 days at 13 deg C.
Burbot	*Lota lota*	Spawning is in rivers and tributaries. Spawning is in low velocity areas, such as in side channels behind deposition bars with substrate of sand or silt. Burbot do not make a nest (USDA Forest Service, 2002). Spawning is generally under ice in water 1 - 4 deg. C. (U.S. Army Corps Engineers, 2002; Becker, 1983). Incubation period is 4 to 5 weeks at 4 deg. C. (Breder and Rosen, 1966, p. 376).
Walleye	*Stizostedion vitreum*	Walleye spawn in shallows of lake, tributary streams, and large river environments (Schultz, 1999; Peterman, 1977). Preferred substrate is rocky or shallow gravel beds (Paulson and Hatch, 2002). Typical spawning temperature is about 9 deg. C. (Schneiders, 2002). Galat and Clark (2002) list range of spawning temperatures of about 3 to 17 deg. C. Fertilized eggs fall to bottom and adhere. Eggs receive no parental care and hatch in about 1-3 weeks. Walleye typically grow to 20 cm length the first year (Pflieger, 1997, p. 346).
Cisco	*Coregonus spp*	Cisco spawn in late fall or early winter in water 1 to 3 meters depth (Walleyes Unlimited, 2002) on reefs in lakes or in mouths of tributary streams. Substrate is generally gravel. Spawning temperature is 4 - 5 deg. C.(Schultz,1999; Galat and Clark, 2002). Eggs are given no parental care and hatch within four months. Temperature over 15.5 deg C is fatal (Schultz, 1999).

Northern Pike	*Esox lucius*	Northern pike spawn in the spring, moving into the heavily vegetated areas of lakes, rivers or small streams either just after ice-out or in some cases prior to ice-out. In many places they spawn in wetlands or marshes or sluggish rivers that will have little or no water later in the season. Spawning temperature range is 4- 11 Deg. C. (Lake Access, 2002) Eggs are broadcast and fall to the bottom and adhere to vegetation (Schultz, 1999; Moen, 1995). The eggs hatch in 12 - 14 days, but the newly hatched embryos attach themselves to the vegetation using an adhesive organ of the tops of their heads until they are completely developed in another 5 - 15 days (Paulson and Hatch, 2002).
Sauger	*Stizostedion canadense*	Spawning is in tributary streams, and rivers (often with turbid water). Spawning can be in lakes on shoals. (Canadian Sportfishing, 2002). Sauger spawn in the spring at temperatures of 4 - 12 deg. C. (Wynne, 2002: Galat and Clark, 2002). In large river systems, the upstream spawning run can cover 100 to 200 miles, although suitable substrate may be near (Schultz, 1999). Data collected by Berg (1981) and Elser and others (1997) show that sauger spawn in the Marias River and Tongue River in response to a temperature cue.
Rainbow trout	*Oncorhynchus MyKiss*	Rainbow trout live in both cool lakes, reservoirs, and in tributary streams. They spawn in small tributaries of rivers, or in inlets or outlets of lakes (Fly Fishing NC, 2002). Paulson and Hatch report that in Minnesota if spawning is in a tributary stream that a stream raise as well as the correct temperature is needed for spawning. However, hatchery studies show that water temperature controls initiation of spawning(Hokanson and others, 1973). Spawning temperatures range from 4 -11 deg. C. (Galat, 2002; U.S. Fish and Wildlife, 2002). Spawning is in nests. Preferred substrate is gravel and sand. Eggs are laid in shallow pits (Pfleiger, 1997, p. 224). There is no parental care. Free-swimming embryos with yolk sacks develop in 20 to 80 days depending on temperature. Embryos remain in gravel for another 2-3 weeks until fins develop (Paulson and Hatch, 2002).
White sucker	*Catostomnus commersoni*	White sucker is predominantly a small creek fish. Spawning is typically in tributary streams or slow rivers on gravel beds but white suckers will spawn on shallow shoals of lakes (Schultz, 1999). Spawning initiates when water reaches 10 deg. C. (Newfoundland and Labrador, 2002; Davis, 2000). Galat lists a 7 - 10 deg. C. spawning range. Eggs are buried in gravel. Hatching is about 19 days at 10 deg. C. (Pfleiger, 1997, p. 179).
Mooneye	*Hiodon tergisus*	Spawning is in spring in rivers and tributary streams on rocky or gravelly strata in moving water (Paulson and Hatch, 2002). Eggs are broadcast. Spawning temperature is 8 to 15 deg. C. (Galat and Clark, 2002).

Shorthead redhorse	*Maxostoma macrolepidotum*	Spawning is in rivers and tributaries with relatively clear water in slow to moderate velocity reaches over submerged gravel or sandbars at temperatures of 8 - 21 deg. C. (Iowa DNR, 2002; Virginia Tech, 2001). Spawning is controlled by slight change of temperatures at different times of the day (Virginia Tech, 2001,Tenn WRA, 2000). Eggs are laid in shallow trenches or circular "nests" (Pfleiger, 1997, p. 190)
Rainbow smelt	*Osmerous Mordax*	Spawning is typically in tributary streams but can spawning can occur along lakeshores. Preferred substrate is believed to be gravel. Typical spawning temperature is 4 - 10 deg. C. Range of spawning temperature is 2 - 15 deg. C. (Schultz, 1999; Galat and Clark, 2002). Eggs with adhesive stalk are laid in gravel, typically near a barrier, such as a log (Carlander, 1969). Eggs hatch in 10 days at 15 deg. C. (Pfleiger, 1997, p.222).
Silver lamprey	*Ichtyomzon unicuspis*	Adults migrate to tributary streams in spring to spawn in sand and gravel among rocks and riffles (Iowa. DNR, 2002; Tenn. WRA, 2000; Ohio DNR, 2002). Spawning temperature range is 9 - 21 deg. C. (Galat and Clark, 2002).
Blue catfish	*Ictalurus furcatus*	Spawning is in rivers, tributaries and lakes. Spawning temperature is typically from 21 - 24 deg. C. (Driscoll, 2000; Iowa DNR, 2002) Blue catfish spawn in constructed nests in holes under logs, in crevices, and undercut banks. After hatching parents give care.
Plains minnow	*Hybognathus placitus*	Plains minnow is typically a big river fish or large tributary fish. However, spawning is typically in shallower tributary streams. Successful spawning in many shallow streams, such as the Cimarron River in Oklahoma only occurs after high flows; although, spawning is intermittent during the long spawning season. Successful spawning is dependent on having adequate stream flow for the survival of the eggs and young fish (Wilde, 2002). Spawning may occur in large rivers as the species is found in the Missouri River. Spawning temperature range is 9 - 27 deg. C. (Galat and Clark, 2002).
Ghost shiner	*Notropis buchanani*	Little spawning data are available for this river and tributary shiner (Harlan and Speaker, 1951, p. 83; Pfleiger, 1997, p.144). Ghost shiner prefers sluggish water and will tolerate turbidity (Iowa DNR, 2002). Spawning temperature range is 9 - 27 deg. C. (Galat and Clark, 2002).
Longnose sucker	*Catostomus catostomus*	Spawning is in tributary streams, inlets, or rock shoals of lakes over sand and gravel (Lentsch and others, 1966, pp. 70-73;). Spawning initiated as water approaches 15 deg. C. (Lentsch and others, 1996). Range of spawning is 10 - 15 deg. C. (Galat and Clark, 2002). Eggs are demersal and initially adhesive. Eggs are left unattended. Incubation time is about 8 days at 15 deg. C.
Logperch	*Percina caprodes*	Spawning is on gravel shoals in lakes and mouths of small tributary streams (PA Fish Boat Com., 2001). Substrate is clean sand and or gravelly sand (Pfleiger, 1197, p.336). Logperch spawn in spring and summer in water 10 to 15 deg. C. (Virginia Tech, 2001;Galat and Calrk, 2002). Eggs that are not buried in the act of mating are often eaten. The eggs are unguarded and hatch in 7 to 14 days.

Blue sucker	*Cyleptus elongatus*	Spawning is in large rivers over gravel and rock riffles. Spawning is between temperatures of 10 to 23 deg. C. (New Mex. GF, 2002; Paulson and Hatch, 2002; Iowa, DNR, 2002). Blue suckers are gregarious spawners broadcasting semi-adhesive eggs directly in the current. Eggs are adhesive and stick to rocks (USGS, 1995).
Goldeye	*Hiodon alosoides*	Spawning is typically in tributary streams or backwater lakes. Spawning is in turbid to semi-turbid water at 10 to 13 deg. C. (Iowa DNR, 2002;Schultz, 2001). Eggs are broadcast in a shallow water column typically over rock or gravel. The eggs are semi-buoyant and hatch in about 2 weeks (Paulson and Hatch, 2002; Breder and Rosen, 1966, p.140; Scott and Crossman, 1973).
Paddlefish	*Polyodon spathula*	Spawning has been observed in tributary rivers such as the Yellowstone River (White and Bramblett, 1993). Paddlefish spawn at night in swift flowing water on gravel (USFWS, 2002). The eggs attach to pebbles and hatch in about 7 to 9 days (Stone, 2002). Spawning has been observed below Gavins Point Dam. Spawning was also observed in the Osage River of Missouri (Purkett, 1961). Spawning has been apparently induced at a location below a dam by a "sudden water level rise of 6 foot"; however no temperature data was included. (Quarry Commando, 2002). Paddlefish larvae were collected in the Big Sioux River in 1978 (Tondreau, 1979). Spawning occurs at temperatures of 10 - 16 deg. C. (Iowa DNR, 2002; Schultz, 1999). Adhesive eggs are released and sink to the bottom where they attach. Eggs hatch in nine days at 14 deg. C. (Pfleiger, 1997, p.54)
Gizzard shad	*Dorosoma cepedianum*	Gizzard shad spawn in shallow water near shore (Penn. Fish Boat, 2001; Virginia Tech, 2001) in tributaries, lakes and rivers. Eggs are broadcast and fall to bottom and adhere to vegetation and debris on bottom. Spawning temperature range is at 10 - 21 deg. C. (Iowa DNR, 2002; Schultz, 1999) Eggs are demersal, and adhesive. Hatching occurs after 95 hours at 17 deg. C., and after 36 hours at 27 degrees C. (Breder and Rosen, 1966, p. 89).
White perch	*Morone Americana*	White perch live in lakes, ponds, and reservoirs in fresh, salt or brackish water. Spawning is in tributary streams in shallow water over many types of bottoms (Schultz, 1999;SC Bass, 1998). Spawning temperature range is 14 - 24 deg. C. White perch are intermittent spawners. The eggs are broadcast and fertilized near surface. Eggs are adhesive and stick to any object. Eggs typically hatch in less than 5 days depending on water temperature (PA Fish Boat, 2001).

Lake Sturgeon	*Acipenser fulvescens*	Spawning is typically in swift tributary streams on gravel bars or below dams (Schultz, 1999; NYS Dept. Envir. Conser., 1999) Spawning has been observed in shallow areas of lakes, such as on large rubble on windswept rocky shores of islands. Spawning may start in the fall and then over winter at the spawning site. Peak spawning is between 9 to 14 deg. C. Large adhesive eggs are deposited on the bottom (Pfleiger, 1997, p.49). Eggs hatch in about 8 days depending on temperature (Paulson and Hatch, 2002)
Longnose dace	*Rhinichthys cataractae*	Spawning is in tributary streams or rivers at swift riffles over gravel and sand (PA Fish Boat, 2001; Iowa DNR, 2002) and along shoreline of lakes (Lentsch and others, 1996, p.61). Spawning temperature range is 12 - 19 deg. C. (Galat and Clark, 2002). Males may guard nest and eggs. Eggs hatch in 7 to 10 days at 16 deg. C.
Smallmouth bass	*Micropetrus dolomieui*	Smallmouth bass spawn in the spring in rivers, tributaries, and lakes between the temperatures of 12 to 22 deg. C. (Virginia Tech, 2001; Galat and Clark, 2002). Spawning in streams is reportedly retarded by floods (Elser and others, 1977, p. 21). Lentsch and others (1996, p.105) list spawning temperatures between 11 and 24 deg C. Spawning is in nests typically in sand near an obstruction, such as a log or rock. Males may guard nest, hatch is about 2 to 9 days depending on temperature (Iowa DNR, 2002; Paulson and Hatch, 2002; PA Fish Boat , 2001)
Johnny darter	*Etheostoma nigrum*	Spawning is typically in tributaries and lakes. Spawning sites are commonly in pools or slow runs, or shallow lake water. Spawning is in the spring between 12 and 24 deg. C (Paulson and Hatch, 2002; Galat and Clark, 2002). Eggs are attached to the underside of debris, such as twigs, tin cans, and rocks. The nests are guarded by the male. The eggs hatch in about 2 weeks depending on the water temperature (PA Fish Boat, 2001).
White bass	*Morone chrysops*	Spawning is in lakes or tributary streams typically starting when the water reaches 16 deg. C. (Paulson and Hatch,2002; So. Dak. GFP, 2002). Substrate is typically sand, gravel or cobble. Spawning temperature range is 13 - 25 deg. C. (Galat and Clark, 2002; Iowa DNR, 2002). White bass tend to return to the same spawning site. Eggs are broadcast near the surface and sink to the bottom and adhere (Paulson and Hatch, 1999). Eggs hatch to embryos in about 2 days (Schultz, 1999).

Mississippi silvery minnow	*Hybognathus placitus*	Spawning is intermittent on the bottoms of lakes, ponds, rivers, and tributary streams including creeks. Substrate is typically silt and mud (Pflieger, 1197, p.124). Spawning is from May to late August depending on water temperature (Tenn. WRA, 2002). Spawning temperature range is 13 - 21 deg. C. (Galat and Clark, 2002. The eggs are attached to submerged or floating objects. Parental care of cleaning and aerating is essential to hatching. Hatching time is 6 to 14 days.
Rock bass	*Ambloplites rupestris*	Intermittent spawning is typically in shallow tributary streams and lakes. Nests are dug into sand or gravel if available (Breder and Rosen, 1966, p.421). Nests are usually built near a log or large rock (Shultze, 1999; PA Fish Boat, 2001). Spawning temperature range is 16 - 26 deg. C. (Virginia Tech, 2002). Male guards nest and eggs which he aerates. Eggs hatch in 3 to 4 days, after which they fend for themselves.
Creek chub	*Semotilus atromaculatus*	Spawning is typically in small tributary streams (creeks). Multiple spawning occurs over a duration of time. Spawning is in nests on gravel or sand bottoms at the lower end of pools (Lentsch and other, 1996, p. 68) Spawning temperature range is 13 -18 deg. C. (Lentsch and others, 1996, p. 68; Paulson and Hatch, 2002). However, Galat and Clark (2002) list a range of 13 - 26 deg. C. The male covers the eggs after each spawning episode and there is no additional parental care.
Inland silverside	*Menidia berrylina*	Spawning is in vegetated backwaters, tidal or fresh, such as those of bays, rivers or tributaries. Multiple spawning, sometimes daily, occurs over a duration of time depending on water temperature (Pfleiger, 1997, p.249). Galat and Clark (2002) list a spawning range of 13 - 30 deg. C. The eggs are demersal and have one to three filaments that is attached to the chorion. The filaments become entangled with vegetation or debris and suspend the eggs in the water column (Berkley Univ., 2002).
Black crappie	*Pomoxis nigromaculatus*	The black crappie is typically found in lakes, reservoirs and tributary streams (Pfleiger, 1997, p. 293). Spawning is in lakes, tributaries, and backwaters of large rivers in shallow or deep water (up to 6 meters deep). Males may build nests in shallow vegetated littoral zones generally in sand, gravel, or even mud bottoms. Spawning temperature range is 14 - 23 deg. C. with optimum between 17 to 23 deg C. (Lenstsch and others, 1996, p.113; Paulson and Hatch, 2002). Males guard the nest. Eggs are demersal and adhesive. Eggs hatch in about 3 to 5 days.
White crappie	*Pomoxis annularis*	Spawning is in lakes, tributaries, and rivers. Spawning is in shallow water often near rooted plants or protective banks (Lentsch and others, 1996, p. 111). Spawning is typically at depths of 10 - 420 cm. Males construct and guard nests in either hard or soft bottom substrate (Tenn. WRA, 2002). Spawning temperature range is 14 -23 deg. C. (Galat and Clark, 2002; Tenn. WRA, 2002). Eggs are demersal and adhesive. Male guards eggs (Breder and Rosen, p. 424. Hatching is between 42 to 93 hours depending on water temperature.

Threadfin shad	*Dorsoma petenensis*	Threadfin typically spawn in tributary streams and lakes. Spawning sites are typically associated with vegetation. There may be multiple spawns per year. Spawning temperature is 14 - 27 deg. C (Tenn. WRA, 2000, Galat and Clark, 2002). Eggs are demersal and adhesive. Hatching time is 3 - 4 days (New Mex. GF, 2002).
Bigmouth buffalo	*Icitiobus cyprinellus*	Spawning is in lakes, tributaries, and rivers. Spawning is typically in clear water over sparse vegetation, rocks or even mud. Water depth is generally .7 to I meter deep (Paulson and Hatch, 2002; Iowa DNR, 2002). The eggs are randomly scattered and adhere to vegetation (Schultz, 1999, Carlander, 1969) Spawning temperature range is between 13 to 27 deg. C. (Galat and Clark, 2002). Eggs hatch in 10 to 14 days unprotected.
Fathead minnow	*Pimephales promelas*	Spawning is in tributaries, lakes, and rivers. Spawning is intermittent. Adhesive eggs are attached to under surface of floating and suspended objects (Schultz, 1999). Eggs are guarded by the males and hatch in 5 to 6 days (Iowa DNR, 2002: Harlan and Speaker, 1951, pp. 84 - 85). Spawning temperature range is 15 - 32 deg. C. (Virginia Tech, 2001; Tenn. WRA, 2000)
Spottail shiner	*Notropis hudsonius*	The spottail shiner is largely a Mississippi River fish and also found in natural lakes. Spawning is in lakes, tributaries, streams and rivers including tidal. Spawning is typically over sand and gravel (Utah DWR, 2002; Cornell Univ., 2002; Pflieger, 1997, p. 148). Eggs attach to sand and gravel (Virginia Tech, 2001). Spawning temperature range is 15 - 20 deg. C. (Galat and Clark, 2002).
Striped bass	*Morone saxatilis*	Spawning is in turbulent, muddy silt-laden areas of large rivers or tributaries in fresh or brackish water characterized by rapids, boulders, and strong currents (Lentsch and others, 1966, p. 96; Pfleiger, 1997, p. 261). Spawning temperature range is 10 - 24 deg. C. (Virginia Tech, 2001: Schultz, 2001). Eggs are non-adhesive and buoyant and are broadcast. Eggs hatch in 62 hours at 25 deg. C. and 34 hours at 21 deg. C. (New Mex. GF, 2002).
Goldfish	*Carassius auratus*	Spawning is typically in lakes (reservoirs) and tributary streams Spawning begins in shallow water at approximately 15 deg. C. and continues intermittently. Eggs adhere to vegetation, submerged objects, or floating debris. Spawning temperature is 15 - 23 deg. C. (New Mex. GF, 2002; Galat and Clark, 2002). Eggs hatch in 76 hours at 25 deg. C. (Breder and Rosen, 1966, .224).
Common carp	*Cyprinus carpio*	Spawning is in rivers, tributary streams, lakes, marshes, and ponds. Spawning is in shallow water over aquatic vegetation and debris, typically over muddy bottoms (Lentsch and others, 1996, p.44). Spawning is intermittent between 10 and 30 deg. C. with 18-to 23 deg. C. considered ideal. Eggs are demersal and adhesive. Hatching time is between 3 to 16 days depending on temperature (New Mex. GF, 2002).

River shiner	*Notropis blinnius*	Spawning is in rivers, especially large rivers (Pfleiger, 1997). Spawning is reported over sand and gravel bars intermittently from late spring through summer (Iowa DNR, 2002, Bonner and Wilde, 2002). However, Breder and Rosen (1966, p. 181) report spawning in water .3 to 0.5 meter deep18 under the protection of submerged vegetation. Results of the Bonner and Wilde study (2002) did not show relationship between spawning and stream flow. Spawning range is 15 - 30 deg. C. (Galat and Clark, 2002).
Smallmouth buffalo	*Ictiobus bubalus*	Spawning is in large rivers and tributary streams and creeks. Spawning is generally over mud bottoms with vegetation (Texas P&W, 2002). However, Iowa DNR (2002) reports spawning is in shallow water of moderate current often over submerged gravel or sand bars that are adjacent to river channels. Spawning typically starts at about 16 deg. C. (Iowa DNR, 2002, Texas P&W, 2002) and spawning temperature range is 15 - 27 degrees C. (Galat and Clark, 2002). Eggs are broadcast at random, fertilized by several males and sink to the bottom where they adhere to any objects. Incubation is from 8 to 14 days.
Largemouth bass	*Micropterus salmoides*	Spawning is in lakes or backwaters of rivers and tributaries typically with vegetation (Virginia Tech, 2001; Paulson and Hatch, 2002; Harlan and Speaker, 1952, p. 112). Spawning is in nests in substrate of soft material, such as mud or silt, or in gravel (Lentsch and others, 1996, p. 108-109). Spawning temperature range is 11 - 24 deg. C. with optimum of 16 - 19 deg. C. Males fan and protect eggs for several days (Paulson and Hatch, 2002). Eggs are demersal, adhesive and hatch in about 3 to 5 days depending on temperature (Lentsch and others, 1966, p. 109). .
Bowfin	*Amia calva*	Spawning is in shallow backwaters of rivers (Harlan and Speaker, 1951, p. 38), and tributaries as well as lakes and ponds. Spawning is in nests in shallow water of 0.3 to 0.6 meter depth. Nests are cleared of vegetation, but generally they are near or around stumps, debris, and vegetation (Ontario FA&H, 2002; Pflieger, 1997, p. 61). Spawning temperature range is 16 - 19 deg. C. (Galat and Clark, 2002). Eggs hatch in 2 weeks or less, generally between 8 to 10 days (Tenn. WRA, 2000). Males guard eggs until they hatch and then guard the fry (Iowa DNR, 2002).
Yellow bass	*Marone mississippiensis*	Spawning is in rivers, tributary streams, and lakes (Harlan and Speaker, 1951, p.105). Yellow bass, like other true basses, spawn in the spring typically on gravel or rock substrate in either lakes or streams. Eggs are deposited in 0.6 – 1.0 meter of water (Texas P&W, 2002). Spawning temperature range is 16 - 21 deg. C. (Galat and Clark, 2002). Semi-buoyant eggs are broadcast and sink slowly to the bottom. Eggs hatch in about 4 to 6 days depending on the temperature (Iowa DNR, 2002).

Skipjack herring	*Alosa chrysochloris*	Skipjack herring prefers low turbidity water (Pflieger, 1997, p. 70). Herring tend to migrate during spawning season, some spawn in rivers and some in freshwater lakes. They may also spawn in the tail waters below dams (Pigg and Gibbs, 1991, p.1). Preferred substrate is likely to be sand and gravel. Spawning temperature range is between 16 and 21 degrees C. (Galat and Clark, 2002). Eggs are broadcast.
Golden redhorse	*Moxostoma erythrurum*	Spawning is in small streams generally in shallow riffles (Iowa DNR, 2002; Virginia Tech, 2001; Breder and Rosen, 1966,pp. 238 -239). The semi-adhesive eggs are broadcast and left unattended to hatch (Tenn. WRA, 2000). Spawning water temperature range is between 10 and 22.5 deg. C.; however, Galat and Clark (2002) reports range of 16 and 21 deg. C.
Mottled sculpin	*Cottus bairdi*	Spawning is in moderate- and high- gradient creeks, tributary streams, and small rivers. Spawning is in clear water in nests, typically under rocks, vegetation or debris on nearly any bottom (Breden and Rosen, 1966, pp. 547 - 548; Paulson and Hatch, 2002). Spawning water temperature range is 5 - 16 deg. C. (Paulson and Hatch, 2002; Virginia Tech, 2001). Male defends adhesive eggs, keeps them clean and eats fungus-covered eggs (Tenn. WRA, 2000; Paulson and Hatch, 2002). Incubation period is 3 to 4 weeks (Pfleiger, 1997, p. 252).
Shovelnose sturgeon and pallid sturgeon	*Scaphirhynchus platorynchus* and *Scaphirhynchus albus*	Little is known directly about spawning characteristics of the pallid sturgeon. However, these characteristics are believed to be very similar to those of the shovelnose sturgeon with which it interbreeds freely (USFWS, 2000, p. 89). Shovelnose sturgeons generally move upstream in the river to small tributaries to spawn over gravel and rock areas with fast water (Paulson and Hatch, 2002). Spawning was reported in the main channel of the Missouri River and on wing dams (USFWS, 2000, p. 94). However, the citations for the mainstem Missouri River apparently are for the Tongue River, a tributary to the Yellowstone River, and for impoundments on the Mississippi River. Spawning runs are the greatest during years of low flow (Iowa DNR, 2002). Data shown by Elser and others (1977, pp. 36 -38) shows that spawning seemingly correlates to temperature and and flow. However, the temperature and flow data shown by Berg (1981, p. 97) shows that spawning is initiated by tempeature. USFWS (200, p. 104) states that spawning is directly due to temperature. Paulson and Hatch (2002) report a water-spawning temperature range of 19 - 22 deg. C. Galat and Clark (2002) list a spawning range of about 15 - 23 deg. C. Keenlyne (1997, p. 291) reports that spawning temperature is 17-21 deg. C. Eggs are laid on gravel and rock substrate and are left unattended. Eggs hatch about 7 days later depending on water temperature. Larval sturgeons are pelagic and drift up to 13 days.
Brassy minnow	*Hybognathus hankinsoni*	Spawning is in quiet, vegetated habitats with silt bottoms, such as river and tributary backwaters. Spawning is typically in or on vegetation (Pfleiger, 1997,p. 123). Spawning temperature range is 16 - 27 deg. C. (Lentsch and others, 1996; p. 51, Galat, 2002). Female will spawn for 7 - 10 days. Eggs are demersal and slightly adhesive
Bigmouth shiner	*Notropis dorsalis*	The bigmouth shiner is largely a tributary fish (Pflieger, 1997,p.145). Spawning is believed to be in lakes or small tributary streams. Substrate is possibly sand. Galat and Clark (2002) list spawning temperature range of 16-27 deg. C.

Yellow bullhead	*Ameiurus natalis*	Spawning is in lakes or slow moving water in rivers and tributaries. Spawning is in nests, which are constructed under overhanging banks, in holes, or near stumps, stones or debris (Lentsch and others, 1996, p. 78). Spawning range is between 16 and 27 deg. C. (Galat and Clark, 2002). The male guards the nest and the YOY. (PA Fish Boat, 2001). The eggs hatch in about 5- -10 days depending on temperature. There is parental care of the young.
Freckled madtom	*Noturus nocturnus*	Little is know about spawning of freckled madtom. Spawning for the closely related tadpole madtom is in nests, which are typically near vegetation or natural or exotic debris with still or slowly moving water (Tenn. WRA, 2000; Pfleiger, 1997, p.211), such as in backwaters of rivers and tributaries. Spawning water temperature range for freckled madtom is about 16 - 27 deg. C. (Galat and Clark, 2002). Parents guard eggs.
Green sunfish	*Lepomis cyanellus*	Green sunfish are multiple spawners in lakes and tributary streams. Spawning is in a nest on the bottom dug by the male generally in sand or gravel and typically near debris. Spawning range is at 15 - 28 deg. C. (Lentsch and others, 1996, p. 99). The male guards the nest. Eggs are demersal and adhesive. Eggs incubate in 2 - 4 days depending on temperature. Free embryos stay in the nest another 5 days (Paulson and Hatch, 2002)
Red shiner	*Cyprinella lutrensis*	Red shiner is primarily a tributary fish (Iowa DNR, 2002) that can destroy aquatic vegetation (USGS, 2002). Red shiner are multiple spawners that typically spawn in lakes or tributary streams in mostly calm water; however, they can spawn in polluted, turbid or unstable water (Iowa DNR, 2002). Substrate can be sand and gravel (Berkley Univ., 2002). Spawning temperature range is 16 - 29. C. (Galat and Clark, 2002). No parental care of the eggs.
Bluegill	*Lepomis macrochirus*	Spawning is in lakes, tributary streams and rivers. Bluegills are multiple spawners at temperatures of 17 to 27 deg. C. (Lentsch and others, 1996, p. 102). Males build colonies of nests in shallow water typically over fine gravel, sand, and mud, with little vegetation (Breder and Rosen, 1966, pp. 413 - 414). Eggs are demersal and adhesive. Males fan and guard nest until several days after larvae have hatched in 1 to 3 days (Paulson and Hatch, 2002).
Freshwater drum	*Aplodinotus grunniens*	Spawning is in deep open water of lakes or rivers. They are pelagic spawners as they release their eggs near the surface (Paulson and Hatch, 2002; Pflieger, 1997, p.348). Spawning temperature range is 18 - 22 deg. C. (Galat and Clark, 2002).The eggs float at the surface and larvae hatch in 1 to 2 days (Swedburg and Walburg, 1970).
River carpsucker	*Carpiodes carpio*	Spawning is in large rivers and tributary streams (Iowa DNR, 2002). Spawning is over gravel, sand, silt and mud bottoms (New Mex. GF, 2002). Some females are multiple spawners. Spawning range is 18 - 22 deg. C. (Galat and Clark, 2002; Iowa DNR, 2002). Adhesive eggs are broadcast at random and typically hatch in 8 - 12 days (Harlan and Speaker, 1951, pp. 62 - 63).

Grass carp (White amur)	*Ctenopharyngodon idella*	Spawning is in large rivers with strong currents and does not occur in ponds or lakes (Virginia Tech, 2001). Spawning is in long stretches of floating water (PA Fish Boat, 2001; Virginia Tech, 2001). Spawning temperature range is 18 - 30 deg. C. (Galat and Clark, 2002).
Bighead carp	*Hypopthmichtys nobilis*	The bighead carp is a large river or large tributary fish (Pflieger, 1997, p. 126). Accordingly, spawning is typically in rivers. Bighead carp migrate upstream in search of spawning grounds, which are characterized by rapid currents with mixing of water, such as at a confluence of rivers or behind sandbars or islands (USFWS, 2000b, p.1). Big head carp are abundant in the lower Missouri River and thrive without a spring rise. USFWS (2000) reports spawning temperature range of 26 - 30 deg. C. Galat and Clark (2002) list temperature range of 18 - 30 deg. C. Spawning may be concurrent with increasing stream discharges (Schrank, 2000).
Orangespotted sunfish	*Lepomis humilus*	Orangespotted sunfish spawn in backwaters of rivers or in small tributary streams (Pfleiger, 1997, p. 280). Multiple spawning is in colony nests constructed by the male in silt, coarse sand, fine gravel (Anon., 2002; Harlan and Speaker, 1951,p. 119; Mew Mex. GF, 2002). Spawning range is 18 - 30 deg. C (Galat and Clark, 2002). The male guards the nest until hatching in about 5 days (New Mex. GF, 2002).
Alabama shad	*Alosa alabamae*	Spawning is in large rivers (NOAA Fisheries, 2001) as for many shad (Breder and Rosen, 1966). Spawning of this anadromous fish is in moderate currents over sand and gravel beds. Spawning temperature is typically between 19 - 22 deg. C. (NOAA Fisheries, 2001; Galat and Clark, 2002); however, Tenn. WRA (2000) lists a range of 15 - 21 deg. C.
Silver chub	*Hybopsis storeriana*	Little is known about the spawning of this dominantly big river fish that can survive in fast and moderately turbid water (Pflieger, 1997, p. 136; Iowa DNR, 2002). Spawning is believed to be in relatively clear water in a big river or in tributaries near the mouths. Spawning occurs from April through June (Iowa DNR, 2002). Spawning temperature range is 19 -23 deg. C. (Galat and Clark, 2002).
Shortnose gar	*Lepisosteus platostomus*	Spawning is in rivers, tributaries, and lakes including oxbow and "natural" lakes. In Texas, the shortnose gar spawns from May into July (Texas P&W, 2002; Illinois DNR, 2002; Iowa DNR, 2002). Spawning is in shallow slow moving water (Breder and Rosen, 1966, pp. 68 -69) where yellow eggs are scattered over vegetation and other submerged objects. Spawning temperature range is 19 - 24 deg. C. (Galat and Clark, 2002). Eggs adhere to vegetation. (Eggs can stand some exposure.) Eggs hatch in 8 or 9 days.
Quillback	*Carpiodes cyprinus*	Quillbacks ascend small (tributary) streams to spawn over sand and mudflats in slow moving water (Paulson and Hatch, 2002). Iowa DNR (2002) reports spawning temperature range of 13 - 21 deg. C. Galat and Clark (2002) report range of 19 to 28 deg. C. Eggs are broadcast in shallow water. Eggs are unguarded and hatch in 8 to 12 days (PA Fish Boat, 2001).

Highfin carpsucker	*Carpiodes velifer*	Spawning of this largely tributary fish (Pfleiger, 1997, pp 177-178) is in shallows and in overflow ponds of rivers and tributary streams (Harlan and Speaker, 1951, p. 63). Spawning is in slow to still water over clean gravel substrate (Iowa DNR, 2002). Iowa DNR (2002) reports spawning temperature range is 13 - 25 deg. C; Galat (2002) lists 19 -30 deg. C.)
Longnose gar	*Lepisosteus osseus*	Gars migrate into tributary streams to spawn if possible; however, the longnose gar spawns in lakes also. Preferred spawning habitat is with vegetation or over gravel beds. (Paulson and Hatch, 2002; Iowa DNR, 2002). Spawning temperature range is 19 - 30 deg. C. (Galat and Clark, 2002). Eggs hatch in about 1 week.
Brook silverside	*Labidesthes sicculus*	Silversides spawn in and around aquatic vegetation in rivers and (tributary) streams. (New York DEC, 2002). Eggs drift until adhesive filament attaches to vegetation (Paulson and Hatch, 2002). The orange colored eggs include numerous oil globules . The eggs are not defended. Spawning temperature range is 20 - 23 deg. C. (Galat and Clark, 2002). Eggs hatch in about 8 days at 45 deg. C. (Iowa DNR, 2002).
Sicklefin chub	*Hybopsis meeki*	Little is known about the sicklefin chub including its spawning requirements. It is believed that they are a large (tributary) stream fish or a river fish and that spawning is in large tributary streams and or rivers in silt free environment. The dams on the mainstem of the Missouri are favorable for creating a silt free substrate (Pflieger, 1997, p.136). Iowa DNR (2002) and Missouri DC (2000) report they spawn in the spring. However, in Montana, spawning is reported in the summer months (Grisak, 1998). Galat and Clark (2002) list spawning temperature range of 20 - 26 deg. C.
Golden shiner	*Notemigonus crysoleucas*	Multiple spawning typically is in quiet waters in ponds, (tributary)streams, and lakes (Tenn. WRA, 2000). Eggs are laid over vegetation to which they stick. The eggs are unprotected. Spawning temperature range is 20 - 27 deg. C. (New Mex. GF, 2002; PA Fish Boat, 2001). No parental care is given to eggs or larvae (Pflieger, 1997, p. 139)
Alewife	*Alosa psuedoharengu*s	Spawning is in quiet pools of rivers (anadromous) and lakes (Virginia Tech, 2001). Alewife randomly release minute sticky eggs that sink to the bottom generally over rocks or gravel in shallow water (PA Fish Boat, 2001; Tenn. WRA, 2000). Most spawning is between 15 and 24 deg. C. (Tenn. WRA, 2000; Galat and Clark, 2002). Hatching time of eggs is temperature dependent; for example, 2 days at 29 deg. C. to 15 days at 8 deg. C. Many alewife eggs are eaten by immature alewives.
Spotfin shiner	*Notropis spiloperus*	Spawning is in quiet or slow water often in tributary streams. Spawning is fractional (multiple) during summer at temperatures of 21 - 24 deg. C. (Tenn.. WRA, 2000; Pflieger, 1997, p. 119). Adhesive eggs are attached in crevices and cracks or vegetation or rocks (Virginia Tech, 2001; Iowa DNR, 2002; Rook, 1999).

Channel shiner	*Notropis wickliffi*	Little is known about this fish. In Missouri, the fish is found in the Mississippi River and in an approximately 100 mile reach on the Missouri River upstream from St Louis. The fish is also found in tributary streams for short distances from the mouths (Pflieger, 1197, p. 156). Galat and Clark (2002) list a spawning temperature range of 21 - 27 deg. C.
Bluntnose minnow	*Pimephales notatus*	Bluntnose minnows are found in lakes, ponds, rivers and creeks. Spawning is likely to occur in each. However, bluntnose minnows are typically a small creek fish and a fractional spawner from spring to late summer (Iowa DNR, 2002). Spawning temperature range is 21 - 26 deg. C. (Galat and Clark, 2002). Adhesive eggs are deposited in masses on the underside of floating logs, flat rocks, or other objects at depths generally less than 0.6 meter (Breder and Rosen, 1966, p. 193). After spawning, males aggressively guard nesting areas (Ohio DNR, 2002). Eggs develop into fry after about 8 - 12 days (Rook, 1999).
Plains minnow	*Hybognathus placitus*	Plains minnows live in large rivers and ascend short distances into tributary streams (Harlan and Speaker, 1951, p. 83). Spawning is in quiet water along sandbars or in backwaters. Spawning occurs during late April through August. Spawning commences at high or receding flow in shallow tributary streams, such as the Cimarron River (Pflieger, 1997, p. 125). Peak spawning appears to correlate with day length and water temperature (Lentsch, 1996, p. 52.) Galat and Clark (2002) report spawning temperature range of 21 - 26 deg. C.
Western silvery minnow	*Hybognathus argyritis*	The western silvery minnow is predominantly a large river fish but is found also in some tributary streams (Pflieger, 1197, p. 172). Spawning is from early May through June at temperatures of 13 - 21 deg. C. Spawning is in well vegetated lagoons or slow moving reaches of tributary streams (USGS NPWRC, 1995).
Sand shiner	*Notropis stramineus*	Little is known about spawning except that spawning is in shallow areas of rivers and small (tributary) streams, as well as lakes, and impoundments (Lentsch, 1996, p.55; Tenn. WRA, 2000; Iowa DNR, 2002). Eggs are likely scattered over clean sand or gravel. Spawning water temperature range is 21 to 27 deg. C. (Lentsch, 1996, p. 55). Spawning is likely fractional over several summer months. Summer spawning in Great Plains rivers may be the result of unfavorable drastic flow fluctuations in the spring.
Channel catfish	*Ictalurus punctatus*	Spawning typically is in rivers, tributaries and lakes. Spawning is in male created nests in areas of undercut banks, logs, rocks, or in mud bottoms. Females generally spawn once a year but males may fertilize more often if needed (Lentsch and others, 1996, p.81; Paulson and Hatch, 2002). Spawning temperature range is about 21 - 29 deg. C. (Lenstsch and others, 1996, p. 81-82; Virginia Tech, 2001). The nest is guarded and aerated by the male. The young are in schools guarded by the male (PA Fish Boat, 2001). Eggs are demersal, adhesive, and deposited in a gelatinous mass. Incubation time is generally 6 - 10 days.

Redear sunfish	*Lepomis microlophus*	Spawning is in lakes, rivers, or tributaries. Spawning is in nests built by the male in substrates, such as sand, mud, sandy-clay, limestone, shell, and gravel. Nests are generally close to vegetation and in water less than 2 meters deep (Tenn. WRA, 2000). Spawning temperature range is about 22 -24 deg. C. (Galat and Clark, 2002; Iowa DNR, 2002). Nest is guarded and aerated by the male. Incubation is in about 6 - 10 days.
Flathead catfish	*Plodictis olivaris*	Spawning is in large rivers and large tributaries. Spawning is in nests on the bottom, typically below a cutout bank or a log. (Tenn. WRA, 2000;) Water spawning temperature range is 22 - 25 deg. C. (Galat and Clark, 2002; Paulson and Hatch, 2002). The sticky gelatinous egg mass and the young are guarded by parents (Iowa DNR, 2002).
Silver carp	*Hypophthalmicthys molitrix*	Little is known about spawning of this species. Silver carp appear to have an affinity to large rivers. Spawning is in large rivers with sufficient current to maintain eggs in suspension until they hatch in two days or less (Pflieger, 1997, p. 126). Silver carp have been observed to migrate during spring floods in April and May in China at water temperatures of 18 - 20 deg C. (Poss, 2000). Pflieger (1997, p. 126) states that spawning is triggered by rising water levels after rains. Galat and Clark (2002) list a spawning temperature range of 22 - 26 deg. C.
Flathead chub	*Platygobio gracilis*	Little is known about spawning of this species. These are typically large river fish and can be found in the Missouri River and its large tributaries as well as other river basins of the interior North America (USGS, 1995; Missouri DC, 2000; Pflieger, 1997, p. 163). Duham and Wilde (2001) report that episodical spawning in shallow streams is believed to be related to high flow events. Eggs are non-adhesive, semi-buoyant and float until hatching occurs. Galat and Clark (2002) report a spawning temperature range of 25 to 28 deg. C.
Stonecat	*Noturus flavus*	Stonecats are typically a tributary fish but can be found in large rivers. Spawning is in tributaries including creeks, large rivers and in lakes. Stonecats spawn in nests in streams or rocky areas of lakes. Preferred spawning sites are in nests in dark areas, such as below submerged logs and rocks. Multiple spawning may occur in the spring and summer between water temperatures of about 25- - 28 deg. C. (Tenn. WRA, 2000; Galat and Clark, 2002; PA Fish Boat Com., 2001). Eggs are guarded by the male and female until hatching. Afterward, the male guards the young (Pflieger, 1997, p. 209).
Silverband shiner	*Notropis shumardi*	Silverband shiners are rare, they are believed to be a big river fish; however, they have also been collected from tributaries including creeks. Little specific information was found on the spawning of the silverband shiner. They are likely to spawn in big rivers (Pflieger, 1997, p. 153) and tributaries including creeks. Spawning characteristics may be similar to other minnow species. Galat and Clark (2002) report spawning water temperature range of 26- 27 deg. C.

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