

**Selected Introduced and Native Fish Species of the Missouri River in
South Dakota and their Potential as Predators of Pallid Sturgeon**

Prepared for

In Re: Missouri River System Litigation

(03-MD- 01555)(and associated litigation)

Prepared by

Wayne Nelson-Stastny

**20641 SD HWY 1806
SDGF&P Missouri River Fisheries Center
Fort Pierre, South Dakota**

March 2004

Introduction

This report discusses several native and introduced species to the Missouri River that have increased in abundance or have become important components of the fish community in the mainstem of the Missouri River in South Dakota. Because of the changes in the fish community, whether through increased abundance of a native species or stocking of a nonnative species, concern has been expressed regarding the potential impacts to native species, in particular predation on pallid sturgeon. Therefore, this report examines the reasons behind the changes to the fish community, the changes to the fish community itself, and individual species ecological characteristics. Lastly, the potential for predation of selected species is reviewed.

General Change in Missouri River

Four mainstem dams, Oahe, Big Bend, Fort Randall and Gavins Point, have dramatically changed the Missouri River that either passes through or borders South Dakota. The Missouri River was often referred to as the “Big Muddy” because of the turbid waters and sediment load. This characteristic was due in part to the two spring floods characteristic of the Missouri River that annually reorganized the river complex of chutes, side channels, back waters and sinuous main channel. A floodplain consisting of highly erodable soils and a relatively low gradient also added to the diversity of habitats and turbidity of the Missouri River (National Research Council 2002). The Missouri River supported a diverse fish community that was dominated by species adapted to high turbidities, shifting substrates, high water velocities and annual flooding events (Galat et al. in press).

The Pick Sloan Plan as part of the Flood Control Act of 1944 authorized the construction of six mainstem dams (four in South Dakota) on the Missouri River. In South Dakota, Fort Randall Dam was the first to be closed in 1952 and Big Bend Dam the last in 1963 (Benson 1988). At full pool, the reservoirs behind the four mainstem dams effectively convert 377 miles of the 498 miles of the Missouri River bordering or passing through South Dakota from a riverine/lotic environment to that of a lake/lacustrine environment. Of the Missouri River bordering or passing through South Dakota, 75.6% has been changed from the turbid, riverine habitat, to a clearer, calmer

lacustrine environment. The majority of the Missouri River floodplain in South Dakota has been effectively flooded since 1967 by the reservoirs behind the mainstem dams. The reservoirs range in average depth from 16 feet (Lewis and Clark Lake) to 62 feet (Lake Oahe) (Martin et al. 1980). The maximum depth in Lake Oahe extends to 205 ft (Benson 1988). Lake Oahe is the only one of the four mainstem reservoirs that normally thermally stratifies (Martin et al. 1980; Benson 1968). Cold water habitat ($\leq 15^{\circ} \text{C}$) normally covers 118,000 acres of the deeper portions of Lake Oahe (Lott et al. 2002). The large lake environments and coldwater habitat created by the construction and filling of the reservoirs were foreign to many of the fish species adapted to the turbid flowing waters of the preimpoundment Missouri River. With the changes in habitat, the composition of fish communities changed. Native species that were in relatively low abundance in the unaltered Missouri River and were more suited for a lacustrine environment increased in relative abundance, while many of the native species which were suited to the turbid waters of the preimpoundment Missouri River declined in abundance. The relationship of fish community changes to habitat alterations will be discussed in more detail throughout this report. The initial policy of the South Dakota Department of Game Fish and Parks (SDGF&P) was to not stock fish into the mainstem reservoirs. Partly because the congressionally authorized use of these projects included fish, wildlife and recreation (USACE 1979), SDGF&P staff eventually sought out and stocked species preadapted to the new lacustrine environment in the postimpoundment Missouri River to enhance sport fisheries and fill habitat niches such as the coldwater portion of Lake Oahe. In a discussion of the mainstem reservoirs project purposes, Sveum (1988), Chief of the Reservoir Control Center for the U. S. Army Corps of Engineers (USACE), stated the following with regard to recreation, one of the authorized project purposes:

The State of South Dakota boasts of the excellent walleye fishing and has attracted many out-of-state fishermen. Angling pressure in North Dakota has been increasing as the word spreads, and it will probably continue as long as quality fishing continues. An important management goal is to maintain the excellent walleye fishing, but other species including cool-water species such as northern pike and muskellunge and cold-water species such as chinook salmon, lake trout, and rainbow and brown trout are also an important part of the long-term reservoir fisheries management plan.

Several species, primarily introduced, have been brought into question with regard to the potential that they would prey on pallid sturgeon. Following is a discussion of introduced and native species which have been stocked, are currently stocked and/or whose native status in the Missouri River has been brought into question in the pending litigation. The species listed in Table 1 have either been introduced into the Missouri River system to utilize the altered habitat or have been stocked to enhance abundance of preexisting native species popular with anglers. Several stocking attempts were made with other fish species to try and utilize the newly created habitat in the South Dakota portion of the Missouri River. The fish species stocked which were eventually discontinued are: *Coregonus clupeaformis* – lake whitefish, *Oncorhynchus nerka* – sockeye salmon/kokanee, *Oncorhynchus clarki* – cutthroat trout, *Salvelinus namaycush* – lake trout, *Prosopium gemmiferu* – Bonneville cisco, *Esox masquinongy* – muskellunge, *Esox lucius x masquinongy* – tiger muskellunge (Hanten and Talsma 1984, Marrone and Stout 1997, SDGF&P fish stocking database). Of this list, only lake whitefish and tiger muskellunge are occasionally sampled either by anglers or in fish population surveys (Missouri River Fisheries Center staff, SDGF&P). In both cases the fish are believed to be from original stocking events, i.e. large adults (Missouri River Fisheries Center staff, SDGF&P). The salmonid species listed in Table 1 are the only species that require regular maintenance stockings because they do not reproduce naturally in the South Dakota portion of the Missouri River (Marrone and Stout 1997). The trout, brown and rainbow, as well as the Chinook salmon fisheries have become established components of the recreational opportunity/sport fisheries on the mainstem of the Missouri River in South Dakota (Johnson et al. 2002; Lott et al. 2002; Stone and Sorensen 2002). Although there are numerous other native and nonnative species in the Missouri River, the majority of the species in Table 1, both native and nonnative, have been suggested in the pending litigation as being potential predators of the federally endangered pallid sturgeon.

Several nonnative species, (spottail shiner, smallmouth bass, white bass, lake herring, and rainbow smelt) have established naturally reproducing populations and are important to the fishery in the Missouri River as either prey fish or sport fish. Following the establishment of rainbow smelt, several coldwater species were stocked and failed to

fill the void as a coldwater predator. However, stocked Chinook salmon were a success and have become the main coldwater predator stocked to utilize rainbow smelt. In addition to their importance as prey to Chinook salmon (Hill 1997), when abundant, rainbow smelt are the primary prey fish in Lake Oahe for several other sport fish populations (Jackson 1992; Bryan 1995; R. P. Hanten, SDGF&P fishery biologist, personal communication).

Table 1. Native and introduced fish species stocked into the Missouri River system discussed in this report (Hanten and Talsma 1984, SDGF&P fish stocking database). Origin as a native (N), introduced (I) or probable native (PN) is denoted along with a superscript for the corresponding reference, (¹Bailey and Allum 1962, ²Cross et al. 1986, ³Galat et al. in press). Stocking status refers to one of the following:

Established sport fishery - stocking required to maintain (EFS)

Established population - stocking discontinued (EPD)

Native – if stocked, additive to natural reproduction (NSA)

Species in this table are actively managed via stocking or other means at the present time and/or have had their status, whether native or nonnative, brought into question by others in the pending litigation.

Species name	Common name	Origin	Stocking status	Years Stocked in Missouri River in SD
<i>Oncorhynchus mykiss</i>	rainbow trout	I	EFS	1951, 56, 57, 64, 68, 69, 1972-2003
<i>Oncorhynchus tshawytscha</i>	Chinook salmon	I	EFS	1982-2000, 2003
<i>Salmo trutta</i>	brown trout	I	EFS	1964, 68, 79, 1981-2003
<i>Morone chrysops</i>	white bass	I	EPD	1960-62
<i>Coregonus artedii</i>	lake herring	I	EPD	1984, 88, 90-92
<i>Polyodon spathula</i>	paddlefish	N ^{1,2,3}	NSA*	1974, 76-78, 1985-2003
<i>Osmerus mordax</i>	rainbow smelt	I	EPD**	-
<i>Notropis hudsonius</i>	spottail shiner	I	EPD	1973-75, 78, 79
<i>Micropterus dolomieu</i>	smallmouth bass	I	EPD	1972, 74, 80, 83-92, 94-98
<i>Esox lucius</i>	northern pike	PN ¹ , N ^{2,3}	NSA	1957, 58, 71, 82, 83, 85, 86, 88-97
<i>Perca flavescens</i>	yellow perch	PN ¹ , N ^{2,3}	NSA	-
<i>Sander vitreum</i>	walleye	N ^{1,2,3}	NSA	1952, 53, 57, 58, 83-98, 2002

*Paddlefish stocking in the last decade has only been in Lake Francis Case. An adult population exists in Lake Francis Case, however natural reproduction has not been documented.

** Rainbow smelt in the South Dakota portion of the Missouri River originated from fish stocked in Lake Sakakawea in North Dakota.

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the establishment of rainbow smelt, several coldwater species were stocked and failed to fill the void as a coldwater predator. However, stocked Chinook salmon were a success and have become the main coldwater predator stocked to utilize rainbow smelt. In addition to their importance as prey to Chinook salmon (Hill 1997), when abundant, rainbow smelt are the primary prey fish in Lake Oahe for several other sport fish populations (Jackson 1992; Bryan 1995; R. P. Hanten, SDGF&P fishery biologist, personal communication).

South Dakota anglers ranked walleye and northern pike first and second respectively as their most preferred fish species in the Missouri River (Stone 1996). Because of anglers' preference for walleye and northern pike, they have been stocked in the past to enhance naturally reproducing sport fish populations in the Missouri River in South Dakota.

Accounts of Stocked Fish Species

A discussion of each of the species listed in Table 1 follows. Some of the discussions will be broad when applicable others will be fairly short. Primary issues discussed include the following: origin (nonnative/native), stocking status, stocking plans, habitat preferences, food habits, and importance to the sport fishery

Rainbow trout

Rainbow trout are an introduced species to the Missouri River in South Dakota (Bailey and Allum 1962; Hanten and Talsma 1984; Cross et al. 1986; Galat et al. in press). The first introduction of rainbow trout into the Missouri River in South Dakota occurred in Lake Francis Case in 1951, a stocking of 600 fingerlings (Hanten and Talsma 1984). Various sizes and quantities of rainbow trout were stocked throughout most of the mainstem Missouri River in South Dakota in past years (SDGF&P fish stocking database). A total of 35,000 catchable rainbow trout (3/lb) are scheduled to be stocked below Oahe Dam in 2004 (SDGF&P). Catchable rainbow trout stockings provide a unique angling opportunity for anglers in the area (Johnson et al. 1998), especially for youth and handicapped anglers, in locations with easy shoreline access, close to Pierre and within Pierre. A portion of the stocked rainbow trout that are not captured in the

several weeks post-stocking eventually add to the tailrace fishery in later months and subsequent years as larger trout often reaching trophy size. One of the primary reasons rainbow trout tend to stay within the Oahe tailrace area is because of the relatively clear, cool-cold water releases from the Oahe powerhouse, even during the hot summer months. South Dakota anglers ranked trout as their eighth most preferred fish in the Missouri River (Stone 1996). Rainbow trout have been stocked below Oahe Dam annually since 1980 (Hanten and Talsma 1984; SDGF&P fish stocking database) enabling the fishery to become well-known and well-established amongst anglers. Because natural reproduction by rainbow trout has not been documented and likely does not occur in the mainstem of the Missouri River in South Dakota (Marrone and Stout 1997), stocking is required to maintain this fishery.

Rainbow trout have an upper lethal temperature limit between 75.2° F (Black 1953) and 77° F (Morrow and Fischenic 2000). Garside and Tait (1958) reported the preferred or optimum temperature as 55.4° F, while a range of 53.6° to 64.4° F was reported by (Morrow and Fischenic 2000). Rainbow trout require a gravelly river in which adults can migrate to spawn in order to be self-sustaining (Scott and Crossman 1973).

In general rainbow trout feed on invertebrates, plankton and occasionally other fish shifting from plankton to insects and crustaceans and then to fish as trout size increases (Scott and Crossman 1973). Lynott (1995) reported a similar pattern in Lake Oahe with rainbow trout's diets shifting from zooplankton, to terrestrial insects to rainbow smelt as rainbow trout size increased. Rainbow smelt dominated the diet of rainbow trout > 460 mm in length in Lake Oahe (Lynott 1995). Because rainbow trout are primarily visual feeders increased turbidity could impact foraging efficiency. Others have reported decreased (19-42%) capture success and prey consumption rates at turbidities of 30-60 NTU's (nephelometric turbidity units) (Noggle 1978; Gardner 1981; Berg and Northcote 1985). Barrett et al. (1992) reported that rainbow trout reactive distances to prey items in the 15 and 30 NTU treatments were only 80% and 45% of those observed at turbidities of 4-6 NTUs. It is apparent from these results that rainbow trout would show an affinity for the cooler and clearer waters available in the Oahe tailrace. Moreover, rainbow trout exhibited decreased reactive distance to prey items at

turbidities as low as 15 NTU's would likely find foraging for prey in the unaltered Missouri River difficult. The mean annual turbidity in the unaltered Missouri River at a Saint Louis water treatment facility ranged from in excess of 1,000 NTU's to more than 2,500 NTU's (Pflieger and Grace 1987).

Chinook salmon

Chinook salmon are an introduced species in the Missouri River in South Dakota (Hanten and Talsma 1984; Cross et al. 1986; Galat et al. in press). Chinook salmon which had been stocked in North Dakota reached Lake Oahe as early as 1979 (Lott et al. 1997), likely after being entrained through the Garrison powerhouse. Eggs taken from Chinook salmon that had passed from Lake Sakakawea into Lake Oahe and from Lake Michigan salmon were utilized for the first stocking of nearly 300,000 Chinook salmon smolts directly into the mainstem Missouri River in South Dakota (Hanten and Talsma 1984; Lott et al. 1997). The majority of the Chinook salmon stocked (90%) into the Missouri River in South Dakota have been stocked into Lake Oahe (SDF&P fish stocking database). A popular fishery for Chinook salmon has been established in Lake Oahe. In 1996, an estimated 33,077 fish were harvested from Lake Oahe, second only to walleye harvest (Johnson et al. 1998). Because natural reproduction by Chinook salmon has not been documented and likely does not occur in the mainstem of the Missouri River in South Dakota (Marrone and Stout 1997) stocking is required to maintain this fishery. A total of 155,000 Chinook salmon (35-100/lb) are scheduled to be stocked in Lake Oahe in 2004 (SDGF&P).

Chinook salmon have an upper lethal temperature limit of 77.2° F (Brett 1952; Morrow and Fischenic 2000). Brett (1952) reported their preferred temperature range as 53.6° - 57.2° F, while a range of 53.1° - 59.9° F was reported by Morrow and Fischenic (2000). Chinook salmon require a gravelly river or stream in which adults can migrate to spawn in order to be self-sustaining (Scott and Crossman 1973).

In Lake Oahe, the diet of age-0 Chinook salmon in May consisted entirely of invertebrates, nearly equal parts by weight of zooplankton, aquatic insects and invertebrates (Hill 1997). By June age-0 rainbow smelt made up the largest part of the diet (73.5%) and dominated the diet through September (Hill 1997). Age-1 and older

Chinook salmon relied almost exclusively on adult rainbow smelt, with the only exception for age-1 and age-2 Chinook salmon which occasionally preyed on age-0 rainbow smelt (Hill 1997). Chinook salmon are generally considered sight feeders, which like rainbow trout, would have difficulty locating prey in increasing turbidity.

Brown trout

Brown trout are an introduced species in the Missouri River in South Dakota (Hanten and Talsma 1984; Cross et al. 1986; Galat et al. in press). The first introduction of brown trout into the Missouri River in South Dakota occurred in Lake Sharpe in 1964 with a stocking of 314,806 fingerlings (Hanten and Talsma 1984). Various sizes and quantities of brown trout were stocked throughout most of the mainstem Missouri River in South Dakota in past years (SDGF&P fish stocking database). A total of 15,000 catchable brown trout (3/lb) are scheduled to be stocked below Fort Randall Dam in the tailrace area in 2004 (SDGF&P). The brown trout stocking in the marina below Fort Randall Dam provides a unique fishery, which is geared primarily towards youth, elderly and handicapped anglers. The relatively easy accessibility from shore makes this a popular local fishery. Fishing use for brown trout more than doubled between 2000 and 2003 (J. Sorensen, SDGF&P resource biologist, personal communication). Brown trout have been stocked in the tailwaters below Fort Randall Dam annually since 1987 (SDGF&P fish stocking database) making this a well-established put-and-take fishery. Because natural reproduction by brown trout has not been documented and likely does not occur in the mainstem of the Missouri River in South Dakota stocking is required to maintain this fishery.

Rainbow trout have an upper lethal temperature limit between 73.4° and 79.5° F (Morrow and Fischenic 2000). Brynildson et al. (1963) reported the preferred or optimum temperature between 65° - 75° F, while a range of 53.6° to 66.2° F was reported by Morrow and Fischenic (2000).

Brown trout feed on a wide variety of prey including terrestrial and aquatic insects, while fish and crayfish become more important in the diet as the size of brown trout increases (Scott and Crossman 1973). Brown trout are generally considered sight

feeders, which like rainbow trout, would have difficulty locating prey in increased turbidity.

White bass

White Bass are generally considered as an introduced species to the Missouri River in South Dakota (Cross et al. 1986; Galat et al. in press), although Baily and Allum (1962) discusses the potential for their natural introduction to the middle Missouri River via stream crossovers. Based on early reports by staff from North Central Reservoir Investigations (NCRI) staff, it is believed that white bass were derived from introductions to Heart Butte Reservoir, North Dakota, which is located on the Heart River, a tributary to the Missouri River (Gasaway 1970; Gabel 1974). White Bass were first sampled in Lake Francis Case in 1961 (Gasaway 1970). The only stocking of white bass directly into the Missouri River in South Dakota occurred in Lewis and Clark Lake, where less than 5,000 adults were stocked from 1960 to 1962 (Hanten and Talsma 1984). White bass have become well established in the Missouri River in South Dakota. White bass had the third highest catch per unit effort in Lake Oahe coolwater fish population surveys from 1998 –2001 (Lott et al. 2002). White bass were ranked twelfth in preference on the Missouri River by South Dakota residents (Stone 1996). Nevertheless, they often are often one of the most abundant fish in angler harvest from Missouri River reservoirs in South Dakota (Johnson et al. 2002; Lott et al. 2002; Stone and Sorensen 2002; Wickstrom 2002). White bass have not been stocked in the Missouri River in South Dakota since 1962 (Hanten and Talsma 1984; SDGF&P fish stocking database). Because this species is well established, there are no plans to stock white bass in the Missouri River in South Dakota.

White bass prefer clear water rather than turbid water and tend to occupy the upper water layers or epilimnion (Scott and Crossman 1973). Scott and Crossman (1973) speculated that low turbidity levels may be important to the survival of white bass because they are visual feeders (Greene 1962) and are not attracted to prey by scent. White bass prefer water temperatures between 66.2° - 82.4° F (Morrow and Fischenic 2000). White bass are carnivorous with young fish feeding on microscopic crustaceans

and insect larvae and fish (Scott and Crossman 1973). Fish become increasingly important in the diet of white bass as they increase in size (Scott and Crossman 1973).

Lake Herring

Lake herring are an introduced species to the Missouri River in South Dakota (Hanten and Talsma 1984; Cross et al. 1986; Galat et al. 2004). Lake Herring were introduced into Lake Oahe to supplement rainbow smelt as a coldwater prey species because of the cyclic nature of rainbow smelt populations. Selgeby et al. (1974) noted an inverse relationship between rainbow smelt and lake herring populations. The first introduction of lake herring into the Missouri River in South Dakota occurred in Lake Oahe in 1984 (SDGF&P fish stocking database). A substantial effort to establish lake herring in Lake Oahe was undertaken from 1990 to 1992, (more than 30 million fry stocked), (SDGF&P fish stocking database). Lake herring have become established as a part of the coldwater fish community in Lake Oahe. Larval lake herring have been sampled annually since 1995 indicating natural reproduction is occurring regularly (Lott et al. 2002). Lake herring are recruiting to the adult population as evidenced by the presence of young, age-1 and age-2, lake herring in recent lake surveys. Although there is a daily creel limit on lake herring, because of their feeding habits they are rarely caught by anglers and are, in general, considered a prey fish, especially during the early portion of their life. Because this species is well established, there are no plans to stock lake herring in the Missouri River in South Dakota.

Lake herring are essentially a lake species (Scott and Crossman 1973). Lake herring are pelagic, forming large schools at midwater depths primarily to remain in cooler waters below the thermocline during summer months (Scott and Crossman 1973). Edsall and Colby (1970) determined young lake herring had an upper lethal temperature of 78.8° F. Zooplankton and immature stages of aquatic insects, such as mayflies and caddisflies are important prey items for lake herring (Scott and Crossman 1973). Lake herring eggs, whitefish eggs and small minnows have also been reported in the diet of lake herring (Scott and Crossman 1973).

Paddlefish

Paddlefish are native to the Missouri River in South Dakota (Bailey and Allum 1962; Cross et al. 1986; Galat et al. in press). The construction of mainstem Missouri River dams has severely impacted paddlefish populations through the loss of spawning habitat, blocked migration routes, altered flow regimes and altered hydrology (Sparrowe 1986; Unkenholz 1986). The concentration of paddlefish below dams during annual spawning migrations following dam construction initially increased paddlefish fisheries, however with riverine spawning grounds blocked or inundated by reservoirs, natural recruitment declined as did paddlefish abundance (Unkenholz 1986). If paddlefish spawning and recruitment can occur above a reservoir, since paddlefish are filter feeders on zooplankton, conditions in reservoirs are more favorable for feeding and growth of paddlefish (Rehwinkel 1978, Russell et al. 1980). Remnant populations with little or no recruitment do exist in between mainstem dams on the Missouri River in South Dakota. The tailrace paddlefish fishery below Big Bend Dam and above Lake Francis Case was one of those that was substantial and then declined because of a lack of recruitment due to the loss of spawning grounds and/or migration routes. In an effort to restore this fishery and maintain a population of paddlefish within Lake Francis Case, with the exception of 1987, paddlefish have annually been stocked into Lake Francis Case since 1985. In Lake Francis Case, the primary sampling of paddlefish occurs at a spawning congregation below the mouth of the White River during broodfish collection. Because sexual maturity isn't reached until about 8 years for males and 11 years for females (Hesse et al. 1989, 1991) it wasn't until recent years that stocked fish began to be sampled in this area (Jason Sorensen, SDGF&P resource biologist, personal communication). A total of 25,000 paddlefish (1.9/lb.) are scheduled to be stocked in Lake Francis Case in 2004. Because of the archetypical status of paddlefish in the Missouri River and their coexistence in the Missouri River with pallid sturgeon, other life history characteristics will not be discussed.

Rainbow smelt

Rainbow smelt are an introduced species to the Missouri River in South Dakota (Cross et al. 1986; Galat et al. in press). However, rainbow smelt have never been

directly stocked into the Missouri River in South Dakota (Hanten and Talsma 1984; SDGF&P fish stocking database), having been introduced via transfer from Lake Sakakawea. In 1971, a total of 7,200 Lake Superior strain adult rainbow smelt were stocked into Lake Sakakawea, North Dakota (Berard 1978 my report). Entrainment of rainbow smelt, flushing fish from Lake Sakakawea, through the Garrison powerhouse led to an introduction of rainbow smelt into Lake Oahe. Rainbow smelt have never been directly stocked in the mainstem Missouri River in South Dakota. With large volumes of suitable coldwater habitat essentially void of coldwater prey fish, rainbow smelt flourished in Lake Sakakawea and Lake Oahe. Larval smelt were first collected in Lake Oahe in 1977 (Nelson 1980). By 1977, rainbow smelt were abundant in Lake Oahe (Burczynski et al. 1987; Warnick 1987) and fisheries managers began efforts at developing a coldwater sport fishery. Because this species is well established, there are no plans to stock rainbow smelt in the Missouri River in South Dakota.

The geographical and vertical distribution of rainbow smelt is strongly temperature dependent (Burczynski et al. 1986; Stone and Nealson 1990; Nelson-Stastny 2001). Age-0 rainbow smelt tend to segregate to higher temperatures away from older rainbow smelt, while age-1 and older rainbow smelt were within and below the metalimnion (Dryer 1966; Emery 1973; Brandt et al. 1980; Argyle 1982; Heist and Swanson 1983; Brandt and Madon 1986; Nelson-Stastny 2001). Observations of rainbow smelt in Lake Erie suggest that after the lake is stratified, adult rainbow smelt remain below the thermocline in water temperatures between 42.8 to 50 °F (Ferguson 1965; MacCallum and Regier 1970). In Lake Oahe, age-0 rainbow smelt were above the thermocline in water greater than 59.9° F, while age-1 rainbow smelt were within and just above the thermocline in water temperatures ranging from 44.6° to 59.9° F (Nelson-Stastny 2001). A high abundance of age-1 and older rainbow smelt might cause age-0 rainbow smelt to occupy water temperatures warmer than preferred.(Nelson-Stastny 2001). In 1996 with a high abundance of age-0 and age-1 and older rainbow smelt, age-0 rainbow smelt were observed in water temperatures as high as 71.6° F in Lake Oahe (Nelson-Stastny 2001). The upper lethal water temperature for rainbow smelt is approximately 77° F (Morrow and Fischenic 2000).

Entrainment of rainbow smelt can and does occur from Lake Oahe through the Oahe powerhouse (Unkenholz 1998; Smith 2000). In 1997, in excess of 400 million rainbow smelt were flushed from Lake Oahe the majority of which were larval and juvenile rainbow smelt (Smith 2000). The transfer of rainbow smelt has been documented downstream from Gavins Point Dam into the Mississippi River below the mouth of the Missouri River (Pflieger 1997). Rainbow smelt were first reported from the Missouri River in 1978 (Pflieger and Grace 1987) which corresponds well to the time frame in which they became established in Lake Oahe. Pflieger (1997) pointed out that there are drastic seasonal fluctuations in the abundance of rainbow smelt from the Missouri River in Missouri. The largest numbers of rainbow smelt were collected in November and December, however no rainbow smelt reported from April to June from the Missouri River in Missouri (Pflieger 1997). No adult rainbow smelt have been sampled from the Missouri River in Missouri (specimens ranged from 1.4 to 3.2 inches) (Pflieger 1997). This is not surprising because of rainbow smelt avoid warmer water temperatures, especially by adult smelt. Additionally, summer water temperatures in riverine stretches, especially in the lower river, often exceed the upper lethal temperature for rainbow smelt. Pflieger (1997) states that few if any smelt survive their first year in the Missouri River in Missouri based on wide fluctuations in abundance and the lack of adults in samples. Escapement of larval and juvenile smelt is the likely source for smelt in the Missouri River in Missouri (Pflieger 1997). Based on larval surveys, entrainment information, temperature preferences and the months smelt were sampled in the Missouri River it is evident that Pflieger's observations are sound. Adult rainbow smelt are entrained through the Oahe powerhouse (Unkenholz 1998; Smith 2000). Thermal tolerance and/or increased vulnerability to predation in more turbid waters likely explain the absence of adult rainbow smelt in the lower river.

Rainbow smelt are a carnivorous fish, feeding on a wide variety of smaller prey items. In the Great Lakes *Mysis relicta*, a shrimp-like crustacean, is the primary prey while other invertebrates eaten included amphipods, ostracods, aquatic insect larvae and aquatic worms (Smith and Crossman 1973). Fish seldom occur in rainbow smelt stomachs but made up about 6-10% of the volume in the Great Lakes (Scott and Crossman 1973). Small rainbow smelt and sculpins were the primary prey of larger

rainbow smelt, while burbot, white bass, whitefish, and emerald shiner have also been reported (Scott and Crossman 1973). Rainbow smelt in Lake Oahe are primarily selective planktivores, selecting for the largest prey item available (Schmulbach et al. 1983; Karnitz 1992) indicative of a visual feeder. Schmulbach et al. (1983) reported that in rainbow smelt examined from Lake Oahe that 99.5% of the prey items were zooplankton, while benthos accounted for 0.4% and fish accounted for <0.1%. Karnitz (1992) reported similar results for rainbow smelt in Lake Oahe, preying primarily on zooplankton and to a lesser extent insect larvae and pupae and fish (fish found in 2 of 320 stomachs examined). Schmulbach et al. (1983) examined 319 rainbow smelt stomachs with 27 (8.5%) containing fish. All of the fish eaten by rainbow smelt were age-0 smelt (Schmulbach et al. 1983). Food habit studies in Lake Michigan, Lake Huron and Lake Erie have shown rainbow smelt prey primarily on fish after reaching 180 mm (Gordon 1961; Price 1963; Foltz and Norden 1977 in Karnitz thesis chapter 2). However rainbow smelt in Lake Oahe rarely exceed 180 mm (Karnitz 1992; Johnson et al. 1998; Nelson-Stastny 2001).

Rainbow smelt are the most important prey species in Lake Oahe (Jackson 1992; Bryan 1995; Lynott 1997; Hill 2000 R. P. Hanten, SDGF&P fishery biologist, personal communication) enabling many sport fish species to grow fast, often achieving trophy size. Without abundant smelt in Lake Oahe, condition and growth decline making the sport fishery less attractive to anglers resulting in less angling pressure and lost revenue for surrounding communities. When abundant rainbow smelt have been popular as a food fish for shoreline seiners during the rainbow smelt's spring spawning run (Missouri River Fisheries Center staff, SDGF&P).

Spottail shiner

The spottail shiner is an introduced species to the Missouri River in South Dakota (Hanten and Talsma 1984; Cross et al. 1986; Galat et al. in press). Spottail Shiners were introduced as an alternative prey species to take advantage of the increased volume of clearer water in the littoral area of the mainstem Missouri River reservoirs in South Dakota. Spottail shiners were introduced in mainstem reservoirs in South Dakota as follows: Lake Oahe 1973-75, Lake Sharpe 1978, Lake Francis Case 1979, Lewis and

Clark Lake 1973 (Hanten and Talsma 1984). Spottail shiners have become well established in the mainstem Missouri River reservoirs in South Dakota. Spottail shiner and emerald shiner *Notropis atherinoides* are two of the most abundant littoral prey species in the mainstem reservoirs in South Dakota (Johnson et al. 2002; Lott et al. 2002; Stone and Sorensen 2002; Wickstrom 2002). Spottail shiners are important as prey for many sport fish in the Missouri River in South Dakota (Jackson 1992). In Lake Oahe, spottail shiner presence in habitats, i.e. the warmer littoral zone, helps to provide a prey source where rainbow smelt are scarce (Sewell 1993). Because this species is well established, there are no plans to stock spottail shiners in the Missouri River in South Dakota.

The most commonly eaten prey items of spottail shiners in Lake Oahe were larger zooplankton (*Daphnia*), aquatic insect larvae (chironomids) and adult insects (Diptera) (Sewell 1993). No fish were present in the diets of spottail shiners sampled from Lake Oahe (Sewell 1993). The propensity for spottail shiners to select larger prey items indicates that they are visual feeders.

Smallmouth Bass

The smallmouth bass is an introduced species to the Missouri River in South Dakota (Bailey and Allum 1962; Hanten and Talsma 1984; Cross et al. 1986; Galat et al. in press). The first introduction of smallmouth bass into the Missouri River in South Dakota occurred in Lewis and Clark Lake in 1972 with a stocking of 46,400 fingerlings (Hanten and Talsma 1984). A substantial effort to introduce and establish smallmouth bass in throughout the mainstem Missouri River in South Dakota began in the early 1980's and continued for more than a decade (Hanten and Talsma 1984; SDGF&P fish stocking database). Smallmouth bass are naturally reproducing and have become well established in the Missouri River in South Dakota (Lott 2000). Smallmouth bass ranked fifth in preference on the Missouri River by South Dakota residents (Stone 1996). They are generally in the top five of most abundant fish in angler harvest from Missouri River reservoirs in South Dakota (Johnson et al. 2002; Lott et al. 2002; Stone and Sorensen 2002; Wickstrom 2002). Smallmouth bass have not been stocked in the Missouri River in South Dakota since 1998 (SDGF&P fish stocking database). Because this species is

well established, there are no plans to stock smallmouth bass in the Missouri River in South Dakota.

Large, clear lakes and reservoirs with an average depth greater than 9 m characterize optimum habitat in lakes (Turner and MacCrimmon 1970; Coble 1975; Miller 1975; Pflieger 1975). Cool, clear, midorder streams were characteristic of optimum riverine habitat (Carlander 1977). Preferred temperature in the field was reported between 68.5° – 70.3° F (Ferguson 1958). Habitat use by smallmouth bass varies with size and time of the year (Scott and Crossman 1973; Lott 2000). Larger adult smallmouth bass move shallower and closer to shore prior to spawning earlier than smaller bass prior to spawning in Lake Oahe (Lott 2000). Later in the season larger smallmouth bass are generally located deeper and further from shore than medium sized bass (Lott 2000). Smallmouth bass tend to found around the protection of cover such as rip-rap, rock, submerged trees, and aquatic vegetation (Scott and Crossman 1973). Higher frequencies of cover use have been documented for smaller smallmouth bass versus larger smallmouth bass (Reynolds and Casterlin 1976). This pattern of cover use by different size groups of smallmouth bass was also observed in Lake Oahe (Lott 2000). Smallmouth bass can tolerate periodic turbidity (Webster 1954; Cleary 1956). However, excessive turbidity and siltation will reduce a population of smallmouth bass (Coutant 1975). Typical smallmouth bass habitat has very low turbidity, usually ≤ 25 JTU (Jackson turbidity units – roughly equivalent to NTU), and almost never > 75 JTU with the exception of flood conditions when turbidity has approached 250 JTU (Hubert and Lackey 1980). Jenkins (1975) found that smallmouth bass populations were more productive in clearer, less fertile reservoirs. In a Kentucky lake with a well-defined nutrient gradient from eutrophic upreservoir to oligotrophic near the dam, stocked smallmouth bass became significantly more abundant in the lower, infertile area compared with the more fertile middle and upper areas (Buynak et al. 1991).

In general, prey size of smallmouth bass increases from zooplankton, to immature aquatic insects and finally crayfish and fish as the size of smallmouth bass increases (Scott and Crossman 1973). While fish and crayfish were well represented in smallmouth bass diets, aquatic and terrestrial invertebrates were also major components of diet in Lake Oahe (Lott 1996). Fish species consumed by smallmouth bass in Lake

Oahe include the following: johnny darter *Etheostoma nigrum*, fathead minnow *Pimephales promelas*, spottail shiner, rainbow smelt and unidentified percids (Lott 1996).

Northern Pike

There is general agreement that northern pike are native to the James-Sioux and Niobrara-Platte drainages (Cross et al. 1986; Galat et al. in press). Bailey and Allum (1962) listed northern pike as a probable native for the same drainages based on the potential distribution via headwater stream connections between the Lac Qui Parle River of the Minnesota River draining to the east, and the western connection with Deer Creek of the Big Sioux drainage and upper Missouri drainages (additional connections were also mentioned. Galat et al. (in press) stated the following regarding the status of northern pike in the upper Missouri River:

However, North Dakota Game and Fish consider it a native species as records indicate its presence at the time Bismarck was settled (1882-1883, Barrett 1895). Rail service arrived in central North Dakota in the 1860s and U.S. Bureau of Fisheries beginning in 1880 do not indicate northern pike stockings until 1899. We therefore list its status to the Little Missouri-White drainage unit drainage as native.

Based on the discussion above it is reasonable to conclude that northern pike are native to the entire South Dakota portion of the Missouri River. Initial sampling in the mainstem Missouri River reservoirs in South Dakota revealed a relatively low abundance of northern pike (Nelson and Walburg 1977). The initial abundance in the mainstem reservoirs in South Dakota was likely indicative of a relatively low abundance in the previously unaltered Missouri River. However, as the reservoirs filled and the prairies were flooded, spawning conditions with abundant flooded vegetation were ideal for northern pike and their abundance increased substantially (Nelson and Walburg 1977). Northern pike's potentially large size, table quality and increased abundance made them popular with anglers. Northern pike were ranked second in preference on the Missouri River by South Dakota residents and were also the second most fished for species on the Missouri River (Stone 1996). Once the mainstem Missouri River reservoirs in South Dakota reached normal operating levels, the frequency of flooded vegetation providing favorable spawning conditions for northern pike became sporadic. Consequently,

production of northern pike became sporadic and northern pike populations declined in abundance (Nelson and Walburg 1977). In an attempt to supplement natural reproduction, northern pike were stocked with increasing frequency as their abundance declined (Hanten and Talsma 1984; SDGF&P fish stocking database). Northern pike stocking attempts in the mainstem of the Missouri River in South Dakota met with limited success, i.e. when conditions were good for natural reproduction stocking success was good and vice versa (John Lott, SDGF&P, personal communication). Northern Pike have not been stocked into the mainstem of the Missouri River since 1997 (SDGF&P fish stocking database). There are currently no plans to stock northern pike in the mainstem of the Missouri River in South Dakota to augment natural reproduction.

Northern Pike occur in a wide range of habitats. Northern pike are a coolwater fish that are most productive in temperate mesotrophic-eutrophic environments in which transparency is high, vegetative cover abundant, and the development of the vegetation-open water interface is high (Casselman 1978). Northern pike inhabit clear, warm, slow, meandering heavily vegetated rivers or warm, weedy bays of lakes (Scott and Crossman 1973). In general, throughout their range, northern pike occur more frequently in lakes than in rivers (Crossman 1978), as they are not adapted for life in strong current velocities. Northern pike move into shallow water in the spring and fall then move to deeper cooler water in the summer (Scott and Crossman 1973). While submerged vegetation is important for spawning northern pike (Scott and Crossman 1973), sufficient macrophyte cover for nursery habitat providing protection predation and cover for prey species where young pike lie in wait, may be more important (Casselman and Lewis 1996). The optimal temperature range for growth of northern pike is 66.2° to 69.8° F, while the incipient lethal temperature of subadult northern pike was 84.9° F (Casselman 1978).

Over a whole season the food of adult northern pike is 90% fish, however at times they will prey heavily on frogs, crayfish, mice, muskrats and ducklings (Scott and Crossman 1973). Northern pike select for, and are especially adept at capturing fish that swim high in the water column and are silhouetted against a lighter background (Casselman 1978). In the St. Lawrence River northern pike preferred soft-rayed species such as alewives that swim in midwater (Casselman 1978). As has been discussed with

other species in this report, for a fish that is a visual feeder, increased turbidity can affect the ability to forage. Craig and Babaluk (1989) showed that decreased water transparency, i.e. increased turbidity, decreased the body condition of northern pike. Craig and Babaluk (1989) concluded that increased turbidity reduced the ability of northern pike to feed.

Yellow Perch

There is agreement that yellow perch are native to the James-Sioux drainage (Evermann and Cox 1896; Bailey and Allum 1962; Cross et al. 1986; Galat et al. in press). It was speculated that the James River may have been the western boundary for yellow perch (Evermann and Cox 1896; Bailey and Allum 1962). However, Galat et al. in press also list the yellow perch as native to the Little Missouri-White drainage. In August of 1952, Bailey and Allum (1962) sampled yellow perch from a connected Missouri River backwater 3 miles southeast of Pierre South Dakota prior to impoundment of Lake Sharpe (a month after the closure of Fort Randall Dam). Yellow perch were sampled during early fish populations surveys in the impoundments of the mainstem Missouri River in South Dakota (Shields 1955; Nelson and Walburg 1977). Finally, yellow perch have not been stocked directly into the mainstem of the Missouri River in South Dakota (Hanten and Talsma 1984; SDGF&P fish stocking database). It is reasonable to conclude that yellow perch are indeed native to nearly all of the Missouri River in South Dakota.

Abundance of yellow perch was low in the original Missouri River. Yellow perch followed the same patterns in abundance as northern pike because of their reliance on flooded vegetation for successful spawning and production. As the mainstem reservoirs filled flooded vegetation was abundant, optimal spawning conditions were created and strong year classes of yellow perch were produced (Beckman and Elrod 1971; Gasaway 1970). After reservoirs filled, the spawning habitat deteriorated and there were strong year classes of yellow perch in years of high water (Nelson and Walburg 1977), likely when high waters flooded vegetation. In recent years, yellow perch production has fluctuated considerably from year to year in the mainstem reservoirs in South Dakota (Lott et al. 2002; Johnson et al. 2002; Stone and Sorensen 2002; Wickstrom 2002). Benson (1968) speculated that the higher turbidity characteristic of Lewis and Clark

Lake, and to a lesser degree, Lake Francis Case, may limit survival of yellow perch. Yellow perch numbers will decline in a body of water in which turbidity increases or vegetation declines (Scott and Crossman 1973). Conditions for yellow perch may be more suitable in the larger mainstem Missouri River reservoirs, which more closely approach lake conditions (Benson 1968). Scott and Crossman (1973) stated that yellow perch are more abundant in the open water of lakes with moderate vegetation, clear water and bottoms of muck to sand and gravel. Nelson and Walburg (1977) reported that yellow perch were most abundant in sections of main stem Missouri River reservoirs in South Dakota that tended to be shallow and productive and least abundant in those that tended to be deep and less productive or river like. The optimal temperature range for yellow perch is 69.8° to 77.0° F (Scott and Crossman 1973), while the upper lethal temperature is 90.1° F (Ferguson 1958). The diet of yellow perch is largely immature insects, larger invertebrates, and fishes, taken in open-water or off the bottom (Scott and Crossman 1973). Yellow perch will prey on fish eggs and young fish of a wide variety of species (Scott and Crossman 1973).

Yellow perch were ranked third in preference on the Missouri River by South Dakota residents and were also the third most fished for species on the Missouri River (Stone 1996). Although, yellow perch are often considered a sport fish, relatively slow growth in the mainstem of the Missouri River reservoirs has relegated them to prey fish status. Yellow perch are an important food item for many of the important sport fish species; this is especially true in Lake Oahe during downward trends in rainbow smelt populations (Jackson 1992).

Walleye

The walleye is listed as native to eastern South Dakota and the Missouri River by Bailey and Allum (1962). Cross et al. (1986) and Galat et al. (in press) list walleye as native to the White-Little Missouri drainage, thereby encompassing much of the mainstem Missouri River in South Dakota. Cross et al. (1986) also listed it as native to the Sioux-James drainage and uncertain in the Platte-Niobrara drainage. Because Galat et al. (2004) combined the Sioux-James and Platte-Niobrara drainage units, walleye were listed as uncertain for the whole unit. Bailey and Allum (1962) added that it persisted in

the Missouri River, but in smaller numbers than the sauger, *Sander canadense*. The lower density of walleye, relative to other species better adapted to the turbid riverine environment of the unaltered Missouri River, such as sauger, in addition to the difficulty in sampling the Missouri River were likely the reason their presence wasn't noted until Everman and Cox (1896) reported them. Moreover, the similarity of walleye to sauger could have led to misidentification of walleye as sauger in the earliest faunal surveys of Missouri River fishes, i.e. less abundant walleye may have been lumped together with more abundant walleye. In fact, Everman and Cox (1896) reported difficulty in identification of younger percid specimens based on external characteristics alone. This is why they counted and measured pyloric caeca which provide reliable differences between the species (Eddy and Underhill 1978). It is important to note the location of sampled walleye reported by Everman and Cox (1896) because of the proximity to the Missouri River and the state of the Missouri River when walleye were sampled. From Chamberlain, South Dakota, Everman and Cox (1896) gave the following account of the Missouri River and the difficulty of sampling it:

The Missouri river itself was examined at Chamberlain, S. Dak., where the stream is divided into two channels by and island, the west channel being 1,200 feet wide and the east 1,436 feet. At the time of the visit the water was higher than usual, "the June rise," as the people call it, and the current was swift, in some places averaging 3 feet per second. Owing to the high water it was impossible to do successful seining, although we attempted it at the north end of the island. As is usually the case with this river, the water was exceedingly muddy. At places the recently deposited silt was so deep that it was dangerous to attempt to wade in the water over it. Where the water had receded enough to allow a light crust to form on top of the mud it was possible to stand and shake the whole mass for a distance of 10 feet or more in all directions. The Missouri was also examined at Running Water, opposite Niobrara, but no specimens were obtained.

The larger more important river fishes, such as sturgeon, cat, and buffalo are said to be abundant in this portion of the river and to furnish a considerable food supply.

Based on their itinerary, Crow Creek, which empties into the Missouri River a couple miles north of Chamberlain, South Dakota, was examined on June 23, 1893, likely the same day or day after the above observation was made.(Everman and Cox 1896). On June 27, 1893, Choteau Creek was sampled by Everman and Cox (1896). Walleye were

sampled from both of these sights and identification confirmed by pyloric caeca counts (Everman and Cox 1896). The timing and size of creeks is significant because the creeks normally would have been had enough flow to support movement of fish, including walleye, moving into them from the Missouri River. Walleye may have moved into these smaller tributaries to spawn and may remained in these smaller tributaries as long as flow was sufficient to support them, i.e. spring runoff was sufficient. However, in many years flows in these streams would have likely dropped sufficiently to force the walleye to vacate these small tributaries and move back into the main stem of the Missouri River. The United States Geological Survey has recorded flows in Choteau creek < 0.01 cfs. Walleye were not stocked into the main stem Missouri River in South Dakota until 1952 (Hanten and Talsma 1984).

Walleye should be classified as native to the Missouri River in South Dakota based on the following: (1) Lack of a stocking record into the main stem Missouri River prior to the first recorded sampling in 1893; (2) Detailed information provided in Everman and Cox (1896) regarding identification, locations of samples with regard to behavior of walleye, difficulty in sampling the main stem Missouri River, especially for a fish in relatively low abundance the walleye; (3) The potential for misidentification of walleye as sauger in initial surveys; (4) The native classification by Bailey and Allum (1962), Cross et al. (1986) and Galat et al. (in press).

Walleye are tolerant of a wide range of environmental conditions, but are most abundant in medium to large lakes with extensive littoral areas, moderate turbidities, and moderate turbidities (Scott and Crossman 1973). Ryder (1977) showed that peak feeding occurs at water transparency levels of 1 to 2 m Secchi disk depth, with a great decrease in activity at < 1 or > 5 m Secchi disk depths. The preferred spawning habitats in lakes are shallow rocky or coarse gravel shoreline areas (Scott and Crossman 1973). The spawning habitat requirements are a likely explanation for the delay in development of abundant walleye populations in the mainstem reservoirs. Optimal temperature for walleye ranges from 71.8° - 73.4° F with an upper limit at 88.9° F (Morrow and Fischenic 2000).

While walleye are native to the Missouri River in South Dakota, stocking of walleye has been utilized to try and enhance the abundance of this important and popular

sport fish. A total of 220,000 walleye fry were stocked into Lake Francis Case in from 1952 –1953 (Hanten and Talsma 1984). From 1957 to 1958, a total of 411,900 walleye fry were stocked into Lewis and Clark Lake (Hanten and Talsma 1984). While the number of stocked fish appears large, they should be put into perspective with the standard stocking protocol of 1,000 walleye fry/acre/year exercised by the South Dakota Department of Game Fish and Parks (SDGF&P). The number of walleye was probably insufficient to change the structure of the fish community. Based on the surface area and walleye stocked per year the stocking density in Lake Francis Case from 1952-1953 was only 1.4 walleye fry/acre and in Lewis and Clark Lake from 1957-1958 only 8.2 walleye fry/acre. These stocking rates were only 0.14% and 0.82% of the SDGF&P stocking protocol for walleye fry and were likely inadequate to change the structure of the fish community. Fish population surveys in Lake Francis during 1954 failed to sample walleyes, however the likelihood of their presence in the reservoir was suggested by the presence of walleye in low numbers in the Fort Randall tailrace (Shields 1955). Four walleye were sampled from Lake Francis Case in 1955, which were determined to be from the 1953 year class (age-2) and 1954 year class (age-1) (Shields 1956). The presence of walleye from the 1954 year class in Lake Francis Case is important because walleye were only stocked in Lake Francis Case in 1952 and 1953. These walleye would not have been sexually mature in 1954 as age-1 and age-2 walleye, since walleye don't reach sexual maturity until at least age-3 or age-4. Therefore, the presence of walleye from the 1954 year class indicates spawning occurred from walleye older than those initially stocked into the Missouri River in 1952. In each of Lakes Oahe, Francis Case, and Lewis and Clark, only a single age-0 walleye was seined in the first 6 years after impoundment (Nelson and Walburg 1977). Evidence is lacking that would show the initial walleye stockings from 1952 and 1953 in Lake Francis Case had any impact on abundance of walleye in the reservoir as populations remained low for several years after the stocking (Shields 1957). Nelson and Walburg (1977) showed that the walleye population in Lake Francis Case developed slowly and was dependent on the development of suitable spawning substrate of rubble and gravel by wave action removing finer soil particles from the lake shores. Adults were abundant in Lakes Oahe, Sharpe and Francis Case by the early 1970's having been the slowest to develop in Lake

Francis Case and the fastest in Lake Sharpe (Nelson and Walburg 1977). In general, spawning habitat developed in the reservoirs over a period of years as mentioned earlier and walleye populations followed. In Lake Sharpe, spawning habitat was available immediately and abundant walleye populations developed soon after impoundment (Nelson and Walburg 1977). It is important to note that abundant walleye populations had developed in the three upper mainstem reservoirs and the only one that had been stocked with no evidence of success, was the lowermost, Lake Francis Case. As of 1955, the policy of the then Game, Fish and Parks Commission was to not stock fish in the main stem reservoirs. Added to that, Shields (1955) stated that despite low abundance of walleye and northern pike, when or if conditions are favorable, the stock is sufficient to perpetuate the species. More favorable habitat conditions, not stocking, in the three uppermost reservoirs had allowed walleye to not only perpetuate but become abundant. No walleyes were stocked in the main stem of the Missouri from 1959-1982 (Hanten and Talsma 1984). Walleyes were stocked in attempts to supplement natural reproduction from 1983-1998. The stocking density in a given year for a given lake was always well below the standard SDGF&P protocol and likely had minimal affect on abundance in a given lake as a whole. The only walleye stocking since 1998 was done in an attempt to lessen the impact of declining reservoir levels in Lake Francis Case during the spring of 2002. There are no plans to stock walleyes into the main stem of the Missouri River in South Dakota in 2004. The walleye populations in the Missouri River mainstem reservoirs of South Dakota are have not collapsed without stocking in recent years, and continue to be one of the most popular and valuable benefits resulting from the Pick Sloan Plan.

Juvenile and adult walleyes are generally piscivorous (Priegel 1963; Kelso 1973; Johnson and Hale 1977; Swenson 1977; Knight et al. 1984; Vigg et al. 1991, Jackson 1992; Mero 1992; Bryan 1995). Age-0 walleye feed on zooplankton, then generally shift to a primarily piscivorous diet at a length between 30 mm and 60 mm (Jackson 1992). Colby et al. (1979) suggested that invertebrates are gradually displaced by fish in the diet of walleye in the summer, probably because immature insects become adults and emerge concurrently with increased availability of age-0 prey fish. However, invertebrates can be important to all lengths of walleyes in late spring and early summer (Kelso 1973;

Forney 1974; Colby et al. 1979; Johnson et al. 1988) and overwinter when prey fish are scarce (Priegel 1963). Both Jackson (1992) and Bryan (1995) noted macroinvertebrates were not a substantial part of the diet of walleye sampled in all of Lake Oahe, but they were more important in upper Lake Oahe than in lower portions of Lake Oahe.

Juvenile and adult walleyes generally eat a variety of fish species. For example, age-0 and yearling walleyes in Lake Erie first fed on yellow perch and then spottail shiners, emerald shiners and alewives in order of importance (Parsons 1971). Yellow perch and freshwater drum are often important in the diets of percids (Priegel 1969; Parsons 1971; Scott and Crossman 1973; Forney 1974, 1977; Wahl and Nielson 1985). Reviews of walleye food habit studies, assuming equal prey availability of soft-rayed and spiny-rayed fishes, revealed a general selection toward soft-rayed prey fishes. In water bodies where rainbow smelt and yellow perch were available, walleyes select for soft-rayed rainbow smelt (Swenson 1977; Hiltner 1983; Lyons and Magnuson 1987; Jackson 1992; Mero 1992; Bryan 1995). Mero (1992) noted the absence of rainbow smelt from walleye food habits corresponded to an increase in availability of age-0 prey fishes of other species. When a variety of prey species are available, no one prey will dominate predator diets unless highly selected. Hiltner (1983) found that walleye in Lake Sakakawea, ND fed exclusively on rainbow smelt spring and summer. Catch data indicated that rainbow smelt were the most abundant and available prey species at that time. Hiltner (1983) rationalized Lake Sakakawea walleye selected for rainbow smelt due to the availability of, walleye preference for, and lack of evasiveness of rainbow smelt. Swenson (1977) showed that walleye consumed a higher percentage of pelagic prey, i.e. rainbow smelt, yellow perch, and spottail shiners, versus a relatively low percentage of demersal prey, i.e. trout perch.

In August 1991, Jackson (1992) noted rainbow smelt dominated the diet of walleye in lower Lake Oahe, while presence of rainbow smelt in walleye diets decreased substantially from lower to middle Lake Oahe and no rainbow smelt were consumed by walleye in upper Lake Oahe. In 1991, reservoir water elevation was low and warm water temperatures established a deep, well-developed thermocline which limited the amount of coldwater habitat in the reservoir (i.e., coldwater habitat was absent in upper Lake Oahe and relatively low in middle Lake Oahe). The diet of walleye was diverse in middle and

upper Lake Oahe, where yellow perch, emerald shiners, spottail shiners, white bass, white crappie, and freshwater drum dominated walleye diets (Jackson 1992). Bryan (1995) documented a predominance of rainbow smelt in the diet of walleye throughout the reservoir in 1993 and related this to cooler water temperatures and coldwater habitat in middle and upper Lake Oahe than in 1991. This allowed rainbow smelt to occupy areas of the reservoir where water temperatures had exceeded their upper thermal limit in 1991. Mero (1992) found similar trends in Lake Sakakawea. Rainbow smelt were the most important prey of walleyes near the dam in August but were less important further up the reservoir. He attributed the decreased importance of rainbow smelt to an increased diversity of the prey base at the upper end of the reservoir, turbidity and water temperatures.

Rainbow smelt are the primary prey fish in Lake Oahe and their numbers declined since 1996 (Nelson-Stastny 2001). Robert Hanten, a fisheries biologist with the SDGF&P is completing a seasonal walleye food habits study in Lake Oahe and reported the following. During the spring of 2001, walleye were eating primarily macroinvertebrates (i.e., aquatic insects). Walleye shifted from a macroinvertebrate diet spring of 2001 to a diet composed almost entirely of fish summer of 2001 through spring of 2002. The fish diet included rainbow smelt, white bass, freshwater drum, emerald shiners, spottail shiner, gizzard shad, yellow perch, lake herring and white crappies. The type of prey fish found in walleye stomachs varied by season and location on the reservoir. Walleye throughout Lake Oahe ate primarily rainbow smelt during the spring. During the rest of the year, rainbow smelt were more common in walleye diets, the nearer walleyes were to Oahe Dam. This is expected as coldwater habitat, necessary for rainbow smelt survival, increases from upper Lake Oahe to lower Lake Oahe (Nelson-Stastny 2001). As reservoir levels have declined in recent years, by early September, cold water habitat has been restricted to the lower one-third of the lake (Nelson-Stastny personal observation). Consequently, rainbow smelt are restricted to the portion of Lake Oahe containing coldwater habitat. During the fall and winter of 2002, gizzard shad were collected for the first time from the stomachs of walleyes in lower Oahe. Gizzard shad provided a food source that helped support walleyes through the fall and winter. This was the first time shad were documented as a significant food source for walleyes in Lake

Oahe. No pallid or shovelnose sturgeon whole fish or bony structures were found in walleye stomachs during the course of spring 2001 through 2002 walleye food habits study. The only evidence of a walleye predating on a sturgeon species, (white sturgeon, *Acipenser transmontanus*, native to the Columbia River), was from a laboratory tank test in clear water with larval white sturgeon as the only prey item available (Dena Gadomski, US Geological Survey, personal communication). However, Mike Parsley, (US Geological Survey, personal communication), was unaware of any documented predation of sturgeon species by walleye in a natural environment. Additionally, a clear water tank is far different from the turbid riverine environment in which pallid sturgeon larvae would be found (Keenlyne 2003)

Fish Community changes

The native fish community of the Missouri River is diverse with 108 species native to the mainstem (Cross et al. 1986). Many of these fishes were well-adapted to a Missouri River characterized by high turbidity, swift current, shifting substrates of a sand-silt bottom, and a hydrologic cycle characterized by two spring rises and low summer flows (Pflieger 1971). Fishes adapted to these conditions were termed “big river” fishes (Pflieger 1971). The big river fishes are ecomorphologically adapted as turbid river, benthic specialists exhibiting several common adaptations including: an inferior mouth position, dorsoventral flattening of the head, streamlined or deep, humpbacked body shape, sickle-shaped or enlarged pectoral fins, reduced eyes and diverse and well developed chemosensory organs (i.e., sturgeons, chubs, buffaloes, carpsuckers, blue suckers, catfishes, burbot, and freshwater drum) (Galat et al. in press).

Over the course of the twentieth century the Missouri River was changed from its relatively natural state, experiencing large floods with a sinuous meandering channel moving across its floodplain and carrying voluminous amounts of sediment to a river that has been channelized, impounded behind massive dams creating large reservoirs, with a controlled hydrologic cycle that has dampened spring rises and increased summer flows, and transformed to a clearer river carrying only a fraction of the sediment it moved

historically, as much of it is now trapped behind impoundments (National Research Council 2002). The river can be broken into thirds with the upper third characterized as relatively natural, the middle third impounded with short interreservoir riverine stretches, and the lower third as a constricted channelized river. Alterations of the Missouri River have had significant impacts to species composition. Several of the native big river species have declined in abundance; this is especially so in the South Dakota portion of the main stem Missouri River as the vast majority of the river is now a lentic environment. The small remaining riverine stretches are either isolated and/or have traditional migration routes blocked and experience decreased water temperatures because of deepwater releases from reservoirs, significantly reduced turbidity levels and altered hydrologic cycles. Native species that have increased in abundance are similar in their adaptations, i.e. largely planktivores and sight-feeding carnivores, similar to those Pflieger and Grace (1987) reported as increasing in Missouri. In addition to habitat changes realized in the state of Missouri, in South Dakota, mainstem fish communities experienced dramatic increases in the amount of lacustrine habitat as 75% of the riverine miles in South Dakota were impounded behind reservoirs. The habitat changes further favored increases in abundance of native species more suited to lacustrine habitat, which had traditionally been in low abundance in the unaltered Missouri River.

One of the most noted examples of increased abundance for a native sight-feeding carnivore was that of the walleye, while the more turbid riverine adapted sauger declined in abundance. Saugers were the predominant percid in the original Missouri River, however after the lake-like conditions fully developed in the reservoirs, and sauger spawning habitat was reduced, sauger declined in all of the mainstem reservoirs in South Dakota except in Lewis and Clark Lake (Nelson and Walburg 1977). Sauger abundance has remained relatively stable in Lewis and Clark because as the smallest of the four mainstem reservoirs in South Dakota, current velocities remain higher and turbidity is higher relative to the other reservoirs. Additionally, there is a 39-mile relatively unaltered interreservoir riverine stretch above Lewis and Clark Lake which is important for spawning sauger (Nelson 1968). Increases in walleye abundance were discussed earlier in this report. The change in abundance of sauger and walleye described by Nelson and Walburg (1977) has been maintained into the 21st century. Relative

abundance (percent composition) of walleye and sauger from coolwater fish population surveys in the main stem reservoirs in South Dakota from 200: Lake Oahe - walleye (29%): sauger (0.2%); Lake Sharpe - walleye (41%): sauger (7%); Lake Francis Case - walleye (26%): sauger (11%); Lewis and Clark Lake – walleye (15%): sauger (17%) (Lott et al. 2002; Johnson et al. 2002; Stone and Sorensen 2002; Wickstrom 2002).

Observations were similar to those in South Dakota for populations of sauger and walleye in the Missouri River. Sauger populations have declined substantially in the Nebraska portion of the channelized Missouri river (Hesse 1994). Walleye abundance has increased since 1956 in Lake Sakakawea following its impoundment on the main stem Missouri River in North Dakota (Hendrickson and Power 1999).

Changes in the fish community as the habitat changed were also evidenced amongst cyprinid (minnow) species. Bailey and Allum (1962) recorded the flathead chub, *Platygobio gracilis*, as the dominant minnow in the turbid flowing waters of the Missouri River in South Dakota. The emerald shiner, *Notropis atherinoides*, was recorded as uncommon in the Missouri River prior to impoundment (Bailey and Allum 1962). Bailey and Allum (1962) pointed out, that following impoundment emerald shiners increased and could likely become a dominant species in the reservoirs. Beckman and Elrod (1971) examined the abundance and distribution of age-0 fishes during the last five years of the filling of Lake Oahe, 1965-1969. The catch of age-0 emerald shiners in seine hauls ranged from 18-50 per haul from 1965-1969 in Lake Oahe, second only to the catch of age-0 yellow perch (Beckman and Elrod 1971), which also had been rare to absent (see earlier discussion) in the preimpounded Missouri River. Flathead chubs which had once been the dominant cyprinid in the Missouri River experienced poor production. In three of the five years of sampling no age-0 flathead chubs were sampled and in the other two years the number per seine haul was 0.1 or less (Beckman and Elrod 1971). Their work was done prior to the stocking of fish in the South Dakota portion of Lake Oahe (Hanten and Talsma 1984). The only record of fish stocked into Lake Oahe prior to the work of Beckman and Elrod was of northern pike into the North Dakota portion of the lake (Hendrickson and Lee 2000). Today emerald shiners continue to be an important component of the prey fish community in the mainstem reservoirs in South

Dakota, however from 1997-20001 flathead chubs were not represented in the same fish population surveys (Johnson et al. 2002; Lott et al. 2002; Stone and Sorensen 2002; Wickstrom 2002). Beckman and Elrod (1971) noted that although adults of long-lived big river species such as pallid sturgeon, shovelnose sturgeon, paddlefish, and flathead catfish were observed in Lake Oahe, during 5 years of seining and trawling no age-0's of these species were captured. Beckman and Elrod (1971) concluded that the loss of river habitat as Lake Oahe filled, and the alteration of the river above Lake Oahe, i.e. altered hydrograph, reduced summer water temperatures and decrease silt load greatly reduced production of those big river fishes.

The walleye/sauger and flathead chub/emerald shiner are but two examples of numerous changes to fish communities as the habitat of the Missouri River was altered. The ability of both prey and predator species to exploit the altered habitat is a testament to the wide array of species present in the native fish fauna of the Missouri River. Based on the examples described above, a review of a wide body of literature and my own experience, habitat alterations were key to the changes in fish communities in the Missouri River. The declines of big river fish species occurred prior to the majority of fish stockings especially the stocking of the various nonnative species eventually stocked. As mentioned earlier, in the initial years of impoundment of the Missouri River in South Dakota, it was SDGF&P policy (Shields 1955) to not stock fish into the mainstem. Nelson and Walburg (1977) summed up the changes in the fish community in the main stem reservoirs in South Dakota as follows:

Species composition and abundance in the four reservoirs are a reflection of the populations originally present in the Missouri River and the adaptability of individual species to a reservoir environment.

Introduced Species

In general, the unaltered Missouri River in South Dakota was a relatively warm water prairie river. The filling of the mainstem reservoirs created one habitat type that was not present year-round in the preimpounded Missouri River, that being coldwater habitat in the largest of the mainstem reservoirs. Despite the diversity of native species present in the Missouri River, the coldwater (hypolimnetic) portions of the largest reservoirs, in South Dakota, primarily Lake Oahe remained relatively unutilized. This

led to several attempts and the eventual success at establishing a viable coldwater prey base, primarily rainbow smelt and secondarily lake herring, as well as an established fishery for Chinook salmon, and smaller tailwater fisheries for rainbow trout and brown trout (Table 1). In addition to the coldwater adapted species, two other sight-feeding predators, smallmouth bass and white bass, as well as the lentic adapted prey species, spottail shiner, have been stocked and become established into the mainstem of the Missouri River.

Pallid Sturgeon Predation

Nonnative fish species contribute to the decline of the native species in the Columbia and Colorado Rivers. However, caution should be used when making generalizations about the impacts of nonnative species in these rivers and imputing similar harm to fishes in the Missouri River. There are relatively small ichthyofaunal assemblages in the Colorado and Columbia Rivers relative to the large and diverse assemblage in the Missouri River. The Columbia River is reported to have 27 native species (McPhail and Carveth 1994), while the Missouri River is home to 108 mainstem species in the mainstem alone (Cross et al. 1986). The following excerpt from Johnson et al. (1993) discusses the native assemblage in the Colorado River and aptly describes why the linkage between predation issues in the Colorado and Columbia Rivers to the Missouri River is untenable:

The native freshwater fish assemblage of the Colorado River drainage consists of about 32 species (Minckley et al. 1986), but many species are confined to small, isolated waters and have little or no association with the 12 or so species of the big-water, mainstream fishes. The Colorado squawfish *Ptychocheilus lucius* is described as the only obligatory piscivore of the system (Vanicek and Kramer 1969; Minckley 1973; Tyus 1991), but some minnows of the genus *Gila*, especially roundtail chub *G. robusta*, may also consume fish (Minckley 1973). We suggest native larval fishes of the Colorado River basin evolved with relatively low predator pressure, resulting in fish that are predator naïve (Minckley 1983; Marsh and Brooks 1989; Magurran 1990; Minckley and Douglas 1991). By contrast, the Mississippi River drainage contains more than 260 native species of fish (Robison 1986) that evolved with high predator contact (Fraser and Cerri 1982; Power et al. 1985; Heins and Matthews 1987; Fraser et al. 1987). Many fishes introduced into the Colorado River basin are piscivorous game species that evolved in

predator-rich environments. We hypothesize that the razorback sucker, endemic to predator-poor waters, is inherently less predator wary than ecologically equivalent species from the Mississippi River drainage and will not avoid predators as readily.

The Johnson et al. (1993) hypothesis was proven correct. The study documented that the northern hog sucker *Hypentelium nigricans*, from the predator rich environment in the Mississippi drainage, had a significantly higher initial avoidance rate of predators compared with the razorback suckers, from the predator poor environment Johnson et al. (1993). Not only did pallid sturgeon evolve in a predator-rich environment, many of the most damaging nonnative piscivores in the Colorado River, such as channel catfish *Ictalurus punctatus* and flathead catfish *Pylodictis olivaris* (Marsh and Langhorst 1988; Marsh and Brooks 1989), not only coevolved with pallid sturgeon but are considered big river fishes sharing the same habitat niches and prey items of the unaltered Missouri River. The same holds true for the Columbia River, as walleye, smallmouth bass and channel catfish, which are native to all or portions of the Missouri River (Cross et al. 1986; Galat et al. 2004), predate on native salmonids in the Columbia River (Vigg et al. 1991).

Several of the species listed in Table 1 are native to the Missouri River in South Dakota, paddlefish, northern pike, yellow perch and walleye, and should be discounted as impacting pallid sturgeon populations. This is simply because they coexisted with pallid sturgeon (although, with the exception of paddlefish, they existed at relatively low abundance levels in the previously unaltered Missouri River). Habitat changes led to increased abundance of northern pike, yellow perch and especially walleyes. One could make the argument that the increased abundance of these sight-feeding predators in the altered Missouri River now pose a greater threat because of their increased abundance. However as was discussed by Keenlyne (2003), the selection of turbid flowing waters would negate predation by sight-feeding predators. Moreover, if predation by a percid such as a walleye were detrimental to pallid populations it is more likely that the sauger, which is more adept in lower light conditions and selects for demersal prey items (Swenson 1977) would have had an even greater impact on pallid sturgeon in the historic Missouri River, yet both species coexisted.

White bass and smallmouth bass are both introduced to the upper Missouri yet are considered native within the lower portions of the Missouri River, (Cross et al. 1986; Galat et al. 1986). Excessive turbidity reduces either the population size and/or feeding efficiency of these sight-feeding predators negating them as damaging predators to pallid sturgeon in their natural environment. Spottail shiners as a forage species could predate on eggs, however the eggs would likely be inaccessible in turbid waters (Keenlyne 2003) to nearly all species especially a sight-feeder.

Coldwater adapted species such as salmonids, rainbow smelt and lake herring are discounted as impacting pallid sturgeon populations because of thermal segregation. Additionally, they are primarily sight feeders and would avoid turbid waters and have difficulty feeding in turbid waters occupied by pallid sturgeon. because of the turbid waters occupied by pallid sturgeon.

Lastly, there has been no documentation in the literature cited in this paper, of any of the species in Table 1 preying on pallid sturgeon.

Summary

Habitat changes to the Missouri River in South Dakota led to increased abundance of several native species which were previously rare or low in abundance in the unaltered Missouri River. These same habitat alterations allowed for successful introductions of other species preadapted to the altered habitat. Some of the introduced species are native to other portions of the Missouri River. While the altered habitat has allowed certain species to flourish, it is this same altered habitat that has led to the endangered status of the pallid sturgeon. The preadaptation of these species to a lacustrine environment precludes such species from impacting pallid sturgeon populations either by preying on them or competing with them. Pallid sturgeon are native to and survived for millions of years in a turbid, dynamic riverine environment with annual flooding events, coexisting with many “big river” piscivorous fishes. If pallid sturgeon and other native Missouri River fauna are going to recover, large portions of the Missouri River will need to be returned to the natural form and function of the unaltered Missouri. The conditions under which pallid sturgeon spawn, where pallid sturgeon eggs develop, the rearing habitat for

young pallid sturgeon, the habitat of native riverine prey species which pallid sturgeon consumed (Keenlyne 2003) are all inhospitable to the introduced species in Table 1 because of one or more of the following: turbidity, temperature, predatory habits and/or current velocities

Literature Cited

- Argyle, R. A. 1982. Alewives and rainbow smelt in Lake Huron: midwater and bottom aggregations and estimates of standing stocks. *Transaction of the American Fisheries Society* 111:267-285.
- Bailey, R. M., and M. O. Allum. 1962. *Fishes of South Dakota*. Miscellaneous Publications No. 119, Museum of Zoology, University of Michigan, Ann Arbor.
- Barrett, J. C., G. D. Grossman, and J. Rosenfeld. 1992. Turbidity-induced changes in reactive distance of rainbow trout. *Transactions of the American Fisheries Society* 121:437-443
- Beckman, L. F., and J. H. Elrod. 1971. Apparent abundance and distribution of young-of-year fishes in Lake Oahe, 1965-69. P. 333-347. *in* G. E. Hall. editor. *Reservoir fisheries and limnology*. American Fisheries Society. Special Publication No. 8.
- Benson, N. G. 1968. Review of fishery studies on Missouri River main stem reservoirs U.S. Fish and Wildlife Service Research Report 71: 61 p
- Benson, N. G. 1988. *The Missouri River the resources their uses and values*. North Central Division American Fisheries Society. Special Publication No. 8.
- Berard, E. E. 1978. Investigate the influence of smelt on the walleye population in Lake Sakakawea. North Dakota Game and Fish Department, Dingell-Johnson Project Report F-2-R-31, Bismark.
- Berg, L., and T. G. Northcote. 1985. Changes in territorial, gill-flaring and feeding behavior in juvenile coho salmon (*Oncorhynchus kisutch*) following short-term pulses of suspended sediment. *Canadian Journal of Fisheries and Aquatic Sciences* 42:1410-1417.
- Black, E. C. 1953. Upper lethal temperatures of some British Columbia freshwater fishes. *Journal of the Fisheries Research Board of Canada* 10(4):196-210.
- Brandt, S. B., J. J. Magnuson, and L. B. Crowder. 1980. Thermal habitat partitioning by fishes in Lake Michigan. *Canadian Journal of Fisheries and Aquatic Sciences* 37:1557-1564.
- Brandt, S. B., and S. P. Madon. 1986. Rainbow smelt (*Osmerus mordax*) predation on slimy sculpin (*Cottus cognatus*) in Lake Ontario. *Journal of Great Lakes Research* 12(4):322-325.

- Brett, J. R. 1952. Temperature tolerance in young Pacific salmon, genus *Oncorhynchus*. Journal of the Fisheries Research Board of Canada 9 (6):265-323.
- Bryan, S. D. 1995. Bioenergetics of walleye in Lake Oahe, South Dakota. M.S. Thesis. South Dakota State University, Brookings, SD.
- Brynildson, O. M., V. A. Haker, and T. A. Klick. 1963. Brown trout, Its life history, ecology and management. Wisconsin Conservation Department. Publication 234:14p.
- Burczynski, J. J., P. H. Michaletz, and G. M. Marrone. 1987. Hydroacoustic assessment of the abundance and distribution of rainbow smelt in Lake Oahe. North American Journal of Fisheries Management 7:106-116.
- Buyanak G. L., L. E. Kornman, A. Surmont, and B. Mitchell. 1991. Evaluation of a smallmouth bass stocking program in a Kentucky reservoir. North American Journal of Fisheries Management 11:293-297.
- Casselman, J. M. 1978. Effects of environmental factors on growth, survival, activity, and exploitation of northern pike. American Fisheries Society Special Publication 11:114-128.
- Casselman, J. M., and C. A. Lewis. 1996. Habitat requirements of northern pike (*Esox lucius*). Canadian Journal of Fisheries and Aquatic Sciences 53(Supplement 1): 161-174.
- Cleary, R. 1956. Observations of factors affecting smallmouth bass production in Iowa. Journal of Wildlife Management. 20:353-359.
- Coble, D. W. 1975. Smallmouth bass. Pages 21-22 in H. Clepper, editor. Black bass biology and management. Sport Fishing Insititute, Washington, DC.
- Colby, P.J., R.E. McNicol, and R. A. Ryder. 1979. Synopsis of biological data on the walleye *Stizostedion vitreum vitreum* (Mitchill 1818). Fisheries and Agricultural Organization of the United Nation, Fisheries Synopsis 119, Rome, Italy
- Coutant, C.C. 1975. Responses of bass to natural and artificial temperature regimes. Pages 272-285 in H. Clepper, editor. Black bass biology and management. Sport Fishing Institute, Washington, D.C.
- Craig, J. F., and Babaluk, J. A. 1989. Relationship of condition of walleye (*Stizostedion vetreum*) and northern pike (*Esox lucius*) to water clarity, with special reference to Dauphin Lake, Manitoba. Canadian Journal of Fisheries and Aquatic Sciences. 46(9):1581-1586.
- Cross, F. B., R. L. Mayden, and J. D. Stewart. 1986. Fishes in the western Mississippi Basin (Missouri, Arkansas, and Red Rivers). Pages 367-412 in C. H. Hocutt and E. O. Wiley (editors). The zoogeography of North American freshwater fishes.

- John Wiley & Sons, New York.
- Crossman, E. J. 1978. Taxonomy and distribution of North American esocids. American Fisheries Society Special Publication 11:13-26.
- Dryer, W. R. 1966. Bathymetric distribution of fish in the Apostle Island region, Lake Superior. Transactions of the American Fisheries Society 94:169-176.
- Eddy, S. and J. C. Underhill. 1978. How to know the freshwater fishes. 3rd edition. Wm. C. Brown Company Publishers, Dubuque, Iowa.
- Edsall, T. A., and P. J. Colby. 1970. Temperature tolerance of young-of-the-year cisco, *Coregonus artedii*. Transactions of the American Fisheries Society 99(3):526-531.
- Emery, A. R. 1973. Preliminary comparisons of day and night habits of freshwater fish in Ontario lakes. Journal of the Fisheries Research Board of Canada 30:761-774.
- Evermann, B.W., and U.O. Cox. 1896. Report upon the fishes of the Missouri River basin. Pages 325-430 (Part5) in United States Commission of Fish and Fisheries. Report of the commissioner for the year ending June30, 1894. U.S. Government Printing Office, Washington, D.C.
- Ferguson, R. G. 1958. The preferred temperature of fish and their midsummer distribution in temperate lakes and streams. Journal of the Fisheries Research Board of Canada 15(4):607-624.
- Ferguson, R. G. 1965. Bathymetric distribution of American smelt *Osmerus mordax* in Lake Erie. Proceedings of the Conference on Great Lakes Research, Great Lakes Research Division, University of Michigan, publication 13:47-60.
- Foltz, J. W., and C. R. Norden. 1977. Food habits and feeding chronology of rainbow smelt, *Osmerus mordox*, in Lake Michigan. Fisheries Bulletin 75:637-640.
- Forney, J. L. 1974. Interactions between yellow perch abundance, walleye predation, and survival of alternate prey in Oneida Lake, New York. Transactions of the American Fisheries Society 103:15-24.
- Forney, J. L. 1977. Evidence of inter- and intraspecific competition as factors regulating walleye *Stizostedion vitreum vitreum* biomass in Oneida Lake, New York. Journal of the Fisheries Research Board of Canada 34:1812-1820.
- Gabel, J. A. 1974. Species and age composition of trap net catches in Lake Oahe, South Dakota, 1963-67. U. S. Fish and Wildlife Service Technical Paper. 75:21 p.

- Galat, D. L., C. R. Berry, W. M. Gardner, J. C. Hendrickson, G. E. Mestl, G. J. Power, C. Stone, and M. R. Winston. in press. Spatiotemporal patterns and changes in Missouri River fishes. Pages xx-yy in J. N. Rinne, R. M. Hughes, and R. Calamusso(editors). Historical changes in fish assemblages of large American Rivers. American Fisheries Society Symposium xx. Accepted.
- Gardner, M. B. 1981. Effects of turbidity on feeding rates and selectivity of bluegills. Transactions of the American Fisheries Society 110:446-450.
- Garside, E. T., and J. S. Tait. 1958 Preferred temperature of rainbow trout (*Salmo gairdneri* Richardson) and its unusual relationship to acclimation temperature. Canadian Journal of Zoology 36(3); 563-567.
- Gasaway, C. R. 1970. Changes in the fish population in Lake Francis Case in South Dakota in the first 16 years of impoundment. U. S. Fish and Wildlife Service Technical Paper. 56:30 p.
- Gordon, W. G. 1961. Food of the American smelt in Saginaw Bay, Lake Huron. Transactions of the American Fisheries Society 90:439-443.
- Greene, G. N. 1962. White bass feeding: scent or sight. Transactions of the American Fisheries Society 91(3): 326.
- Hanten, R.L. and A. Talsma. 1984. Fish stocking summary for Missouri River reservoirs. South Dakota Department of Game, Fish, and Parks, Report No. 84-1, Pierre.
- Heist, B. G., and W. A. Swenson. 1983. Distribution and abundance of rainbow smelt in western Lake Superior as determined from acoustic sampling. Journal of Great Lakes Research. 9(3):343-353.
- Hendrickson, J. and J. Lee. 2000. Aquatic investigations of the Missouri manstem in North Dakota. North Dakota Game and Fish Department, Division Report 36.
- Hendrickson, J. C., and G. J. Power. 1999. Changes in fish species abundance in a Missouri River manin stem reservoir during its first 45 years. Journal of Freshwater Ecology 14(4):407-416.
- Hesse, L. W., G. E. Mestl, and D. G. Schumacher. 1989. The status of paddlefish and the snag fishery in the Missouri River from Lewis and Clark Lake to the Big Sioux River. Nebraska Game and Parks Commission. Dingell-Johnson Project F-75-R-6 Job No. 4.

- Hesse, L. W., G. E. Mestl, M. R. Vorderstrasse, and C. D. Trail-Cook. 1991. The status of paddlefish and the snag fishery in the Nebraska portion of the Missouri River. Nebraska Game and Parks Commission. Dingell-Johnson Project F-75-R-8 Job No. 4.
- Hesse, L. W. 1994. The status of Nebraska fishes in the Missouri River. 6. Sauger (Percidae: *Stizostedion canadense*). Transactions of the Nebraska Academy of Sciences 21:99-108.
- Hill, T. D. 1997. Life history and bioenergetics of chinook salmon in Lake Oahe, South Dakota. Ph.D. Dissertation, South Dakota State University, Brookings.
- Hiltner, R. J. 1983. Comparison of walleye, *Stizostedion vitreum vitreum* (Mitchell), ecology and biology from three discrete areas of Lake Sakakawea, North Dakota. Master's thesis. University of North Dakota, Grand Forks.
- Hubert, W. A., and R. T. Lackey. 1980. Habitat of adult smallmouth bass (*Micropterus dolomieu*) in a Tennessee River reservoir, USA. Transactions of the American Fisheries Society 109(4):364-370.
- Jackson, J. J. 1992. Food habits of walleyes in Lake Oahe, South Dakota. M.S. Thesis, South Dakota State University, Brookings, SD.
- Jenkins, R. M. 1975. Black bass crops and species associations in reservoirs. Pages 114-124 in H. Clepper, editor. Black bass biology and management. Sport Fishing Institute, Washington, D.C.
- Johnson, B., D.L. Smith, and R.F. Carline. 1988. Habitat preferences, survival, growth, foods and harvests of walleyes and walleye x sauger hybrids. North American Journal of Fisheries Management 8:292-304.
- Johnson, B., J. Lott, and W. Nelson-Stastny. 1998. Annual fish population and angler use and harvest surveys on Lake Sharpe, South Dakota, 1997. South Dakota Department of Game, Fish and Parks, Wildlife Division, Annual report 98-14, Pierre.
- Johnson, B., R. Hanten, and Lott, J. 2002. Annual fish population angler use, harvest and preference surveys on Lake Sharpe, South Dakota, 2001. South Dakota Department of Game, Fish and Parks, Wildlife Division, Annual report 02-04, Pierre.
- Johnson, F. H. and J. G. Hale. 1977. Interrelations between walleye (*Stizostedion vitreum vitreum*) and smallmouth bass (*Micropterus dolomieu*) in four northeastern Minnesota lake, 1948-1969. Journal of the Fisheries Research Board

of Canada 34:1633-1642.

- Johnson, J. E., M. G. Pardew, and M. M. Lyttle. 1993. Predator recognition and avoidance by larval razorback sucker and northern hog sucker. *Transactions of the American Fisheries Society* 122:1139-1145.
- Karnitz, K. S. 1992. Influence of rainbow smelt predation on zooplankton community composition in Lake Oahe, south Dakota. Master's thesis. South Dakota State University, Brookings.
- Keenlyne, K. D. 2003. Life history and habitat use of the pallid sturgeon. prepared for South Dakota Office of the Attorney General
- Kelso, J. R. M. 1973. Seasonal energy changes in walleye and their diet in West Blue Lake, Manitoba. *Transactions of the American Fisheries Society* 102:363-368
- Knight, R. L., F. J. Margraf, and R.F. Carline. 1984. Piscivory by walleyes and yellow perch in Western Lake Erie. *Transactions of the American Fisheries Society* 113:677-693.
- Lott, J. P. 1996. Relationships between smallmouth bass feeding ecology and population structure and dynamics in lower Lake Oahe, South Dakota. South Dakota Department of Game, Fish and Parks, Wildlife Division, Completion report 96-03, Pierre.
- Lott, J., G. Marrone and D. Stout. 1997. Influence of size-and data at stocking, imprinting attempts and growth on initial survival, homing ability, maturation patterns and angler harvest of chinook salmon in Lake Oahe, South Dakota. Department of Game, Fish and Parks, Wildlife Division, Special Report No. 97-20.
- Lott, J. 2000. Smallmouth bass movement, habitat use and electrofishing susceptibility in lower Lake Oahe, South Dakota. South Dakota Department of Game, Fish and Parks, Wildlife Division, Completion report 00-15, Pierre.
- Lott, J., B. Johnson, and W. Nelson-Stastny. 2002. Annual fish population and angler use, harvest and preference surveys on Lake Oahe, South Dakota, 2001. South Dakota Department of Game, Fish and Parks, Wildlife Division, Annual report 02-19, Pierre.
- Lynott, S. T. 1997. Bioenergetics of rainbow trout in Lake Oahe, South Dakota. M.S. Thesis. South Dakota State University, Brookings, SD.
- Lyons, J. and J.J Magnuson. 1987. Effects of walleye predation on the population dynamics of small littoral-zone fishes in a northern Wisconsin Lake. *Transactions of the American Fisheries Society* 116:29-39.

- MacCallum, W. R., and H. A. Regier. 1970. Distribution of smelt, *Osmerus mordax*, and the smelt fishery in the early 1960's. *Journal of the Fisheries Research Board of Canada* 27:1823-1846.
- Marrone, G. M., and D. A. Stout. 1997. 1996 Whitlocks Bay spawning station annual report. South Dakota Department of Game, Fish and Parks, Wildlife Division, Annual report 97-01, Pierre.
- Marsh, P. C., and J. E. Brooks. 1989. Predation by ictalurid catfishes as a deterrent to re-establishment of hatchery-reared razorback suckers. *Southwestern Naturalist* 34:188-195.
- Marsh, P. C., and D. R. Langhorst. 1988. Feeding and fate of wild larval razorback sucker. *Environmental Biology of Fishes* 21:59-67.
- Martin, D. B., J. F. Novotny and G. K. O'Bryan. 1980. Limnology of four Missouri River reservoirs Part I: physiochemistry and phytoplankton production. *Proceedings of the South Dakota Academy of Science* 59:91-114.
- McPhail, J. D., and R. Carveth. 1992. A Foundation for Conservation: The Nature and Origin of the Freshwater Fish Fauna of British Columbia. Fish Museum, Department of Zoology, University of British Columbia. 39 pp.
- Mero, S. W. 1992. Food habits of walleye in Lake Sakakawea, North Dakota. M.S. Thesis, South Dakota State University, Brookings, SD.
- Miller, R. J. 1975. Comparative behavior of Centrarchid basses. Pages 85-94 in H. Clepper, editor. *Black bass biology and management*. Sport Fisheries Institute, Washington, DC.
- Morrow, J. V., and Fischenich, J. C. 2000. Habitat requirements for freshwater fishes. EMRRP Technical Notes Collection (ERDC TN-EMRRPSR-06), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/emrrp
- National Research Council. 2002. *The Missouri River Ecosystem: Exploring the prospects for recovery*. National academy Press. Washington, D.C.
- Nelson, W. R. 1968. Reproduction and early life history of sauger, *Stizostedion canadense*, in Lewis and Clark Lake. *Transactions of the American Fisheries Society* 97(2):159-166.
- Nelson, W.R. and C.H. Walburg. 1977. Population dynamics of yellow perch (*Perca flavescens*), sauger (*Stizostedion canadense*), and walleye (*S. vitreum vitreum*) in

- four man stem Missouri River reservoirs. *Journal of the Fisheries Research Board of Canada* 34:1748-1763.
- Nelson, W. R. 1980. Ecology of larval fishes in Lake Oahe, South Dakota. United States Department of the Interior, Fish and Wildlife Service Technical Paper 101, Washington D. C.
- Nelson-Stastny, W. 2001. Estimates of abundance, biomass, and distribution of rainbow smelt and other pelagic fish in Lake Oahe using hydroacoustic techniques, 1996-1999. South Dakota Department of Game, Fish and Parks. Wildlife division, 2000. Special Rport No. 01-06, Pierre.
- Noggle, C. C. 1978. Behavioral, physiological and lethal effects of suspended sediment on juvenile salmonids. Master's thesis. University of Washington, Seattle
- Parsons, J.W. 1971. Selective food preferences of walleyes of the 1959 year class in Lake Erie. *Transactions of the American Fisheries Society* 100:474-485.
- Pflieger, W. F. 1971. A distributional study of Missouri fishes. University of Kansas Publications, Museum of natural history 20(3):225-570.
- Pflieger, W. L. 1975. Reproduction and survival of the smallmouth bass in Courtois Creek. Pages 231-239 *in* H. Clepper, editor. Black bass biology and management. Sport Fisheries Institute, Washington, DC.
- Pflieger, W. L. and T. B. Grace. 1987. Changes in the fish fauna of the lower Missouri River, Pages 166-177 *in* W. L. Matthews, and D. C. Heins (editors). Community and evolutionary ecology of North American stream fishes. University of Oklahoma Press, Norman
- Pflieger, W. L. 1997. The fishes of Missouri. Revised Edition. Missouri Department of Conservation, Jefferson City.
- Priegel, G.R. 1963. Food of walleye and sauger in Lake Winnebago, Wisconsin. *Transactions of the American Fisheries Society* 92:312-313.
- Priegel, G. R. 1969. The Winnebago sauger: age, growth, reproduction, food habits and early life history. Wisconsin Department of Natural Resources, technical Bulletin No. 43, Madison.
- Price, J. W. 1963. A study of food habits of some Lake Erie fish. *Bulletin of the Ohio Biological Survey, New Series* 2:1-18.
- Rehwinkel, B. J. 1978. The fishery for paddlefish at Intake, Montana during 1973 and 1974. *Transactions of the American Fisheries Society* 107(2):263-268.

- Reynolds, W. W., and M. E. Casterlin. 1976. Activity rhythms and light intensity preferences of *Micropterus salmoides* and *Micropterus dolomieu*. Transactions of the American Fisheries Society 105:400-403.
- Russell, t. R., L. K. Graham, D. M. Carlson, and E. J. Hamilton. 1980. Maintenance of the Osage River – Lake of the Ozarks paddlefish fishery. Missouri Department of Conservation, Columbia, Missouri. Final Report.
- Ryder, R. A. 1977. Effects of ambient light variations of behavior of yearling, subadult, and adult walleyes (*Stizostedion vitreum vitreum*). Journal of the Fisheries Research Board of Canada. 25(7):1347-1376.
- Schmullbach, J. C., T. J. Banek, and M. K. Musyl. 1983. Bionomics of the Rainbow Smelt (*Osmerus mordax*) in Lake Oahe, South Dakota. University of South Dakota and South Dakota Department of Game Fish and Parks, Wildlife Division, Completion Report No. 83-7.
- Selgeby, J. H., W. R. MacCallum, and M. H. Hoff. 1994. Rainbow smelt-larval lake herring interactions: competitors or casual acquaintances? U.S. National Biological Survey, Great Lakes Science Center, Biological Report 25, Ashland, Wisconsin.
- Sewell, D. C. 1993. Food habits and distribution of the emerald shiner, *Notropis atherinoides* Rafinesque, and the spottail shiner, *Notropis hudsonius* (Clinton), in Lake Oahe, South Dakota. Master's thesis. South Dakota State University, Brookings.
- Shields, J. T. 1955. Report of fisheries investigations during the second year of impoundment of Fort Randall Reservoir, South Dakota, 1954. South Dakota Department of Game, Fish and Parks, Federal-aid Job Completion Report, Project F-1-R-4.
- Shields, J. T. 1956. Report of fisheries investigations during the third year of impoundment of Fort Randall Reservoir, South Dakota, 1955. South Dakota Department of Game Fish and Parks, Federal-aid Job Completion Report, Project F-1-R-5.
- Shields, J.T. 1957. Report of fisheries investigations during the fourth year of impoundment of Fort Randall Reservoir, South Dakota, 1956. South Dakota Department of Game, Fish and Parks, Federal-aid Job Completion Reportk Project F-1-R-6.
- Scott, W. B., and E. J. Crossman. 1973 Freshwater fishes of Canada. Fisheries Research Board of Canada. Bulletin 184, Ottawa.
- Smith, K. A. 2000. Factors influencing rainbow smelt entrainment through Oahe Dam, South Dakota. Master's Thesis. South Dakota State University, Brookings.

- Sparrowe, R. D. 1986. Threats to paddlefish habitat. *in* J. G. Dillard, L. K. Graham, and T. R. Russell, editors. The paddlefish: status, management and propagation. North Central Division, American Fisheries Society, Special Publication number 7.
- Stone, C. C., and P. Neelson. 1990. An estimate of abundance and distribution of rainbow smelt in Lake Oahe reservoir using hydroacoustic techniques, 1988-1989. South Dakota Department of Game, Fish and Parks, Wildlife Division, 1990. Progress Report No. 90-8.
- Stone, C. C. 1996. South Dakota angler use and preference survey, Supplement 2, data breakdown by management region and fisheries program areas. South Dakota Department of Game, Fish, and Parks, Wildlife Division, Supplemental Report No. 96-2.
- Stone, C. C. and J. Sorensen. 2002. Annual fish population and angler use and sport fish harvest surveys on Lake Francis Case, South Dakota, 2001. South Dakota Department of Game, Fish and Parks, Annual Report 02-03, Pierre.
- Swenson, W.A. 1977. Food consumption of walleye (*Stizostedion vitreum vitreum*) and sauger (*S. canadense*) in relation to food availability and physical environmental conditions in Lake of the Woods, Minnesota, Shagawa Lake, and western Lake Superior. *Journal of the Fisheries Research Board of Canada.* 34:1643-1654.
- Sveum, D. J. 1988. Regulation of Missouri River main stem reservoirs in Benson, N. G., editor. The Missouri River the resources their uses and values. North Central Division American Fisheries Society. Special Publication No. 8.
- Turner, G. E., and H. R. MacCrimmon. 1970. Reproduction and growth of smallmouth bass. *Micropterus dolomieu*, in a Precambrian Lake. *Journal of the Fisheries Research Board of Canada.* 27:395-400.
- USACE (Unites States Army Corps of Engineers). 1979. Missouri River Main Stem Reservoir System Reservoir Regulaiton Manual (Master Manual). Omaha, NE: U.S. Army Engineer Division, Missouri river Corps of Engineers.
- Unkenholz, E. G. 1998. Entrainment of rainbow smelt through Oahe Dam, South Dakota. Master's Thesis. South Dakota State University, Brookings.
- Unkenholz, D. G. 1986. Effects of dams and other habitat alterations on paddlefish sport fisheries. In J. G. Dillard, L. K. Graham, and T. R. Russell, editors. The paddlefish: status, management and propagation. North Central Division, American Fisheries Society, Special Publication number 7.

- Vigg, S. T. P. Poe, L. A. Prendergast, and H. C. Hansel. 1991. Rates of consumption of juvenile salmonids and alternative prey fish by northern squawfish, walleyes, smallmouth bass, and channel catfish in John Day Reservoir, Columbia River. *Transactions of the American Fisheries Society* 120:421-438.
- Wahl, D. H., and L. A. Nielsen. 1985. Feeding ecology of the sauger *Stizostedion canadense* in a large river. *Canadian Journal of Fisheries and Aquatic Sciences* 42:120-128
- Warnick, D. 1987. The introduction of selected fish species into the Missouri River system, 1984-85. South Dakota Department of Game, Fish, and Parks, Wildlife Division Report No. 87-10, Pierre.
- Webster, D. A. 1954. Smallmouth bass, *Micropterus dolomieu*, in Cayuga Lake, Part I. Life history and environment. Cornell University Agricultural Experiment Station. Mem. 327. 39pp.
- Wickstrom, G. 2002. Annual fish population surveys of Lewis and Clark Lake, 2001. South Dakota Department of Game, Fish and Parks, Wildlife Division, Annual Report 02-17, Pierre.