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FISH PASSAGE AND PROTECTION PROGRAM IN THE YELLOWSTONE RIVER BASIN, MONTANA

LITERATURE SUMMARIES FOR KEY FISH SPECIES

BUREAU OF RECLAMATION
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LITERATURE SEARCH

Yellowstone River Basin
Fish Passage and Protection Program

Introduction

Bibliographic research must be regarded as a tool of importance equal to those used in the laboratory or field (Moore, 1980)[1]. The task of planning and conducting the literature search for the Yellowstone River Basin Fish Passage and Protection Program was initiated with the above concept in mind.

The first step required a clearly defined problem statement:

What is known about the life history of fishes in the lower Yellowstone River, their susceptibility to entrainment into irrigation canals, and their ability to navigate passage barriers associated with canal headworks, that will help us both in understanding population impacts and in designing appropriate canal screening and passage facilities?

Next, clear subject boundaries were identified; the search was limited to life history, habitat requirements, entrainment, and passage studies. No information on age and growth, nutritional requirements, genetics, diseases, or population dynamics was included. Of the 56 fish species present in the lower Yellowstone River, the search was limited to species that were (1) threatened, endangered, or candidate species; (2) encountered frequently by other fisheries workers in the lower Yellowstone River; and (3) species that were present in the preliminary canal entrainment sampling effort at Intake during 1996.

Fish Species

The following 23 species were included in the initial literature search:

Bigmouth Buffalo *(Ictiobus cyprinellus)*
Blue Sucker (*Cycleptus elongatus)*
Brassy Minnow (*Hybognathus hankinsoni*)
Burbot (*Lota lota*)
Channel Catfish (*Ictalurus punctatus*)

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1 Moore, J. L. 1980. Wildlife management literature. Pages 7-38 *In* Wildlife Management Techniques Manual, Fourth Edition. The Wildlife Society, Washington, D.C.

Common Carp (*Cyprinus carpio*)
Flathead Chub (*Hybopsis gracilis*)
Freshwater Drum (*Aplodinotus grunniens*)
Goldeye (*Hiodon alosoides*)
Longnose Dace (*Rhinichthys cataractae*)
Longnose Sucker (*Catostomus catostomus*)
Mountain Sucker (*Catostomus platyrhynchus*)
Paddlefish (*Polyodon spathula*)
Pallid Sturgeon (*Scaphirhynchus platorynchus*)
Plains Minnow (*Hybognathus placitus*)
River Carpsucker (*Carpoides carpio*)
Sauger (*Stizostedion canadense*)
Shorthead Redhorse (*Moxostoma macrolepidotum*)
Shovelnose Sturgeon (*Scaphirhynchus platorynchus*)
Sicklefin Chub (*Hybopsis meeki*)
Stonecat (*Noturus flavus*)
Sturgeon Chub (*Hybopsis gelida*)
White Sucker (*Catostomus commersoni*)

Other species that may be done at a later time include: walleye (*Stizostedion vitreum*); lake chub (*Couesius plumbeus*); smallmouth buffalo (*Ictiobus bubalus*); green sunfish (*Lepomis cyanellus*); smallmouth bass (*Micropterus dolomieui*); and plains killifish (*Fundulus kansae*); Creek Chub (*Semotilus atromaculatus*); Western Silvery Minnow (*Hybognathus argyritis*)

Dialog Searches

Once a clear problem statement and subject boundaries were established, the next step involved conducting Dialog literature searches for each of the species, as well as the subjects of fish passage and fish entrainment. "Dialog" is an online literature database search service that the Bureau of Reclamation's Denver Library subscribes to. It contains over 120 databases. Thirteen databases were relevant to the task at hand and these are described below. Ruth Ann Zook, Librarian, indicated that we can be confident that these searches are very comprehensive and accurate. These databases cover every major journal in print. The only area likely to be missed are the agency gray literature, local conferences, and papers. In that case, the best approach is to identify those data sources during personal communications with workers in the area. The databases are:

- ✔ **Aquatic Sciences and Fisheries Abstracts** - Comprehensive database on the science, technology, and management of marine and freshwater environments.

- ✔ **BIOSIS Previews** - Constitutes the major English-language service providing comprehensive worldwide coverage of research in the biological sciences.

- ✔ **CAB Abstracts** - Comprehensive file of agricultural and biological information, containing all records in the 26 main abstract journals published by CAB International—over 8,500 journals in 37 different languages are scanned for inclusion.

- ✔ **Conference Papers Index** - Provides access to records of more than 100,000 scientific and technical papers presented at over 1,000 major regional, national, and international meetings each year.

- ✔ **Dissertation Abstracts Online** - Database covers virtually every American dissertation accepted at an accredited institution since 1861. Covers more than 1.2 million doctoral dissertations and masters theses.

- ✔ **E.I. Compendex Plus** - Machine readable version of the Engineering Index which provides abstracted information from the world's significant literature of engineering and technology—worldwide coverage of approximately 2,600 journals and government reports and books.

- ✔ **Geobase** - Covers the worldwide literature on geography, geology, ecology, and related disciplines—it includes Ecological Abstracts.

- ✔ **GPO Monthly Catalog** - Machine-readable equivalent of the print Monthly Catalog of U.S. Government publications.

- ✔ **NITS** - Database provides access to the results of U.S. Government-sponsored research, development and engineering, plus analyses prepared by Federal agencies, or their contractors.

- ✔ **Pascal** - A multidisciplinary database equivalent to 79 print Pascal journals which cover international science; this covers foreign language research.

- ✔ **Research Centers and Services Directory** - Comprehensive source of detailed information on over 27,000 organizations conducting research worldwide.

- ✔ **WATERNET** - Provides a comprehensive index of premier publications relating to water and wastewater.

- ✔ **Zoological Record Online** - Worldwide coverage of zoological literature, with particular emphasis on systematic/taxonomic information.

Data Compilation

In order to understand the factors that influence a particular fish species' susceptability to entrainment into an irrigation canal, or that cause difficulty in surmounting passage barriers (such as occurs at Intake Dam), the search was divided into 15 components described below.

1. Habitat use.

2. Egg/larval characteristics including drift, use of gravel; backwaters; type of nest; etc.

3. Migratory characteristics: none at all; spawning migrations; rearing/drifting larvae; species ability to pioneer new habitat.

4. Period of peak activity—nocturnal or diurnal.

5. Size of territory (how much to fish move around). Permanent/seasonal territories.

6. Location in river—where in the river cross section do fish most frequently occupy: main channels, edges, backwaters.

7. Location in water column—surface, midcolumn, substrate.

8. Swimming performance—actual measurements, lifestyle (performance implied by lifestyle such as a lie-in-wait-predator vs a scavenger vs a pelagic plankton feeder).

9. Ability to surmount passage barriers including velocity barriers and physical obstructions.

10. Susceptibility to entrainment—presence of fish species in entrainment study catches.

11. Fish passage studies—presence of fish species in fish passage studies.

12. Physical structure of fish related to entrainment or passage.

13. Areas literature indicates information is sparse or lacking.

14. Areas literature indicates information is well known.

15. Threats/causes of population decline.

The Dialog searches result in voluminous lists of titles, citations, and abstracts. These lists were reviewed for relevant articles. In some cases, Reclamation's in-house library contained the needed citations; in others it was necessary to request them through interlibrary loan.

Each article was reviewed, appropriate information summarized, and a bibliography was prepared. The following section contains the summarized information for each species for the 15 categories of relevant information.

The final step will be to synthesize the information into a user-friendly format for use in understanding and designing fish screens and passage improvements.

Species	**Bigmouth buffalo** *Ictiobus cyprinellus*
Habitat Use . Adult . Spawning . Rearing	**Pflieger 1975.** Bigmouth buffalo primarily inhabit deeper pools of large streams, natural lowland lakes, and manmade impoundments. They are more tolerant of high turbidity than other species. Young feed principally on midges and other bottom-dwelling invertebrates. Older individuals eat primarily small crustaceans that live in midwater. They spawn in late May in Missouri on rock riprap in quiet backwater. Eggs are broadcast and hatch in 9 to 10 days at 62°F. **Scott and Crossman 1973.** Bigmouth buffalo inhabit shallow depths in slow, sluggish, or still water of larger rivers, oxbows, and flood plain lakes, sloughs, bayous, and shallow lakes. They are well adapted to reservoirs and apparently tolerant of turbid water. They tend to occur in schools of about 25 individuals. **Brown 1971**. In Montana, spawning occurs May into July in shallow water when water temperatures reach about 60 °F. Bigmouth buffalo inhabit large rivers and impoundments where it leads a more or less pelagic life. **Johnson 1963.** Spawning takes place in the spring, for a short period from mid-May possibly to early June. It peaks when water temperatures are 60 to 65 °F.
Egg/Larval Characteristics . Drift . Gravel . Backwaters . Nest	**Berg 1981** found that bigmouth buffalo, along with other carpsucker and minnow, was a major group found in larval collections on the Missouri R. above Fort Peck Reservoir. Ictiobinae/Cyprinidae accounted for 61 percent of the larvae sampled at Robinson Bridge, Montana. **Johnson 1963**. Eggs are adhesive and stick to vegetation. No nest is built; the eggs are scattered and abandoned. Eggs hatch in approximately 2 weeks.

Species	Bigmouth buffalo *Ictiobus cyprinellus*
Migratory Characteristics . None at all . Spawning . Rearing/drifting larvae . Pioneering abilities/colonizing new habitat	**Berg 1981** reports that both bigmouth and smallmouth buffalo move considerable distances in the Missouri R. between Morony Dam and Fort Peck Reservoir, particularly during their spawning periods. One Bigmouth Buffalo, tagged on 6/13/78 while spawning in a backwater near Fort Benton, was harvested 52 days later and 278 km downstream in Fort Peck Reservoir. Distances moved ranged from 106 to 325 km from the tag site to the harvest site. Electrofishing surveys indicate that large numbers of bigmouth and smallmouth buffalo are found seasonally in the Missouri R. during the spawning period as far upstream as Horseshoe Falls, 5 km below Morony Dam. Migrant bigmouth and smallmouth buffalo made significant use of the lower Marias R. for spawning. Electrofishing data indicated that bigmouth and smallmouth buffalo made significant seasonal movements from the lower portions of the Missouri R. above Fort Peck Reservoir into upstream areas. Berg concludes that this seasonal movement of buffalo was evidently related to spawning since most of the fish dispersed back downstream shortly after the spawning period. **Berg 1981** reported significant spawning runs of river carpsucker along with blue sucker, smallmouth and bigmouth buffalo, shorthead redhorse, longnose sucker, and goldeye in the lower Marias R. during the spring/summer migration period from 1976 through 1979. **Berg 1981** reported that migrant river carpsucker and smallmouth and bigmouth buffalo were conspicuously absent from electrofishing surveys conducted in the lower Teton R. These species usually spawn in the larger streams with backwater areas (**Brown 1971**); therefore, it is unlikely they spawn in the lower Teton R. Significant spawning runs of these three species were found in the lower Marias R. The lower Marias is a substantially larger stream than the lower Teton R., and it contains more slow-moving and backwater areas. **Pflieger 1975.** Bigmouth buffalo sometime enter rather small creeks to spawn. Young remain in smaller streams first summer of life. **Johnson 1963.** Adults move out of lakes and large rivers into small tributary streams and into marshes or flooded lake margins to spawn. Onset of spring freshets and flooding is apparently needed to initiate spawning activity.

Species	Bigmouth buffalo *Ictiobus cyprinellus*
Migration (cont'd)	**Hesse et al. 1982** recovered seven tagged bigmouth buffalo tagged in the Missouri R. in Nebraska. Mean upstream distance traveled was 101.6 km, mean downstream distance was 350.8 km. Six individuals traveled upstream, one traveled downstream.
Period of peak activity . Nocturnal . Diurnal	
Size of Territory (how much do they move around) . Permanent . Seasonal	
Location in River . Midchannel . Edges	**Pflieger 1975.** Commonly occurs in schools in midwater or near bottom. **Scott and Crossman 1973.** On warm, still days they spread out over the surface of a lake where they rest quietly, often with the dorsal fin projecting and often in the midst of clumps of dense algal bloom. **Brown 1971.** Adults easily taken by commercial gear since adults school. **Johnson 1963.** Unlike other suckers, this species eats planktonic as well as benthic organisms. Cladocera and copepods are the most important food of the young with chironomid larvae next and small amounts of aquatic beetles, amphipods, nauplii, ostracods, and diatoms often present. Bigmouth buffalo swim about at an angle of 55 degrees to the bottom, bouncing with short up and down motions searching through the mud and debris. Johnson estimates that this species occupies a food niche overlapping bottom feeders and limnetic plankton feeders.
Location in Water Column . Surface . Midcolumn . Substrate	

Species	Bigmouth buffalo *Ictiobus cyprinellus*
Swimming Performance . Actual measurements . Lifestyle (performance implied by lifestyle) - cruiser - lie in wait predator - scavenger	**Schmulbach et al. 1982** experimentally determined critical velocities to be 64.9 $\pm$ 47 cm/s. They felt this was a tenuous number because of small sample size. In comparing preferred habitat with swimming performance, they found that the bigmouth buffalo preferred quiet water habitat, but were common in some habitats with considerable current velocity.
Ability to Surmount Passage Barriers . Velocity barriers . Physical obstructions	
Susceptibility to Entrainment . Presence in entrainment study catches	
Fish Passage Studies . Presence in passage studies	
Physical Structure related to Entrainment/Passage	
Areas literature says don't know anything/much about	
Areas literature says well known/studied	**Brown 1971.** Reproduction, timing, egg incubation period. Food.

Species	**Blue sucker** *Cycleptus elongatus*
Habitat Use . Adult . Spawning . Rearing	**Liebelt 1996** reported that in an extensive study of the lower Yellowstone R. below Intake Dam to the confluence of the Missouri R. and in the Missouri R. above the confluence, only one YOY blue sucker was captured. It was caught about 1 mile below the Milk R. confluence in 1994. **Brown and Coon 1994.** Several taxa that are common in the Missouri R. as adults, including blue sucker, channel catfish, and white bass, were captured almost exclusively in tributaries as larvae but in low numbers. Authors speculate that each of these taxa have restrictive spawning requirements, such as coarse substrates, moderate depths, and discharges or high amounts of cover which might not be met in the channelized Missouri R. **Watson and Stewart 1991** collected 28 blue suckers from 545 to 735 mm during the summer of 1990 in the lower Yellowstone R. **Posewitz 1963** collected 23 blue suckers in 1963 in the lower Yellowstone R. **Hendrickson (NDGFD, unpubl. data**) reported four blue suckers in 1991 between 674-1835 g at RM1.5 in the lower Yellowstone R. **Cowley and Sublette 1987a** indicated species composition in stomach samples suggests that blue sucker may select firm substrata with a more dense algal growth (aufwuchs). In general, food habits are similar to that reported by **Moss et al. 1983** in Neosho River, Kansas, preferring benthic invertebrates associated with solid substratum, particularly riffles. **Cowley and Sublette 1987b**. Studies of fish species distribution in relatively clean river systems indicate that species diversity increased downstream (several citations given). They confirmed this in the Black R., New Mexico. They only caught three blue suckers in slowly flowing pools with silty bottoms. The blue sucker may be limited in distribution in Black R. by the size and quality of available foraging areas. The absence of juvenile blue suckers in their samples suggested to the authors that this species may be in danger of being extirpated from Black R. Alternatively, juveniles may inhabit the adjacent Pecos R., with only adults moving into Black R. to forage.

Species	Blue sucker *Cycleptus elongatus*
Habitat (cont'd)	**Moss et. al. 1983.** May spawning period, young were 100 mm long by midsummer and over 200 mm in autumn of first year. Major spawning site in the Neosho R., Kansas, area where river narrows over bedrock limestone with cobble-sized rocks. Flow velocity was 1.8 m/s (depth = 1.43 m). Food of adults was aquatic insects and filamentous algae. **Moss et al. 1983.** Lab stream experiments found juveniles preferred smooth substrate of fine gravel >2 mm, large cobble >128 mm, and bedrock >256 mm. Found in strongest current (1-1.2 m/s) **Moss et al. 1983.** Young caught in Neosho R., Kansas, over large substrates in shallow swift current. In broad riffle areas, juveniles were captured in local areas where channel constructions increased water velocity. Adults were captured over exposed limestone bedrock in deep riffles 1 to 2 m deep. Fastest velocity measured 2.6 m/s at 0.6 m depth with most adults captured in currents greater than 1 m/s. **Moss et al. 1983.** Adults associated often with manmade structures such as stilling basins, dam bases, bridge abutments, ends of wing dykes—tough habitats to sample because of swift current; may be the reason not found in surveys. **Moss et al. 1983.** Presence of adequate areas of swift, deep water over firm substrates with sufficient spring flows over spawning riffles is probably the most important factor in maintaining populations of blue suckers. **Rupprecht and Jahn 1980** caught 100 blue suckers by electroshocking over rocky substrate below Dam 19 around bridge abutments and over wing dams. Food habits are also reported.

Species	Blue sucker *Cycleptus elongatus*
Habitat (cont'd)	**Haddix and Estes 1976** sampled four backwater habitats in the lower Yellowstone R. in 1974. They found carp (67), river carpsucker (62), and goldeye (34) were the most abundant (numbers in parentheses are the fish per run). Sauger was the next most abundant species (16/run). Shovelnose sturgeon and blue sucker were lacking in backwater collections **Berg 1981**. There were 214 blue suckers captured from middle Missouri R. Length/weight relationships, growth rates, condition factors, and spawning periods were determined. Blue sucker were common below the confluence of the Marias R., uncommon above. **Pflieger 1975.** Inhabits deep, swift channels of large rivers over bottom of sand, gravel, or rock. Tolerant of high turbidity— if enough current is present to prevent silt deposit. Dams which decrease current velocity permit siltation have been unfavorable to blue sucker. **Brown 1971.** Preferred habitat is in deep water of large rivers and reservoirs. Prefers low turbidity and swift current.

Species	Blue sucker *Cycleptus elongatus*
Egg/Larval Characteristics . Drift . Gravel . Backwaters . Nest	**Berg 1981** indicated that Catostominae were the most abundant larvae in the Missouri R. above Fort Peck Reservoir; however, he did not identify to species level. The presence of blue sucker larvae could not be confirmed as a result. **Brown 1971.** Very few young have been found and none have been reported in Montana.
Migratory Characteristics . None at all . Spawning . Rearing/drifting larvae . Pioneering abilities/colonizing new habitat	**USFWS 1993.** Eggs and larval blue sucker may be carried downstream as water levels decline. Movement patterns of adults and juveniles are unknown. **Yeager and Semmons 1987.** Tailrace of Lock and Dam No. 8 is used by blue sucker for spawning and rearing of young in Wisconsin on upper Mississippi R. **Berg 1981.** Electrofishing indicated blue suckers made significant seasonal movements related to spawning from lower portions of middle Missouri R. into upstream areas. Fish dispersed back downstream after spawning. Movement can be as far as 320 km upstream of Fort Peck Reservoir. Blue sucker also made significant spawning migrations up the Marias R. A significant spawning run in lower Teton R. was also found. **Berg 1981** reported that blue sucker were common in the Missouri R. below the confluence of the Marias R. but generally uncommon above the Marias R. However, blue sucker were common in the Missouri R. upstream of the confluence during their spawning period. **Berg 1981** observed a significant spawning run of blue sucker in the lower Teton R. on 5/13/79. Most were found in the lower 2 km of the river, with the run confined to the lower 15 km. This run was substantially higher in numbers than the run observed on the Marias R. **Pflieger 1975**. Highly mobile fish. Streamlined body and sickle-shaped fins adapted for maintaining position in swift currents. Formerly important spring runs and lesser fall runs in upper Mississippi R. (**Coker 1930**). **Cross 1967** notes that blue sucker may have declined because of destruction and inundation of spawning habitat and blocked migration routes.

Species	Blue sucker *Cycleptus elongatus*
Period of peak activity . Nocturnal . Diurnal	
Size of Territory (how much do they move around) . Permanent . Seasonal	
Location in River . Midchannel . Edges	**Semmens 1985** captured adults in Alabama R. using gill nets 11 to 8 feet deep fished midchannel at night.
Location in Water Column . Surface . Midcolumn . Substrate	From **Pflieger 1975.** If mostly caught with trammel net, then it is in midcolumn or surface—not the bottom since the net is suspended from floats.

Species	Blue sucker *Cycleptus elongatus*
Swimming Performance . Actual measurements . Lifestyle (performance implied by lifestyle) - cruiser - lie in wait predator - scavenger	See **Moss et al. 1983** above for currents preferred by juveniles. **Schmulbach et al. 1982.** Determined experimental sustained swimming speeds. This species exhibited a behavior which helped them maintain their position in the experimental chamber. Fish frequently extended pectoral fins and clung to the chamber wall so that constant critical velocity of 11 mature blue suckers was 80.1 $\pm$ 41.8 cm/s. Blue suckers exhibited the highest Cv of all fish tested. In comparing habitat preference with swimming performance compatibility, **Schmulbach et al.** found the blue sucker also has rather exacting environmental requirements and tends to be distributed in habitats with substantial current velocities. It was the only species in the unchannelized river which preferred the main channel border, mean = 55 (20-85 cm/s); and chutes, mean = 70 (50-145) cm/s. The mean revetment current velocity exceeded the mean sustained speed of the blue sucker although the range of current velocities overlapped the mean sustained speed. Speculated that the blue sucker clinging behavior assists them in adapting to revetments because it may enable them to maintain their position against strong currents without expending a great deal of energy swimming.
Ability to Surmount Passage Barriers . Velocity barriers . Physical obstructions	**Pflieger 1975**. Streamlined body and sickle-shaped fins are adaptions for maintaining a position in swift currents. It is a highly mobile fish.
Susceptibility to Entrainment . Presence in entrainment study catches	**McInerny and Held 1988**. Collected nine blue sucker juveniles from 37 to 53 mm in Pool 9 of upper Mississippi R. Current velocity averaged 0.3 m/s at shoreline and 0.8 m/s 20 m from shore. Current along riprap shoreline presumably attracted these YOY.
Fish Passage Studies . Presence in passage studies	

Species	Blue sucker *Cycleptus elongatus*
Physical Structure related to Entrainment/Passage	**Moss et al. 1983.** Extremely muscular, heavy-bodied, their terete shape and fin placement adapt them to strong currents. In lab studies in discharge >1.2 m/s fish are able to maintain position with only slight caudal fin movement **Pflieger 1975**. Streamlined body and sickle-shaped fins are adaptions for maintaining a position in swift currents. It is a highly mobile fish. Formerly there were important spring runs and lesser fall runs in upper Mississippi. R. (**Coker 1930**). **Brown 1971.** Individuals up to 40 inches reported. In Montana, record is 28 inches and 7.7 lbs.
Areas literature says don't know anything/much about	**USFWS 1993.** Ambiguous locality information—Yellowstone R. and Missouri R. Historically known populations where current status not known: Missouri R. in Chouteau County. **USFWS 1993.** Reproductive biology is unknown. Guess on timing, water temperatures required, and flow changes. Movement patterns of adults and juveniles unknown. Little to no information exists on population ecology of blue suckers. Parasites and diseases have not been studied. Interspecific competition unknown. Hybridization unknown. Causes for species decline need to be identified and means to reverse the causes need to be determined. Important habitat areas and critical components need to be determined, especially spawning and rearing requirements. **Cowley and Sublette 1987**. Food habits poorly known. **Semmens 1985.** Because of its preference for moving water in large rivers, little information is available on life history. **Moss et al. 1983.** Little natural history information has been available. They collected information on habitat, spawning, age/growth, and food habits in Neosho R., Kansas. **Rupprecht and Jahn 1980**. An uncommon and little-known species inhabiting major river systems of the United States. **Pflieger 1975**. Habits not well known. "Probably" eats insect larvae and small inverts from the bottom. **Brown 1971**. Very little is known about life history.
Areas literature says well known/studied	

Species	**Blue sucker** ***Cycleptus elongatus***
Threats/Causes of Decline	**Rupprecht and Jahn 1980.** 1894-1899 caught commercially >900,000 kg in Pool 20. After Locks and Dam 19 constructed at Keokuk, Iowa, in 1910, catch in Pool 20 declined to 320,000 kg. Cause of decline is reduction of current velocity below the dam (**Pflieger 1975**) and resulting loss of a series of rapids that had been a prime habitat for the fish (**Coker 1930**).

Species	Brassy minnow *Hybognathus hankinsoni*
Habitat Use . Adult . Spawning . Rearing	**Hlohowskyj et al 1989.** Hybognathus is a genus of nearctic cyprinids characterized mainly by adaptations associated with herbivory. The center of distribution of the seven recognized species in this genus is in central Mississippi and Missouri drainages where five species are found. They live in lowland habitats from small streams to large rivers, feeding primarily on diatoms, desmids, filamentous algae, and organic material filtered from the bottom ooze. **Schlosser 1988.** Habitat use of brassy minnow is affected by presence of predators. In absence of predators, brassy minnow selected structurally complex pools. In presence of smallmouth bass, brassy minnow experienced high predation rates and were forced to select shallow riffle areas. Presence of creek chub caused little shift in preferred habitat. Very light predation rates as well. **Propst and Carlson 1986** collected brassy minnow from quiet pools. However, brassy minnow was rarely found if flowing water was not proximate to the pool. It has been extirpated from much of its former range in the Platte R. drainage due to anthropogenically induced habitat deterioration. This species appears to be tolerant of the range of physiochemical conditions characteristic of fluctuating plains streams. Individuals found in midchannel were often associated with schools of sand and/or bigmouth shiners; and those collected from pools were found with fathead minnow and creek chub. **Pflieger 1975.** Brassy minnow ingests the thin layer of organic-rich ooze that forms over the stream bottom from which it digests out the algae and other organic material. Spawns apparently early in spring. **Copes 1975** found that 95 percent of the 4,000 brassy minnows he captured in Wisconsin and Wyoming were found in slow runs or pools with little or no velocity, with mud bottoms. Very few were captured or observed in habitats with current velocity over 2 ft/s. Copes found the brassy minnow to be a schooling species except during the breeding season. Schools of adults were seen in areas of little or no current with a mud bottom. **Brown 1971.** It is a herbivore, feeding mainly on diatoms and other algae which it scrapes from the bottom. It prefers clear, slow streams with sandy bottoms, but it has been taken in several larger rivers where turbidities are higher.

Species	Brassy minnow *Hybognathus hankinsoni*
Egg/Larval Characteristics . Drift . Gravel . Backwaters . Nest	
Migratory Characteristics . None at all . Spawning . Rearing/drifting larvae . Pioneering abilities/colonizing new habitat	**Copes 1975** found the brassy minnow adults in schools of 15 to 50 fish during the summer in the early morning. Later in the day these schools merged and moved about feeding. These schools frequented shallow flooded areas. There was no movement into flooded areas until they became 2 to 4 °C warmer than the stream. Brassy minnows then left the flooded areas at dusk or when water temps dropped below that of the stream. The approach of darkness or a sudden drop in water temperature caused large schools (200 to 500 fish) to cease feeding and to break up into smaller schools which moved into quiet areas and became inactive. During the summer months, schools of small brassy minnows spent the night in muskrat channels and other openings in the aquatic vegetation of runs. Adults spent the night in pools and deeper runs near shelter or vegetation. In early spring and late fall, schools spent the night in pods or scattered over the bottom. Brassy minnows wintered in pools and deep runs that contained shelter, such as willow roots or other debris.
Period of peak activity . Nocturnal . Diurnal	
Size of Territory (how much do they move around) . Permanent . Seasonal	**Copes 1975**. Brassy minnows are a schooling species and as such do not exhibit territoriality. Even when sexually mature, males disperse from the schools into vegetation, they exhibit no territoriality.
Location in River . Midchannel . Edges	**Copes 1975.** Brassy minnows school along the edges of streams in areas of low velocity.

Species	Brassy minnow *Hybognathus hankinsoni*
Location in Water Column . Surface . Midcolumn . Substrate	**Pflieger 1975.** See below - lives on bottom.
Swimming Performance . Actual measurements . Lifestyle (performance implied by lifestyle) - cruiser - lie in wait predator - scavenger	**Pflieger 1975.** Lives in schools on or near the bottom. **Hlohowskyj et al. 1989.** Extensive pharyngeal modifications encountered in Hybognathus are unique among cyprinids.
Ability to Surmount Passage Barriers . Velocity barriers . Physical obstructions	
Susceptibility to Entrainment . Presence in entrainment study catches	
Fish Passage Studies . Presence in passage studies	
Physical Structure related to Entrainment/Passage	**Pflieger 1975.** Inhabits small, moderately clear prairie streams with permanent pools and sandy or gravelly bottoms in Missouri. **Brown 1971.** Maximum length is about 4 inches. Largest in Montana is 3.2 inches.
Areas literature says don't know anything/much about	**Copes 1975** indicated that little is known about the ecology of the brassy minnow. As of 1975, no life history studies, descriptions of spawning activity or sites, or age/growth data appear to have been done. **Brown 1971.** Practically nothing is known about the life history. Guesses on spawning.
Areas literature says well known/studied	

Species	Brassy minnow *Hybognathus hankinsoni*
Threats/Causes of Decline	

Species	Burbot *Lota lota*
Habitat Use . Adult . Spawning . Rearing	**Krentz 1996** found YOY in riverine backwater habitats on the Missouri and Yellowstone Rivers. Water depths ranged from 0.5 to 1.5 meters, with minimal flows. Sampled effectively with fyke nets. **Fisher et al. 1996** found burbot populations from rivers and reservoirs had consistently lower relative weight than populations from lakes. Some reports of declining burbot populations and possible listing of species in Idaho. **Hesse 1993.** Burbot populations are reportedly healthy in Montana. **Berg 1981** found that burbot along with sauger, white sucker, longnose sucker, shorthead redhorse, river carpsucker, carp, goldeye, freshwater drum, emerald shiner, western silvery minnow, and longnose dace were the most widely distributed fish species in the Missouri R. above Fort Peck Reservoir. **Hanson and Qadri 1980.** YOY were electrofished from Ottawa R. Bottom was sand with beds of *Elodea* and *Vallisneria* with stumps and boards. Scarcity of specimens may be because juveniles can pass through most mesh sizes used in gill nets and trap nets. Also they try to burrow between rocks and into cavities in the substrate. Young burbot usually caught over rocky or gravel bottoms or rocky shorelines, but burbot did use sandy area with cover in Ottawa R. **Hanson and Qadri 1980.** YOY ate amphipods, darters, *Gammarus* sp., and ephemeropterans. **Haddix and Estes 1976.** Angling for burbot is popular in late winter and early spring below irrigation diversion structures of Cartersville and Intake and at tributary mouths. Most angling is done during the late evening, corresponding to the burbot's feeding habits. Good catches are made by anglers from late February through early April in the lower reaches of some of the Yellowstone's tributaries, including the Bighorn and Tongue Rivers.

Species	Burbot *Lota lota*
Habitat (cont'd)	**Haddix and Estes 1976** found that most burbot stomachs collected in February through March in the Yellowstone R. were empty. The remainder of the stomachs contained mostly longnose dace, flathead chub, and young burbot. They speculate that burbot does not readily feed during the spawning period, but spawned-out fish feed very heavily. While the adult burbot is highly piscivorous, young burbot rely heavily on aquatic insects. **Brown 1971.** Burbot is native to Montana and is found throughout the Missouri, Saskatchewan, and Kootenai River drainages. It is common in the Yellowstone R. near Big Timber to the confluence with the Missouri R.
Egg/Larval Characteristics . Drift . Gravel . Backwaters . Nest	**Hesse 1993**. Burbot spawn communally in water a meter or less deep, over gravel or compacted sand, at night, in winter. Young burbot inhabit weed beds on gravel bottoms in swift current (**Cross 1967**). **Haddix and Estes 1976.** Burbot are apparently spawning in the Yellowstone between late November and early January. The specific spawning period, physical parameters, and location of burbot spawning sites in the lower Yellowstone will be difficult to determine because of severe ice conditions and fluctuating water levels.

Species	Burbot *Lota lota*
Migratory Characteristics . None at all . Spawning . Rearing/drifting larvae . Pioneering abilities/colonizing new habitat	**Carl 1995** reviewing literature: early telemetric work indicated burbot fairly sedentary throughout day and night. In Finland, burbot homed after displacement and occasionally migrated up to 20 km. In an Alaskan river system burbot traveled up to 125 km. Another study found fish rarely moved in winter and early spring. In Lake Michigan, fish were stationary during daylight hours. **Carl 1993.** Juvenile burbot found in inshore habitat areas, whereas adults were located in deeper water >2 m deep offshore. **Breeser et al. 1988** suggested that burbot are sedentary except during spawning movements. They documented lengthy upstream migration associated with breeding periods. Burbot were found to prefer the turbid glacial rivers in Alaska, moving into clear tributaries only in late summer after velocity declined. **Berg 1981**. Only 3 burbot were recaptured in the Missouri R. above Fort Peck Reservoir out of 169 tagged: 2 traveled 0 km; 1 traveled 4 km in a tributary. Berg did not consider this sample size adequate to evaluate movement patterns. **Haddix and Estes 1976.** Though 60 burbot were tagged in the lower Yellowstone R. during 1974 and 46 during the spring of 1975, no tag recoveries were made. **McCrimmon 1959** felt that late winter runs of burbot were primarily feeding movements rather than spawning movements.
Period of peak activity . Nocturnal . Diurnal	**Carl 1993**. Preliminary tracking indicated burbot moved primarily at night. Confirmed by further study. **Hergenrader et al. 1982**. The first larvae collected in the Missouri R. in 1978 in Nebraska were two burbot, river temperature 8.2 °C. This evidence of early spawning is not of significance to the overall ichthyoplankton drift since burbot is not an important contributor to the ichthyoplankton. **Haddix and Estes 1976.** Burbot are primarily nocturnal feeders.

Species	Burbot *Lota lota*
Size of Territory (how much do they move around) . Permanent . Seasonal	**Carl 1993** found restricted activity areas, and fidelity to those sites.
Location in River . Midchannel . Edges	
Location in Water Column . Surface . Midcolumn . Substrate	**Scott and Crossman 1973; and Edsall, T.A. et al. 1993.** Burbot are benthic, located on the bottom. **Carl 1993** also captured burbot on bottom of Lake Opeongo, Ontario.
Swimming Performance . Actual measurements . Lifestyle (performance implied by lifestyle) - cruiser - lie in wait predator - scavenger	**Carl 1993.** Swimming speed for all burbot in Lake Opeongo, Ontario, was 1.4 m/min from sunrise to 1800 hrs; 2.3 m/min from 1800 hours to sunset and 5.4 m/min from sunset to sunrise. Individuals hit peaks of more than 20 m/min followed by slow swimming periods.
Ability to Surmount Passage Barriers . Velocity barriers . Physical obstructions	

Species	Burbot *Lota lota*
Susceptibility to Entrainment . Presence in entrainment study catches	**McKinley et al. 1986.** Assessed ichthyoplankton entrainment at the Bruce A Nuclear Generating Station in Ontario. Found that 55 million eggs were entrained with peak occurring in April. Total larval entrainment was 59.6 million with an initial peak in June and a lesser peak in August. Burbot, along with three other species, accounted for 88 percent of the eggs entrained and 98 percent of the larvae. Burbot survival was greatest for alewife and smelt, followed by burbot and deepwater sculpin. Greatest mortality attributable to intake passage.
Fish Passage Studies . Presence in passage studies	
Physical Structure related to Entrainment/Passage	
Areas literature says don't know anything/much about	**Carl 1995.** Little known about movement patterns, habitat requirements, or role in the benthic community.
Areas literature says well known/studied	

Species	Burbot *Lota lota*
Threats/Causes of Decline	**Hesse 1993**. Dam construction of mainstem of the Missouri R. and most of its tributaries has prevented burbot from migrating to satisfactory breeding grounds. Channelization of the Missouri R. in Nebraska to Missouri has eliminated essential off-channel habitat, important to young burbot. These areas provided abundant insects. Elimination of large wood debris eliminated burbot habitat and substrate for aquatic insects. Available coarse particulate organic matter, due to settling out in large reservoirs and reduced flooding, has reduced the availability of amphipod shredders. Overfishing in tailwaters below dams occurred. Need to expedite implementation of restoring habitat projects such as hydraulic reconnection of cutoff backwaters, return to a semblance of a natural hydrograph, restoration of sediment and organic matter dynamics, recovery of large woody debris in the river, and construction of fish bypasses at selected dams.

Species	Channel catfish *Ictalurus punctatus*
Habitat Use . Adult . Spawning . Rearing	**Jackson 1995** summarizes habitat literature for channel catfish: channel cats are often found in deep pools and backwater areas of rivers (**Bailey and Harrison 1948**) where they are generally associated with cover and low current velocity (**McMahon and Terrell 1982**). **Trautman (1957**) reported the largest populations of channel catfish in waters with fairly clean bottoms of sand, gravel, or boulders and also over bottoms of silt, if silt deposition was slow. **Dames et al. 1989** found small and large catfish were more abundant in mainstream habitats while midsize individuals were more abundant in backwaters. **Trautman 1957** found that yearling and subadult channel cats in streams tolerated fast currents better than adults. **Jackson 1995** speculates that the shelter seeking tendencies of channel cats applies mostly to clear streams, not to turbid rivers. **Brown and Coon 1994**. Missouri R. tributaries play an important but complex role in the recruitment of fish into Missouri R. populations. Densities of most taxa were greater at tributary stations than at the corresponding Missouri R. station, and the composition of the fish assemblages in the tributaries was different from that in the Missouri R. It is difficult to identify the source of fish larvae and juveniles captured in the lower tributary habitats or to describe movement of these fish because the tributary flow patterns are so complex. **Brown and Coon 1994.** Several taxa that are common in the Missouri R. as adults, including blue sucker, channel catfish, and white bass, were captured almost exclusively in tributaries as larvae but in low numbers. Authors speculate that each of these taxa have restrictive spawning requirements, such as coarse substrates, moderate depths and discharges, or high amounts of cover which might not be met in the channelized Missouri R. **Berg 1981**. Channel catfish were in the Missouri R. below the confluence of the Marias R. but generally uncommon above the Marias. This species is common and important game fish in the Missouri R., but responds poorly to many kinds of sampling gears. Boom shocking, gill netting, frame trapping, and seining all failed to produce a sufficient sample. Baited hoopnets had good success.

Species	Channel catfish *Ictalurus punctatus*
Habitat (cont'd)	**Propst and Carlson 1986** found that channel catfish were rare in the Platte R. drainage. Lack of deep pools, lack of warm water for spring spawning, poor water quality in many reaches, and/or competition are probably responsible for its low abundance. **Haddix and Estes 1976**. Channel catfish are native to the lower Missouri and Yellowstone River drainages in Montana. They are common in the Yellowstone below the Huntley diversion and are found in the lower reaches of the Bighorn, Tongue, and Powder Rivers. **Haddix and Estes 1976** captured more channel catfish in backwater areas of the lower Yellowstone R. (268) than in the slow current main channel (116). **Pflieger 1975.** Occurs in a variety of habitats but is especially characteristic of large streams having low or moderate gradients. Adults are found in larger pools, in deep water or about submerged logs and other cover. Young often occur in riffles or the shallower parts of pools. **Pflieger 1975.** Channel cats take most of their food from the bottom. Diet is varied, including fish, insects, crayfish, mollusks, and plant material. Young cats <4 inches fed almost entirely on small insects. **Scott and Crossman 1973.** The habitat of the channel catfish in Canada is lakes and moderate to large rivers. They usually inhabit cool, clear, deeper water with sand, gravel or rubble bottoms—not the shallower, more turbid vegetated areas frequented by bullhead. **Brown 1971.** Locally abundant throughout the Missouri R. below the dams at Great Falls and in the Yellowstone R. as far upstream as Pryor Cr. **Brown 1971.** Preferred habitat is large rivers and lowland lakes.

Species	Channel catfish *Ictalurus punctatus*
Egg/Larval Characteristics . Drift . Gravel . Backwaters . Nest	**Armstrong and Brown 1983** in reviewing the literature state that the drift of fish larvae can exceed invertebrate drift both in numbers of organisms and total biomass within a stream reach. Fish larvae in small streams usually drift with a diel periodicity synchronous with that of drifting invertebrates. Both groups generally have a strong peak of drift about 2 hours after sunset and a lesser peak 2-3 hours before sunrise—a bigeminous pattern. With few exceptions, invertebrates have a very low drift rate during the day and the time setting factor is light intensity. Fish larvae rarely drift at all during the day in small streams. **Armstrong and Brown 1983.** Channel catfish were dominant component of the larval-fish drift assemblage in the Illinois R., Arkansas. They found that the diel drift of channel catfish alevins and invertebrates coincided and approximated the typical nocturnal bigeminous pattern described above. No drifting alevins were collected during the day in the drift. Live alevins were observed to burrow deeply into small, well-aerated interstices in the gravel substrate during the day, emerging only during darkness to congregate at the upstream end of the channel. **Armstrong and Brown 1983** speculate that as the alevins emerge to feed on benthic organisms, they are swept into the current and are passively transported downstream. The displaced alevins "somehow" leave the drift actively or passively. Toward dawn, the cycle repeats itself. **Berg 1981** reported that the peak of channel catfish spawn occurred during the first 3 weeks of July in the Missouri R. above Fort Peck Reservoir. Berg found one channel catfish alevin on the Marias R. June 19 and three on July 28, 1978, confirming that catfish spawn successfully in the lower Marias R. None were found in the mainstem Missouri R.

Species	Channel catfish *Ictalurus punctatus*
Egg/larval (cont'd)	**Scott and Crossman 1973.** Spawning takes place in secluded, semidark nests built by the male in holes, undercut banks, log jams, or rocks. Eggs hatch in 5-10 days at temperatures from 60 to 82 ^{0}F. Newly hatched fish have large yolks and remain on the bottom for 2-5 days and then swim to the surface and begin to feed. The males brood the young. **Brown 1971.** Spawning occurs from May into July after water temps exceed 75 ^{0}F. The male locates a suitable spawning area which must be in a dark cavity such as a muskrat burrow, depression in or under the bank, crevice in lodged debris, etc. Male guards egg mass and fry. Hatching occurs in 6-10 days and fry disperse after about 5 days.

Species	Channel catfish *Ictalurus punctatus*
Migratory Characteristics . None at all . Spawning . Rearing/drifting larvae . Pioneering abilities/colonizing new habitat	**Brown and Coon 1994** summarize some literature for channel cat migrations: adult channel catfish frequently move between the main channel and tributaries, apparently to feed on abundant prey fishes and to spawn (**Dames et al. 1989**). Other studies have documented transport of fish larvae from tributaries to the Missouri R. (**Tondreau 1979; Hergenrader et al. 1982; Muth and Schmulbach 1984**). **Dames and Coon 1989**, in examining the importance of tributary stream habitat to Missouri R. channel cats, found that most fish (59 percent) initially caught, recaptured, or both in the Missouri R. moved into or out of Perche Cr. and most of these transient fish (72 percent) used the lower 8 km of the tributary. The tributary population was made up predominantly of resident fish (79 percent) which were initially caught and captured in Perche Cr. Channel catfish moved greater distances in the spring than in the fall and were more likely to move upstream in the spring and downstream in the fall. Fish <250 mm were more abundant in the river than in the creek. More fish >380 mm moved from the creek to the river (44 percent) than from the river to the creek (26 percent). Tributary habitat was thus used most frequently by fish 280-380 mm long. Missouri R. residents showed similar seasonal movement patterns. Fish moved greater distances in spring than in fall. Fish also showed seasonal direction with 73 percent moving downstream in fall and the reverse in spring. No movement was detected by tagged fish in winter. **Smith and Hubert 1989** found that of 21 spp. collected in the Powder R., Wyoming, and its tributary, Crazy Woman Cr., only 5 showed seasonal spawning movements into Crazy Woman Cr.: goldeye, common carp, river carpsucker, shorthead redhorse, and channel catfish. Eggs and larvae of all five spp. were found in the drift at the mouth of the tributary indicating that they spawned in the tributary. Goldeye eggs appeared to drift downstream out of Crazy Woman Cr. before hatching. At least some common carp, river carpsucker, and channel catfish used the tributary creek as nursery habitat.

Species	Channel catfish *Ictalurus punctatus*
Migration (cont'd)	**Rehwinkel et al. 1978** report similar observations as **Smith and Hubert 1989** of the use of tributary streams on the Great Plains as spawning and nursery habitat for channel catfish as were made for two other tributaries to the Powder R. in Montana, and for tributaries to the Missouri R. in Nebraska (**Hesse et al. 1979**.) Movement of common carp, river carpsuckers, and channel catfish into tributaries to spawn was noted June 1977 by **Hesse et al. 1979** and **Nelson 1980**. **Hesse et al. 1982** found that 38.8 percent of tag returns for channel catfish in the Missouri R. in Nebraska came from tributary streams. They concluded that tributaries play a vital role in the life cycle in species such as the channel catfish. Of 297 tag returns, they found the mean upstream distance traveled was 60.2 km; mean downstream distance was 38.6 km. Maximum upstream distance traveled was 325.9 km; maximum downstream distance was 270.4 km. There were 194 individuals that traveled upstream, while 103 traveled downstream. **Berg 1981** found channel catfish in the Missouri R. above Fort Peck Reservoir exhibited extensive spawning migrations ranging from 5 to 267 km. Other research also reported extensive movements in large rivers: **Elser et al. (1977)** observed channel catfish movements ranging from 1 to 333 km in the lower Yellowstone and Tongue Rivers, Montana. **Hubley (1963)** reported channel catfish movements of up to 344 km upstream and 275 km downstream in the upper Mississippi R. Berg reports that most channel catfish were recaptured in Fort Peck Reservoir following or prior to the spawning period. **Haddix and Estes 1976.** Two channel catfish tagged in the Yellowstone R. below Intake exhibited extensive upstream movements. One tagged in August was caught in the Tongue R. the following May. Another tagged in May was caught near Miles City in June. **VanEeckhout 1974** reported movements of two channel catfish tagged in the Little Missouri River, North Dakota, and caught in the Yellowstone R. near Intake, Montana. He also reported movements of channel catfish from Garrison Reservoir up the Little Missouri R., North Dakota.

Species	Channel catfish *Ictalurus punctatus*
Migration (cont'd)	**Scott and Crossman 1973**. Depending on habitat, the spawners may or may not migrate into rivers or moving water at spawning time. Although largely a sedentary species, local movements in lakes have been recorded and in some areas there are marked downstream movements in the fall. Marked fish liberated at lake center returned quickly to the site of marking. Greatest periods of movement appear to be just before sunrise and sunset. Fish tagged in the St. Lawrence River by Magnin and Beaulieu (summarized in english in **Scott and Crossman 1973**) were later recaptured upstream, downstream, and some distance upstream to tributary rivers. Distances traveled ranged from 0 to 99 miles, with approximately 50 percent of the individuals moving 10-39 miles.
Period of peak activity . Nocturnal . Diurnal	**Pflieger 1975.** Catfish in general are most active at night. During the daylight hours, they often hide in natural cavities and crevices or remain quietly in the deeper parts of pools. However, if there is a sudden sharp rise in the stream level, they go on a feeding spree and forage actively at all hours of the day or night. Channel cats, in particular, retire to deep water or lie about drift piles, submerged logs, or other cover during the day. At night, they move onto riffles or into shallows of pools to feed. **Scott and Crossman 1973.** Channel catfish feed on a wide variety of plant and animal material, both at night and during the day. This species, like other catfishes, doubtless depends on its barbels and sense of taste at night, but there is a suggestion it feeds more by sight than other catfishes in its clearer habitat.
Size of Territory (how much do they move around) . Permanent . Seasonal	
Location in River . Midchannel . Edges	**Scott and Crossman 1973.** Bottom feeding is more characteristic, but food is taken at the surface, especially by younger fish.

Species	Channel catfish *Ictalurus punctatus*
Location in Water Column . Surface . Midcolumn . Substrate	
Swimming Performance . Actual measurements . Lifestyle (performance implied by lifestyle) - cruiser - lie in wait predator - scavenger	**Schmulbach et al. 1982** experimentally determined the critical velocity for sustained swimming performance was 62.0 ± 16 cm/s. The channel catfish had no preferred habitat. It is considered a good or moderately good swimmer in swimming performance experiments.
Ability to Surmount Passage Barriers . Velocity barriers . Physical obstructions	
Susceptibility to Entrainment . Presence in entrainment study catches	**Hesse et al. 1982** found that the most common fish impinged on traveling screens in the Missouri R. at the Cooper Nuclear Station in Nebraska included freshwater drum (18.8 percent) and river carpsucker (9.3 percent) and gizzard shad (58.0 percent). At the Fort Calhoun Station, the most commonly impinged species included freshwater drum (29.5 percent), gizzard shad (21.1 percent), and channel catfish (9.0 percent).
Fish Passage Studies . Presence in passage studies	
Physical Structure related to Entrainment/Passage	
Areas literature says don't know anything/much about	**Haddix and Estes 1976** felt there was little data about channel catfish in the larger rivers of the northern latitudes.
Areas literature says well known/studied	**Scott and Crossman 1973.** Poorly known in Canada, but voluminous information published in the United States.

Species	Channel catfish *Ictalurus punctatus*
Threats/Causes of Decline/Status	

Species	Common carp *Cyprinus carpio*
Distribution	
Habitat Use . Adult . Spawning . Rearing	
Egg/Larval Characteristics . Drift . Gravel . Backwaters . Nest	**Beckett and Pennington 1986.** Three principal factors determine ichthyoplankton composition and distribution: larval phenology, habitat characteristics, and river stage. Progeny of early spawners such as goldeye, common carp, buffalo (*Ictiobus* sp.), and sauger dominated spring and early summer ichthyoplankton collections, while freshwater drum, carpsucker (primarily river carpsucker), and *Lepomis* sp. dominated the mid to late summer ichthyoplankton community. **Gale and Mohr 1978.** Of the 18 spp. of larva in the drift sampled on the Susquehanna R., found white sucker, common carp, and shorthead redhorse in large numbers. Nearly all larvae collected at night on the surface, peaking at 2400 h, very few during the day. Of those collected during day, most were near the bottom. Density of drifting larvae captured somewhat higher near either shore than in the channel. But greater volume in main channel thus probably more fish drifting there than along shore. Iron contaminants may have influenced diel patterns though **Beckett and Pennington (1986)** believe it is a behavioral response to increased activity triggered by darkness.
Migratory Characteristics . None at all . Spawning . Rearing/drifting larvae . Pioneering abilities/colonizing new habitat	**Smith and Hubert 1989** found that of 21 spp. collected in the Powder R., Wyoming, and its tributary, Crazy Woman Cr., only 5 showed seasonal spawning movements into Crazy Woman Cr.: goldeye, common carp, river carpsucker, shorthead redhorse, and channel catfish. Eggs and larvae of all five spp. were found in the drift at the mouth of the tributary indicating that they spawned in the tributary. Goldeye eggs appeared to drift downstream out of Crazy Woman Cr. before hatching. At least some common carp, river carpsucker, and channel catfish used the tributary creek as nursery habitat.

Species	**Common carp** ***Cyprinus carpio***
Period of peak activity . Nocturnal . Diurnal	
Size of Territory (how much do they move around) . Permanent . Seasonal	
Location in River . Surface . Substrate . Midchannel . Edges	
Location in Water Column . Surface . Midcolumn . Substrate	
Swimming Performance . Actual measurements . Lifestyle (performance implied by lifestyle) - cruiser - lie in wait predator - scavenger	
Ability to Surmount Passage Barriers . Velocity barriers . Physical obstructions	

Species	Common carp *Cyprinus carpio*
Susceptibility to Entrainment . Presence in entrainment study catches	
Fish Passage Studies . Presence in passage studies	
Physical Structure related to Entrainment/Passage	
Areas literature says don't know anything/much about	
Areas literature says well known/studied	
Importance Economically	
Threats/Causes of Decline/Status	

Species	Flathead chub *Hybopsis gracilis*
Habitat Use . Adult . Spawning . Rearing	**U.S. Fish and Wildlife Service 1995.** Most often collected in large streams and rivers in western North Dakota. They still inhabit some unchannelized and channelized portions of the Missouri R. It inhabits a diverse range of habitats. In the Missouri R., it is found in more or less continuously turbid waters where the current is swift and the bottom is composed of sand or fine gravel. In some portions of its range, it is found in pools with moderately clear water, little current, and coarse gravel and bedrock substrate. **Smith and Hubert 1989** found flathead chub in both the Powder R. and its tributary, Crazy Woman Cr. The Powder R. is characterized as a meandering, highly braided stream with an unstable sand and silt bottom. The water is naturally turbid. Crazy Woman Cr. has a more confined channel that is stabilized by vegetated banks, and the water is less turbid. It has gravel riffles; pools; cut banks; and large, woody debris throughout its entire length. **Pflieger and Grace 1985.** Under presettlement conditions, the Missouri R. supported a relatively limited fauna comprised of species adapted for life in an environment characterized by persistent high turbidity, wide seasonal fluctuations in flow and temperature, and an unstable sand-silt substrate. The more distinctive species in this fauna were pallid sturgeon, western silvery minnow, plains minnow, flathead chub, sturgeon chub, and sicklefin chub. The pallid sturgeon and flathead chub have declined markedly in abundance from 1940 to 1983 due to increased competition, and reduced habitat diversity. Sicklefin chub and sturgeon have fared better. These species have increased in abundance in the middle and lower sections of the Missouri R. in Missouri. Habitat for them (open channels with swift current and firm substrate) has actually been increased by channelization. This habitat is sparsely inhabited by most other fishes, reducing potential competitors and predators. Their close association with the substrate may result in their being less vulnerable to predation than the midwater flathead chub. The two common species of minnows (western silvery and plains) declined in relative abundance over the period of record. These species typically occur in silty backwaters. These habitats became less prevalent as the river was channelized and its sediment load was reduced.

Species	Flathead chub *Hybopsis gracilis*
Habitat Use (cont'd)	**Gould 1985.** Flathead chub typically inhabit fluctuating streams with alkaline, turbid waters and shifting sandy-loam substrates (**Olund and Cross 1961, Brown 1971**). **Haddix and Estes 1976** conducted extensive fish sampling in the lower Yellowstone R. They document species and habitats where captured, but did not document numbers captured. Backwater below Forsyth 9/29/75: flathead chub, emerald shiner, silvery minnow, fathead minnow, and mountain sucker. Backwater below Intake 10/3/75: flathead chub, emerald shiner, sand shiner, fathead minnow. Main channel habitat at Intake 8/21/75, 9/18/75, and 10/3/75: plains minnow, sturgeon chub, emerald shiner, flathead chub, longnose dace, finescale dace, silvery minnow. **Brown 1971.** Habitat is the plains streams—large and small—where turbidities are normally high. It is found in shallow and fairly deep water over mud or rocky bottom and in slow or fairly swift water. Large numbers have been seined from the pools of intermittent streams. **Olund and Cross 1961.** It is well designed for life in swift, turbid water as its elongate body, pointed snout, and elongate fins attest. It is seldom found in the clear, still waters of ponds or lakes. It is predaceous and feeds on a wide variety of organisms, probably both by sight and also by using the tastebuds associated with the barbels. Insects—adults especially—form a major part of the diet in Saskatchewan and Alberta.
Egg/Larval Characteristics . Drift . Gravel . Backwaters . Nest	**Smith and Hubert 1989** found larval flathead chub in the drift at the mouth of Crazy Woman Cr. It was the most abundant species (41 percent) followed by river carpsucker (38 percent). **Gould 1985** reports a July to August spawning season for flathead chub.
Migratory Characteristics . None at all . Spawning . Rearing/drifting larvae . Pioneering abilities/colonizing new habitat	**Olund and Cross 1961** report that flathead chub sometimes move into smaller streams during the spawning season from the turbid, flowing waters in main channels of large rivers.

Species	Flathead chub *Hybopsis gracilis*
Period of peak activity . Nocturnal . Diurnal	
Size of Territory (how much do they move around) . Permanent . Seasonal	
Location in River . Midchannel . Edges	**Liebelt 1996.** Flathead chub were the most abundant species captured in both 1994 and 1995 using beach seines in both the Yellowstone R. from Intake to the confluence of the Missouri R. and in the Missouri R. upstream from the confluence. **Tews 1993** reported flathead chubs were the most common species captured in both rivers based on seining efforts.
Location in Water Column . Surface . Midcolumn . Substrate	
Swimming Performance . Actual measurements . Lifestyle (performance implied by lifestyle) - cruiser - lie in wait predator - scavenger	
Ability to Surmount Passage Barriers . Velocity barriers . Physical obstructions	

Species	Flathead chub *Hybopsis gracilis*
Susceptibility to Entrainment . Presence in entrainment study catches	
Fish Passage Studies . Presence in passage studies	
Physical Structure related to Entrainment/Passage	
Areas literature says don't know anything/much about	**Gould 1985.** Basic information available on food habits, age and growth, and fecundity is fragmentary and inadequate. Information on the seasonal movements and habitat use, spawning behavior, embryology, and interactions with other fish appears to be nonexistent.
Areas literature says well known/studied	
Threats/Causes of Decline/Status	

Species	Freshwater drum *Aplodinotus grunniens*
Habitat Use . Adult . Spawning . Rearing	**Brown and Coon 1994** observed carpsucker and goldeye were found in greater densities in the Missouri R. than in the tributaries. Freshwater drum and common carp also were more abundant in the Missouri R. than in some tributaries. Goldeye and freshwater drum have pelagic eggs and hatched larvae, both of which often are more common in the main channel of large rivers than in backwaters and tributaries (**Holland 1986**). **Brown and Coon 1994** found that common carp, freshwater drum, buffalo, carpsucker, and goldeye were abundant in the deeper tributaries of the Missouri R. and were usually associated with higher turbidity and greater depth. Correspondingly, they found that densities of sunfish, crappie, and nearctic cyprinid were greater in clearer tributaries. **Pflieger and Grace 1987** attributed the increased abundance of white crappie and emerald shiner in the Missouri R. over the past 40 years to reductions in turbidity in the main channel. **Brown and Coon 1994** summarizes literature: **Kallenmeyn and Novotny 1977** and **Hergenrader et al. 1982** found that sunfish, crappie, cyprinid, and gizzard shad were the predominant taxa in backwaters and tributaries in the Missouri R. Freshwater drum, a pelagic spawner, was the most abundant main-channel species in both studies. Brown and Coon conclude that their study demonstrates that Missouri R. fishes use the lower reaches of tributaries as backwater habitat for early life history stages. **Bodensteiner and Lewis 1992**. Demonstrated the use and importance to young freshwater drum of winter thermal refuges in backwaters and sloughs, where they rested on the bottom. **Pflieger 1975**. It occurs in large streams over much of Missouri, but is most abundant in the Missouri and Mississippi Rivers and the downstream sections of their major tributaries. In streams, the drum is usually found in the larger pools; in reservoirs, it often occurs at depths of 30 feet or more. It avoids strong current but is tolerant of high turbidity. **Scott and Crossman 1973.** The freshwater drum inhabits large, shallow bodies of water and though it seems to prefer clear water, it can obviously adapt to relatively high turbidity levels. Available evidence, though scarce, indicates it lives mostly in shallows. **Brown 1971**. In Montana, freshwater drum was confined to the lower reaches of the Missouri and Yellowstone Rivers and a short distance into some of their larger tributaries. Freshwater drum inhabit deep pools of large streams and in large lakes and reservoirs. Prefers areas where the bottom is clean and turbidities are moderate.

Species	Freshwater drum *Aplodinotus grunniens*
Egg/Larval Characteristics . Drift . Gravel . Backwaters . Nest	**Beckett and Pennington 1986**. Three principal factors determine ichthyoplankton composition and distribution: larval phenology, habitat characteristics, and river stage. Progeny of early spawners such as goldeye, common carp, buffalo (*Ictiobus* sp.), and sauger dominated spring and early summer ichthyoplankton collections, while freshwater drum, carpsucker (primarily river carpsucker), and *Lepomis* sp. dominated the mid to late summer ichthyoplankton community.[1] The backwaters (*Lepomis* sp) differed markedly from main channel (drum and carpsucker). In general, backwater and slack-water habitats supported much higher ichthyoplankton densities than lotic areas. **Muth and Schmulbach 1984.** Predominant taxa collected in larval drift in James R., South Dakota, were freshwater drum. Collectively ichthyoplankton showed no significant diel periodicity, but four taxa did so including the freshwater drum. Freshwater drum drifted predominantly during the day. See this citation for excellent discussion of data and literature. Vertical distribution is also important in determining exposure to entrainment at the intake. **Gallagher and Conner 1983**. In ichthyoplankton sampling in the lower Mississippi R., Louisiana, freshwater drum and shads composed 93.5 percent of the total ichthyoplankton. Freshwater drum were most abundant in the site characterized by swift surface currents (75-90 cm/s) and was absent from the site characterized by sluggish surface currents (0 cm/s). **Holland and Sylvester 1983** found larval freshwater drum were more abundant near the surface at midnight than during the day in ichthyoplankton sampling on the upper Mississippi R. Eggs and larvae were collected from mid-May through July. They found the increase in lower-pool densities of eggs and larvae during summer was due primarily to freshwater drum, whose neustonic eggs and protolarvae were transported by river current.

[1] I will only list fish species that are also found in the Yellowstone and upper Missouri Rivers. See citation for the full text of all the species found and discussed.

Species	Freshwater drum *Aplodinotus grunniens*
Egg/Larval (cont'd)	**Holland and Sylvester 1983** found a distinct diel periodicity in larval abundance was observed during May and June 24-h sampling periods. In general, peak catches of larvae occurred at dusk. However, the magnitude and nature of the diel patterns were closely associated with the habitats sampled and species composition. Most larvae collected at dawn were in backwaters. At dusk, larvae were more abundant at the main-channel surface than at other stations. Relative abundance of larvae was greatest in the backwaters at midnight. Noticeable taxon-specific diel variations existed during the study. Suckers were generally most abundant in the catches at midday, whereas crappies, white bass, and common carp were abundant at dusk. Freshwater drum were most common in the catch at midnight, and other cyprinids were about equally abundant at dusk and dawn. **Holland and Sylvester 1983**. These specific diel patterns also varied by habitat. At midday, crappies were common in backwaters, became abundant in the main channel at dusk, and again were most abundant in backwaters at midnight and dawn. Common carp and other cyprinids showed slight preferences for littoral areas during most of the day. At dusk they were more evenly distributed. Suckers inhabited littoral and bottom areas during the day, but showed no consistent distribution pattern during other periods. Unlike the other species, freshwater drums yielded consistently greatest catches in main-channel bottom waters except at midnight. **Holland and Sylvester 1983** found that of the three most common species of larvae they collected in the upper Mississippi R., freshwater drum alone exhibited signs of vertical migration, negative phototropism, or gear avoidance. **Holland and Sylvester 1983**'s findings agree with most published accounts (gives citations) but differs with **Gallagher and Conner (1980)** on their findings on freshwater drum. Although freshwater drums were more abundant at night in Pool 7, **Gallagher and Conner (1980)** found greater numbers in daylight samples in the lower Mississippi R. They attributed this to the increased turbulence and turbidity in the river.

Species	Freshwater drum *Aplodinotus grunniens*
Egg/Larval (cont'd)	**Burch et al. 1981**. Ohio R. sampling indicated common carp, *Carpoides* sp. and freshwater drum were most abundant. Found over 3-yr period that peak ichthyoplankton density varied between years. Also found no horizontal or vertical stratification in sampling densities of larval fish. **Cada and Hergenrader 1980**. Freshwater drum feed strictly on zooplankton, and begin switching to a diet of benthic insects at 20 mm in length. Freshwater drum larvae begin migrating to deeper waters at approx 10 mm. **King 1978**. Larval freshwater drum were the most abundant fish entrained at Fort Calhoun Station, Missouri R. near Omaha, Nebraska, accounting for 43.7 percent to 88 percent in the 4-yr study. Carpsucker sp., white sucker, buffalo sp., and redhorse sp. were the second most common larvae. These species are random or pelagic spawners. Together they totaled 94.5 percent of the entrained larvae. Other pelagic spawners commonly found in the drift included carp, catostomids, and goldeye. Game fish, including bass, sunfish, perch sauger, walleye, and crappie comprised less than 1 percent of the larvae collected. These fishes are either nest builders or random spawners that lay adhesive or demersal eggs. Catfish (flathead and channel) were not collected from the drift. Earliest date larval fish taken was 3/17 and relatively sparse in drift by late July and absent by mid-August. Peak larval densities occurred from mid-June concerning diel periodicity in downstream movement of fish larvae through mid-July when water temperatures were 21 to 25 ^{0}C.

Species	Freshwater drum *Aplodinotus grunniens*
Egg/Larva (cont'd)	**King 1978**. Freshwater drum population in the Missouri R. was most affected by entrainment. It was most abundant in the drift and experienced the greatest entrainment losses. Freshwater drum spawn planktonic eggs and the prolarvae are semibuoyant, which may account for its relative abundance in the drift. **King 1978.** Determined the horizontal distribution of larval fish in the Missouri R. to estimate the percentage of larvae exposed to entrainment. Results indicated significantly higher densities along the cutting bank of the river adjacent to Calhoun Station's intake structure. Densities were lowest at midchannel location. Larval densities nearing the filling bank were similar to the midchannel location. During 1977 an estimated 3.3 billion larvae passed Fort Calhoun Station between 5/13 and 7/25, 2.9 billion of which were freshwater drum. **Probatov and Liashenko 1974.**[2] Fry and adult fish carried into irrigation canals are not traumatized by this, and emerging from the turbulence, become oriented within a short distance of the headworks. More fish usually are carried over at night, a fact that has been noted at other intake structures in the Soviet Union. **Scott and Crossman 1973**. Freshwater drum are unique among North American fishes since the egg is buoyant and floats at the surface. The floating egg, which can be carried by currents, is probably one of the more significant factors responsible for the extremely wide range of the drum. **Brown 1971**. Freshwater drum are reported to spawn in May and June after surface water reaches 65-70 ^{0}F. Lake spawning observations indicate mature fish tightly school near the surface. Eggs are small and buoyant and readily distributed by water currents. Hatching time is short and fry float near the surface for a time. When they are about 1 inch long, they seek the bottom where water is fairly deep.

[2]Their observations placed arbitrarily in freshwater drum account. No drum were found in any of their studies.

Species	Freshwater drum *Aplodinotus grunniens*
Migratory Characteristics . None at all . Spawning . Rearing/drifting larvae . Pioneering abilities/colonizing new habitat	**Berg 1981** tagged 216 freshwater drum in the middle Missouri R., but only 1 tag was recovered; Berg was unable to evaluate migration characteristics of this species. **Pflieger 1975.** Spawning in late April or May in Missouri is preceded by movements of adults out of large rivers and reservoirs into tributary streams.

Species	Freshwater drum *Aplodinotus grunniens*
Period of peak activity . Nocturnal . Diurnal	**Beckett and Pennington 1986**. Diel studies including this one showed maximum ichthyoplankton diversity at dusk with relatively high diversity at night and dawn, and low diversity in the daytime. Lowest total densities occurred at midday. They feel the most likely explanation for this is a behavioral response of the larval fishes (e.g., increased movement) triggered by darkness. **Gallagher and Conner 1983.** In their lower Mississippi R. ichthyoplankton investigation, they found freshwater drum were most abundant during daylight, with a preponderance of protolarvae, and abundance was markedly lower at night. Nocturnal collections contained a much greater proportion of older larvae. Freshwater drum protolarvae seemed to be concentrated in the 50- to 100-cm stratum of the water column during the day, whereas night-time distributions were more uniform within the top meter of water. **Hergenrader et al. 1982** found densities of living freshwater drum and carpsucker (*Carpiodes* sp.) larvae were significantly greater at night in their ichthyoplankton sampling on the Missouri R. in Nebraska. **Hesse et al. 1982** found that impingement rates at the Fort Calhoun Station on the Missouri R. in Nebraska exhibited diel differences. Impingement rates during the night (2000 to 2200 and 0200 to 0400 h) were significantly higher than during midday (1400 to 1600 h). At the Cooper Nuclear Station, hourly impingement rates were generally higher at night than during daylight hours (did not refer to species - but to total numbers of fish impinged). **King 1978**. Collections of larval fish made over a 24-hour period showed no significant differences in densities between mean day and night. High turbidity and velocity of the Missouri R. may reduce the diurnal periodicity that has been reported for fish larvae. **Brown 1971**. Freshwater drum reported to move into shallow water at night and feed on bottom organisms.

Species	**Freshwater drum *Aplodinotus grunniens***
Size of Territory (how much do they move around) . Permanent . Seasonal	

Species	Freshwater drum *Aplodinotus grunniens*
Location in River . Midchannel . Edges	See **Beckett and Pennington 1986** for descriptions of where larval freshwater drum are found in lower Mississippi R. **Holland and Sylvester 1983** found freshwater drum (predominant species) and other larval species most abundant in the main channel border (4.6/100 m^3); followed by main-channel surface (4.2/100 m^3); main-channel bottom (3.1/100 m^3) and backwaters (3.8/100 m^3). **Hergenrader et al. 1982** found that annual mean larval densities from the cutting bank location (1.34 larvae/m^3) usually exceeded those from the filling bank (0.85 larvae/m^3). The mid channel had the lowest numbers (0.40 larvae/m^3). Hydraulic forces tend to concentrate passively drifting particles into areas where current velocity is highest (which is the cutting bank). Consequently, if ichthyoplankton respond to hydraulic forces like passively drifting particles, their distribution in the river would be consistent. Also the presence of spawning areas along the shoreline, in backwaters, and behind channel control structures would contribute larvae to the sides rather than the middle of the channel. **Hergenrader et al. 1982** found that the relative abundance of taxa collected from all tributaries was markedly different from the main channel collections. Carp (26.3 percent) was most abundant followed by catostomids (24.4 percent), cyprinids (excluding carp) (19.4 percent), and gizzard shad (11.0 percent). The low relative abundance of freshwater drum (2.5 percent) was in sharp contrast to the main channel composition where it comprised 72.5 percent of the total.

Species	Freshwater drum *Aplodinotus grunniens*
Location in Water Column . Surface . Midcolumn . Substrate	**Hergenrader et al. 1982** found vertical distribution of larvae in the Missouri R. near Omaha as follows: 0.80 larvae/m^3 surface; 0.60 larvae/m^3 middepth; and 0.25 larvae/m^3 near bottom. They found that surface densities were significantly greater than near-bottom mean densities. **Holland and Sylvester 1983** found in ichthyoplankton sampling on the upper Mississippi R., Wisconsin, that freshwater drum were more abundant near the surface at midnight than during the day. **Pflieger 1975**. Freshwater drum live most of the time near the bottom. It feeds by grubbing on the bottom, often moving rocks with its snout to capture the insects and other small aquatic life thus disturbed. **Scott and Crossman 1973**. It is adapted to bottom feeding, as the position of its mouth suggests. YOY eat mostly zooplankton and chironomids; young drum, to 30 mm, eat entromostracans, but as they grow larger aquatic insects become increasingly important. Mayflies and amphipods are important food items at all sizes. With larger sizes, crayfish, molluscs and larger fish become more important.
Swimming Performance . Actual measurements . Lifestyle (performance implied by lifestyle) - cruiser - lie in wait predator - scavenger	**Schmulbach et al. 1982** experimentally determined critical velocities averaged 75.6 ± 23.3 cm/s. Freshwater drum were distributed throughout several habitats with varied current velocities, exhibiting no apparent preferences. In conclusion, after experimentally determining critical velocities for sustained swimming, Schmulbach et al., conclude that current velocities in several Missouri R. habitats were species limiting. The main channel habitat of channelized river with a mean current velocity of 110 cm/s is well above the sustained and prolonged swimming abilities of even the best swimmers. No species preferred this habitat or even used it commonly. In the unchannelized river no species preferred the main channel habitat with its mean current velocity of 85 cm/s but at least eight species used it commonly. All the remaining habitats had current velocities slow enough to provide potential habitation by most species.

Species	Freshwater drum *Aplodinotus grunniens*
Ability to Surmount Passage Barriers . Velocity barriers . Physical obstructions	

Species	Freshwater drum *Aplodinotus grunniens*
Susceptibility to Entrainment . Presence in entrainment study catches	**Bodensteiner and Lewis 1992**. Annual winter impingement of large numbers of primarily dead, dying, and incapacitated young freshwater drum on screens of a power station intake on the Mississippi R. led to an investigation of the cause of impingement. Lab studies found juveniles became disoriented, incapacitated, and suffered increased mortality as water temperatures dropped to 1 ^{0}C and below; 0 ^{0}C was found in main and side channels of the river, but pockets of water above 1 ^{0}C existed in backwater areas. Large numbers of young were observed in these thermal refuges. Speculate that declining O^2 levels during winter caused periodic disruption of the thermal refuges, forcing young into colder water with higher O^2 levels, leading to the incapacitation and eventual appearance in the drift impinging on the intake screens. **Hergenrader et al. 1982.** To assess entrainment effects on the total ichthyoplankton assemblage at a specific location, four components are required: (1) hydraulic and hydrographic characteristics of the river at that point (bottom contour, stage, width, flow); (2) spatial distribution of larvae (horizontal, vertical); (3) temporal distribution of larvae (daily, seasonally); and (4) mortality associated with station operation. **Hergenrader et al. 1982.** Relative abundance of fish larvae in the drift generally did not correspond to the relative abundance of adult fish near the Fort Calhoun Station and the Cooper Nuclear Station on the Missouri R. Few game fish larvae were expected, based on relatively smaller populations of most game fish in the channelized river. Also, game fishes (including white bass, sunfish, crappie, sauger, walleye, and channel catfish) are either nest builders or random spawners that lay adhesive and/or demersal eggs and some species provide parental care. In contrast, freshwater drum, which comprised approximately 5 percent of the adult fish at the two stations, contributed 70 to 90 percent of the larvae collected. Freshwater drum are pelagic spawners (citations) which accounts for the high abundance of drum larvae in the drift. Carp, catostomids, gizzard shad, and goldeye are random or pelagic spawners and larvae of these species occurred commonly in the drift. Larval fish were common in the drift from early May through July. In particular, sauger and walleye and *Ictiobus* sp. were dominant in May while freshwater drum and *Carpiodes* sp. were dominant from June through July. **Hesse et al. 1982** found that the most common fish impinged on traveling screens in the Missouri R. at the Cooper Nuclear Station in Nebraska included freshwater drum (18.8 percent), river carpsucker (9.3 percent), and gizzard shad (58.0 percent). At the Fort Calhoun Station the most commonly impinged species included freshwater drum (29.5 percent), gizzard shad (21.1 percent), and channel catfish (9.0 percent).

Species	Freshwater drum *Aplodinotus grunniens*
Entrainment (cont'd)	**Hesse et al. 1982** found the dominant species behind wing dikes in the Missouri R. in Nebraska were gizzard shad, river carpsucker, and black and white crappie; while carp, short head redhorse, and freshwater drum dominated trail dike habitat. Both the gizzard shad and river carpsucker are reported to inhabit pools and backwater areas of rivers and large streams, which accounts for their abundance along the wing dikes. While freshwater drum inhabit more sluggish habitat within a stream, Hesse et al., felt the high relative abundance of freshwater drum along the trail dikes could be in response to food abundance or the lower abundance of other species. **Hesse et al. 1982.** Total impingement for all species from 5/73 to 12/77 at Fort Calhoun Station on the Missouri R. in Nebraska was 491,996 fish and at Cooper Nuclear Station from 3/74 through 12/77 it was 306,645 fish. Of these totals only 49 percent were collected alive. The major concern regarding impingement losses is the effect the loss has on the number of fish reaching sexual maturity and the number being recruited to the sport and commercial fisheries. Based on the expected high mortality of YOY fish (>80 percent) and survival rates of Missouri R. fish established by Hesse and Wallace (1976), only 0.4 to 10 percent of the YOY fish stocks in the Missouri R. would reach sexual maturity or be recruited into the sport and commercial fishery.
Fish Passage Studies . Presence in passage studies	
Physical Structure related to Entrainment/Passage	

Species	Freshwater drum *Aplodinotus grunniens*
Areas literature says don't know anything/much about	**Cada and Hergenrader 1980**. Mortality rate estimates for early life stages of freshwater species are rare, even though it is generally believed that mortality during the egg and larval stages plays a major role in determining eventual year-class strength. Additionally, **Walburg 1971** estimates a peak loss of 10 million freshwater drum larvae from the Clark Reservoir on the Missouri R. in Nebraska on a single date. The fate of larval fishes leaving the reservoir is unknown, but it is likely that many are carried downstream to become an important source of recruitment to the adult populations in the channelized river. In the case of the Yellowstone River, the fate of larvae entrained into irrigation canals is unknown, nor is the amount of such entrainment known. **Holland and Sylvester 1983.** There are major data gaps in the basic information on distributions of larval fishes in the Mississippi R. Even after their study, they felt a more detailed understanding of the diel, species-specific, and seasonal and annual variations in abundance of larval fish was needed. **Muth and Schmulbach 1984.** Diel periodicity in the downstream movement of fish larvae, either active or passive drift, is not well understood. **Van Den Alveoli 1990**. Limited mobility of larvae can make them vulnerable to entrainment, and knowledge of spatial and temporal patterns can help define the potential for entrainment and identify operational guidelines for minimizing entrainment. **Hergenrader et al. 1982.** Factors causing drift of warmwater fish larvae are poorly understood. Factors affecting the vertical distribution of larval fish have not been studied for the Missouri R.
Areas literature says well known/studied	
Threats/Causes of Decline/Status	

Species	Goldeye *Hiodon alosoides*
Habitat Use . Adult . Spawning . Rearing	**Brown and Coon 1994** observed carpsucker and goldeye were found in greater densities in the Missouri R. than in the tributaries. Freshwater drum and common carp also were more abundant in the Missouri R. than in some tributaries. Goldeye and freshwater drum have pelagic eggs and hatched larvae, both of which often are more common in the main channel of large rivers than in backwaters and tributaries (**Holland 1986**). **Brown and Coon 1994** found that common carp, freshwater drum, buffalo, carpsucker, and goldeye were abundant in the deeper tributaries of the Missouri R. and were usually associated with higher turbidity and greater depth. Correspondingly, they found that densities of sunfish, crappie, and nearctic cyprinids were greater in clearer tributaries. **Plieger and Grace 1987** attributed the increased abundance of white crappie and emerald shiner in the Missouri R. over the past 40 years to reductions in turbidity in the main channel. **Berg 1981** indicates that goldeye along with sauger, burbot, white sucker, longnose sucker, shorthead redhorse, river carpsucker, carp, goldeye, freshwater drum, emerald shiner, western silvery minnow, and longnose dace were the most widely distributed fish species in his study area of the Missouri R. above Fort Peck Reservoir. **Haddix and Estes 1976** sampled four backwater habitats in the lower Yellowstone R. in 1974. They found carp (67), river carpsucker (62), and goldeye (34) were the most abundant (numbers in parentheses are the fish per run). Sauger was the next most abundant species (16/run). Shovelnose sturgeon and blue sucker were lacking in backwater collections. **Pflieger 1975**. This fish is most often found in the open waters of large rivers where it frequents areas with strong current as well as quiet pools. It is occasionally encountered in the deeper pools of small rivers and creeks where these are tributaries of large rivers. It is tolerant of continuous high turbidity.

Species	Goldeye *Hiodon alosoides*
Habitat Use (cont'd)	**Scott and Crossman 1973**. Goldeye habitat is most frequently found in quiet, turbid water of large rivers; the small lakes, ponds, and marshes connected to them; and the muddy shallows of larger lakes.
Habitat (Continued)	**Miller 1970** reviewing literature: goldeye very abundant in Missouri R. and its impoundments and moderately abundant in tributaries. **Miller 1970** found goldeye in Garrison Reservoir ate cladocera, chironomids, tricopterans, and various terrestrial insects.

Species	Goldeye *Hiodon alosoides*
Egg/Larval Characteristics . Drift . Gravel habitat characteristics and river stage. Progeny of early spawners . Backwaters . Nest	**Liebelt 1996** found that the largest number of eggs in the drift sampled on the Missouri R. and the lower Yellowstone R. in 1995 consisted of goldeye. A total of 7,361 eggs were collected—most of which were goldeye. **Beckett and Pennington 1986.** Three principal factors determine ichthyoplankton composition and distribution: larval phenology, such as goldeye, common carp, buffalo (*Ictiobus* sp.), and sauger dominated spring and early summer ichthyoplankton collections, while freshwater drum, carpsucker (primarily river carpsucker), and *Lepomis* sp. dominated the mid to late summer ichthyoplankton community. **Berg 1981.** Goldeye was a very common species in the Missouri R. and tributaries above Fort Peck Reservoir, but very few larvae were sampled; those found were sampled only at the three lower study sites. The scarcity of goldeye is probably related to their preference for calm waters for spawning and incubation (**Scott and Crossman 1973**). Larval fish samples were collected in the Missouri R. only at sites where current velocity was sufficient enough to stretch out the sampling net. Calm water, which probably was preferred by goldeye for spawning, was not sampled. **Berg 1981** reports that goldeye, along with walleye, sauger, northern pike, and longnose suckers were relatively early spawners in the Missouri R. above Fort Peck Reservoir, beginning in April. **Scott and Crossman 1973.** Spawning occurs from May to the first week of July, starting just after ice breaks up. It occurs in pools in turbid rivers or in backwater lakes and ponds of these rivers. Eggs are unique among freshwater North American fishes in that they are semi-buoyant; they hatch in about 2 weeks. Newly hatched larvae are just over 7 mm long and at first float vertically at the water surface. **Miller 1970** reviewing literature: ova are bathypelagic or semi-buoyant.

Species	Goldeye *Hiodon alosoides*
Migratory Characteristics . None at all . Spawning . Rearing/drifting larvae . Pioneering abilities/colonizing new habitat	**Pigg and Tyler 1990** document the existence of a spawning migration of goldeye in the Red River. **Berg 1981** does not indicate any recapture data for goldeye in the mainstem Missouri R. above Fort Peck Reservoir; however he does state that goldeye, along with river carpsucker, shorthead redhorse, longnose sucker, sauger, shovelnose sturgeon, and channel catfish were the most abundant spring migrants using the lower Marias R. for spawning. **Scott and Crossman 1973**. Goldeye overwinter in deeper areas of lakes and rivers and move toward the shallow, firm-bottomed spawning sites as the ice is breaking up in the spring. In the N. Saskatchewan R. there is a yearly upstream migration in the spring; after spawning the adult fish continue upstream apparently to feed. There is a downstream migration in the fall (**Paterson 1966**). They are probably inactive in winter as growth, in Canada, ceases during that period. **Smith and Hubert 1989** found that of 21 spp. collected in the Powder R., Wyoming, and its tributary, Crazy Woman Cr., only 5 showed seasonal spawning movements into Crazy Woman Cr.: goldeye, common carp, river carpsucker, shorthead redhorse, and channel catfish. Eggs and larvae from common carp, flathead chub, longnose dace, river carpsucker, channel catfish, and stonecat were collected in the drift at the mouth of the tributary indicating that they spawned in the tributary. Goldeye eggs appeared to drift downstream out of Crazy Woman Cr. before hatching. At least some common carp, river carpsucker, and channel catfish used the tributary creek as nursery habitat. Goldeye use of tributary streams for spawning was confirmed by **June 1977** and **Nelson 1980**.

Species	Goldeye *Hiodon alosoides*
Period of peak activity . Nocturnal . Diurnal	**Pflieger 1975**. Much of its feeding is done in late evening or at night. **Scott and Crossman 1973**. Goldeye are apparently mainly nocturnal and their eyes, which have rods only and reflect light, are adapted to dim light conditions and to their turbid habitat. **Scott and Crossman 1973.** Spawning is assumed to occur at night **Cooper 1973.** Gillnetting in the clear waters of Fort Peck Reservoir yielded most fish at night. Sets in turbid shallow water often produced substantial catches during the day. It is possible goldeye could see and avoid the net during day in clear water. Stomach contents showed that goldeye did most feeding at night during the summer and early fall when zooplankton and terrestrial and emergent aquatic insects are available on or near the surface. **Evenhuis 1970** found greatest activity of goldeye at night. Catches were generally much larger at night with peaks from 0400 to 0600 h, dropping sharply between 0600 and 0800 h. **Miller 1970** reviewing literature: goldeye are generally nocturnal surface feeders, feeding primarily on terrestrial and aquatic insects and larvae.
Size of Territory (how much do they move around) . Permanent . Seasonal	
Location in River . Midchannel . Edges	

Species	Goldeye *Hiodon alosoides*
Location in Water Column . Surface . Midcolumn . Substrate	**Pflieger 1975**. The goldeye is an active, fast-moving fish, taking much of its food at or near the surface of the water. **Schadewald 1973** sampled goldeye in Lake Oahe, and determined Cladocera, principally *Daphnia,* comprised 75 percent of the average stomach volume. YOY fed entirely on microcrustaceans. Older goldeye fed predominantly on microcrustaceans as well as terrestrial insects. Goldeye concentrated in surface waters when food was abundant, usually at night. Cladocerans exhibited a nocturnal migration to the surface at night. These and other food organisms were concentrated in the surface strata of Lake Oahe during periods of darkness and may have attracted goldeye. Catch of goldeye during daylight was smaller than night, indicating reduced surface activity. But when insects were numerous on the surface, goldeye were also present indicating goldeye distribution follows food availability, not light. **Scott and Crossman 1973**. Goldeye feed extensively at the surface in summer. Food is of a great variety, consisting of almost any organism encountered. Whatever is most available predominates, and there is no indication of any strong food preference. Food of YOY is mainly microcrustaceans. **Cooper 1973.** In the clear water of Fort Peck Reservoir, goldeye appeared to follow zooplankton food source during the season. During summer and early fall they were within 8 feet of the surface. In late fall, greatest concentration was between 32 and 40 feet. During winter they appeared to concentrate between 8 and 32 feet. **Evenhuis 1970** found in the Little Missouri Arm of Lake Sakakawea that goldeye were predominately in the upper 10 feet during months of June, July, and August. **Miller 1970** reviewing literature: turbidity, temperature, and oxygen levels were not correlated with goldeye vertical distribution in Garrison Reservoir. May be influenced by feeding habits and temperature. Increased catch with turbidity may not indicate greater fish density, but more a result of poor visibility and inability to avoid the net. Miller's work on Garrison revealed greatest goldeye catches in warm turbid areas. In literature, Miller found that it is "well established that goldeye are very abundant in Garrison Reservoir and that they are generally found near the surface." Other workers obtained greatest catches with surface set gillnets.

Species	Goldeye *Hiodon alosoides*
Swimming Performance . Actual measurements . Lifestyle (performance implied by lifestyle) - cruiser - lie in wait predator - scavenger	**Schmulbach et al. 1982** experimentally determined critical velocities which averaged 79.5 $\pm$ 39.4 cm/s. Goldeye swimming performance was variable but when their average critical speed was compared with other species they were among the better performers. Previous workers on the Missouri R. ichthyofauna have all agreed that except for the small cyprinids, only four are very abundant and ubiquitous (gizzard shad, goldeye, carp, and river carpsucker). Among this group only the goldeye was considered a good swimmer in their experiments, suggesting that factors other than swimming ability are major contributing factors determining distribution and species abundance.
Ability to Surmount Passage Barriers . Velocity barriers . Physical obstructions	
Susceptibility to Entrainment . Presence in entrainment study catches	
Fish Passage Studies . Presence in passage studies	
Physical Structure related to Entrainment/Passage	
Areas literature says don't know anything/much about	**Scott and Crossman 1973.** In contrast to so many Canadian fishes, the biology of goldeye is well documented.
Areas literature says well known/studied	
Threats/Causes of Decline/Status	

Species	Longnose dace *Rhinichthys cataractae*
Habitat Use . Adult . Spawning . Rearing	**Smith and Hubert 1989** found stonecat along with flathead chub, shorthead redhorse, and longnose dace in both the Powder R. and its tributary, Crazy Woman Cr. The Powder R. is characterized as a meandering, highly braided stream with an unstable sand and silt bottom. The water is naturally turbid. Crazy Woman Cr. has a more confined channel that is stabilized by vegetated banks and the water is less turbid. It has gravel riffles, pools, cut banks, and large woody debris throughout its entire length. **Propst and Carlson 1986** found longnose dace throughout the Platte Basin but most commonly in foothill stream reaches. Riffle habitat was a major determinant of its distribution and abundance. In upstream reaches it was the only inhabitant of rapid riffles, but in mid-reaches it shared riffle habitat with bigmouth and sand shiner, stoneroller, and small white and longnose sucker. **Edwards et al. 1983**. (summarizes literature) Longnose dace most abundant in swift flowing, steep gradient, headwater streams in large river systems. Habitat usually boulder strewn, with gravel and rock beds. Will occupy quiet shallow pools with few predators or competitors. Adults usually live in protection of crannies between stones in very fast water. In streams will spawn only in riffles with velocity of 45 to 60 cm/s. **Pappantonious and Dale 1982**. Longnose dace prefer stream segments with water velocities >45 cm/s in New York. Main food is hydropsychid larvae followed by chironomid larvae and plecopteran nymphs. Observed diet overlap with blacknose dace. Concluded relative lack of feeding selectivity may be adaptive advantage in streams where food availability can drastically change. **Anderson and Brazo 19___**. Longnose dace commonly occur in swiftly flowing streams throughout northcentral North America. Morphologically suited for bottom foraging (long snout greatly overhangs mouth). Is a bottom feeder. Food is 74 percent terrestrial insects. **Finger 1982** found longnose dace were characteristic species in riffle sections of a central New York stream. It also uses pool tail and run habitats to some degree. **Brazo et al. 1978.** Longnose dace preferred gravel-rock substrates to sandy areas in Lake Michigan.

Species	Longnose dace *Rhinichthys cataractae*
Habitat (cont'd)	**Brown 1971.** Spawns in shallow riffle areas over gravel beds. Large numbers of fry collected during July and August in backwaters and in small quiet pockets along shore. **Bartnik 1970**. Overhead cover and velocity shelters always present. **Bartnik 1970.** Spawning habitat restricted to substrate that is course enough to provide natural depressions for egg deposition. **Gerald 1966** found in the Yellowstone R. that small longnose dace relied on algae—differs from others who found heavy reliance on invertebrates and fish eggs *in* **Brazo et al.**
Egg/Larval Characteristics . Drift . Gravel . Backwaters . Nest	**Edwards et al 1983.** Eggs are demersal and adhesive and are deposited in natural depressions. Optimum spawning temperatures 14 to 19 ^{0}C. Fry become pelagic and are abundant in protected margins of quiet shallow water. Within 6 weeks young begin to move to areas of swift water.
Migratory Characteristics . None at all . Spawning . Rearing/drifting larvae . Pioneering abilities/colonizing new habitat	**Edwards et al. 1983.** Longnose dace select and defend territories during breeding. Peak occurs in June to early July. **Brazo et al. 1978.** Females moved in and out of male territories. No reference to size of movements or of size of male territories. In surge zone, longnose dace densities are low in April/early May; increase markedly in mid-May with increased water temperatures (8-14 ^{0}C). 75%+ were adults moving shoreward to spawn. Numbers peaked in late May and June. Declined to low numbers after that. YOY peaked in early August. **Trautman 1957** reported complete absence nearshore May-September. Suggests that dace move offshore into deeper waters. ??parallel movement in YSR??

Species	Longnose dace *Rhinichthys cataractae*
Period of peak activity . Nocturnal . Diurnal	**Reebs et al. 1995** in discussing the literature on longnose dace: longnose dace, a minnow of lotic habitats, is known to be nocturnal (**Kavaliers 1981; Culp 1989**); this nocturnality has been attributed to possible competition from juvenile trout and to predator avoidance (**Culp 1989**). **Anderson and Brazo 19__**. In Lake Michigan, dace seined along shore. Nearly all caught from 10 p.m. to midnight (44 dace). There were 15 dace caught from 2 a.m. to 6 a.m. and 6 dace from 6 p.m. to 10 p.m. Very few caught rest of time. Most abundant in spring and decreasing throughout summer and fall. Captured large number of YOY in August. **Brazo et al. 1978.** Longnose dace least abundant during daylight hours in surge-zone waters of Lake Michigan. Nearly all caught sunset to sunrise period.
Size of Territory (how much do they move around) . Permanent . Seasonal	
Location in River . Surface . Substrate . Midchannel . Edges	**Brazo et al. 1978.** Males highly territorial. Females move in and out of male territories—had greater spatial movement. **Edwards et al. 1983**. All age groups occur in very shallow water, usually <0.3 m, rarely >1 m.
Location in Water Column . Surface . Midcolumn . Substrate	**Edwards et al. 1983.** Adult longnose dace more or less benthic and inhabit region directly above the substrate.

Species	Longnose dace *Rhinichthys cataractae*
Swimming Performance . Actual measurements . Lifestyle (performance implied by lifestyle) - cruiser - lie in wait predator - scavenger	**Edwards et al. 1983.** Usually collected in streams with a current velocity >45 cm/s. Will live in areas with current velocity as high as 182 cm/s. Longnose dace swimming against strong currents for even short periods (5 minutes) become fatigued and lose ability for coordinated locomotion. Shelter from current must be present. **Brazo et al. 1978** got greatest longnose dace numbers in Lake Michigan surge zone during heavy waves and turbulence. **Gee and Machniak 1972** found on a very windy day longnose dace numbers approached those of **Bartnik's (1970)** stream riffles. **Brown 1971.** Little doubt of its adaptation to life in fast water on the bottom among the stones. **Gee and Northcote 1963.** Fraser R., British Columbia, longnose dace most frequently taken in riffles with flows >0.5 m/s.
Ability to Surmount Passage Barriers . Velocity barriers . Physical obstructions	
Susceptibility to Entrainment . Presence in entrainment study catches	
Fish Passage Studies . Presence in passage studies	
Physical Structure related to Entrainment/Passage	
Areas literature says don't know anything/much about	**Brazo, Liston, Anderson 1978.** Studied extensively in stream habitats where it is common. Little known about lake dwelling longnose dace and its ecological role. Studied life history in Lake Michigan.
Areas literature says well known/studied	

Species	Longnose sucker *Catostomus catostomus*
Habitat Use . Adult . Spawning . Rearing	**Propst and Carlson 1986** found longnose sucker throughout the Platte R. drainage, most commonly in foothill streams. Despite its occupation of a variety of habitats, it was seldom more than a minor component of sampled communities. They found it in rapid-velocity riffles, along undercut banks, and in shaded pools, but rarely at sites lacking rapid-flow runs or pools. The white sucker was its most common associate, and it was collected with longnose dace in riffles and with creek chub and carp in pools. This species was one of 11 commonly collected in the Platte Basin. Their well-being is due, in large measure, to wide environmental tolerances. Despite their survival in a highly variable system and tolerance to numerous stresses, the common species have been measurably effected by habitat degradation and/or pollutants. Community diversity and species populations are low in stressed reaches, and diseased specimens are common. **Scott and Crossman 1973.** The longnose sucker is the most successful and widespread cypriniform in the north, occurring almost everywhere in clear, cold water in moderately large numbers. It occurs in the south more sporadically, in more restricted environments (the deeper areas only of lakes), and in fewer numbers. Generally it is restricted to freshwater lake bottoms or tributary streams.
Habitat (Cont'd)	**Brown 1971.** Most abundant in clear, cold streams and lakes, but some in drainages with moderately warm temperatures and high turbidities. Eats algae, midge larvae, and most other aquatic inverts. Lots of unidentified debris in stomachs. Avid for angleworms. **Smith & Hubert 1989** found longnose sucker and white sucker were residents in Crazy Woman Cr., a tributary of the Powder R., but not the Powder R. The Powder R. is a meandering, highly braided stream with an unstable sand and silt bottom. The water is naturally turbid. Crazy Woman Cr. is less turbid, and has a confined stable channel.

Species	Longnose sucker *Catostomus catostomus*
Egg/Larval Characteristics . Drift . Gravel . Backwaters . Nest	**Edwards 1983**. On the HSI models, Edwards says embryo component is the most important component of the model. Eggs settle to bottom in gravel near the tail of the riffle (**Walton 1980**). Fry remain in gravel 1 to 2 weeks. After emerging from gravel, they drift downstream primarily at night (**Walton 1980**). Fry seek food and shelter in shallow, quiet water with vegetation. Fry congregate in the top 150 mm of water and within 2 m of shore. Fry assumed to tolerate temperature fluctuations common to shallower water. Reservoir drawdowns in June and July (before fry begin to move to deeper water) may cause fry mortality. **Edwards 1983** (summarizing literature): juveniles live in lentic waters and frequent shallow, weedy areas. Remain in subsurface areas and have not been observed feeding on the bottom. Juveniles seek out areas with some current and may enter the lower reaches of streams to live, yet they will only move into the upper reaches as adults to spawn **(Walton 1980).** **Edwards 1983**. For HSI models, she says "Because longnose suckers that live in a lacustrine habitat enter riverine habitat only to spawn or overwinter..." Would YSR fish be migrating down to Lake Sakakawea on the Missouri?? Do we have year round populations of longnose suckers? **Walton 1980.** Spawning movements begin at 5 to 9 ^{0}C. Spawning itself occurs about 10 to 15 ^{0}C. Movement is influenced by fluctuations in discharge. **Barton 1980** found that both water temperatures and discharge play a role in initiation of spawning migration, depending on which condition is limiting in the spring. **Scott and Crossman 1973.** Spawning takes place in stream water 6 to 11 inches deep with a current velocity from 30 to 45 cm/s and a bottom of gravel 50 to 100 mm in diameter. Spawning fish move from quiet water near shore to the stream center. No nest is built, the adhesive demersal eggs are laid in small numbers, and they adhere to the gravel and substrate. After spawning, the adults return to their previous stream positions. **Geen et al. 1966** found that white sucker and longnose sucker larvae moved downstream almost exclusively between dusk and dawn. They confirmed light intensity was a factor by placing artificial illumination on river.

Species	Longnose sucker *Catostomus catostomus*
Migratory Characteristics . None at all . Spawning . Rearing/drifting larvae . Pioneering abilities/colonizing new habitat	**Edwards 1983.** Spawning occurs usually in tributary streams of large water bodies. Spawning migrations begin from mid-April to early July as ice breaks up in the spring. Peaks in June. **Barton 1980**. Longnose sucker began migrating upstream from Paine Lake, Alberta, first of June continuing for 43 days, while white sucker began earlier in late May, continuing for 51 days. Found correlation between temperature and discharge. **Geen et al. 1966** found no such correlation. They concluded that water temperature was most important. **Barton 1980.** Major peak of downstream white sucker movement was in early July, while longnose sucker returned later from mid-June through early July. Barton felt this was correlated with stream discharge alone. **Walton 1979** found discharge most important trigger. **Scott and Crossman 1973.** Longnose sucker spawn in the spring, in streams where available, but otherwise in shallow areas of lakes. They enter spawning streams as soon as stream temperatures exceed 45 ^{0}F usually in mid-April to mid-May. The spawning run begins and reaches a peak several days before the run of white sucker in the same stream. Longnose sucker move upstream between noon and midnight with the greatest number moving in the evening. **Scott and Crossman 1973**. As early as 5 days after the spawning migration begins, some adults are leaving the spawning streams. Eggs hatch in about 2 weeks at the prevalent stream temperatures. Young remain in the gravel 1 to 2 weeks before emerging and in June, or about 1 month after spawners first appear, fry are moving down to the lake. **Brown 1971.** Spawning fish usually move upstream or from lakes into tributaries and seek out loose gravel beds in riffle areas. Eggs hatch in 10 to 20 days and young soon find their way into quiet waters where they remain for first summer.
Period of peak activity . Nocturnal . Diurnal	

Species	Longnose sucker *Catostomus catostomus*
Size of Territory (how much do they move around) . Permanent . Seasonal	
Location in River . Midchannel . Edges	
Location in Water Column . Surface . Midcolumn . Substrate	**Edwards 1983**. Longnose sucker tend to be more pelagic feeders than other suckers.
Swimming Performance . Actual measurements . Lifestyle (performance implied by lifestyle) - cruiser - lie in wait predator - scavenger	
Ability to Surmount Passage Barriers . Velocity barriers . Physical obstructions	
Susceptibility to Entrainment . Presence in entrainment study catches	

Species	Longnose sucker *Catostomus catostomus*
Fish Passage Studies . Presence in passage studies	
Physical Structure related to Entrainment/Passage	
Areas literature says don't know anything/much about	**Brown 1971.** Fishermen think it competes or damages game fish populations, but true ecological relationship of suckers and game fishes is poorly understood.
Areas literature says well known/studied	**Scott and Crossman 1973.** The biology of this species in Canada is not so well documented as that of the white sucker, but more information is available than for many other species.

Species	Mountain sucker *Catostomus platyrhynchus*
Habitat Use . Adult . Spawning . Rearing	**Campbell 1992**. Sympatric with and hybridizes with longnose sucker and white sucker —identification is often difficult. Mountain sucker are adapted to cool water, moderate to rapid currents, and rocky substrates. Mountains are barriers leading to variability between populations. **Campbell 1992**. In Canada, found in small mountain streams <12 m wide and 1 m deep with moderate to swift current over mud, sand, gravel, and boulders, but usually rubble. Have been found in Yellowstone R. in Wyoming. **Campbell 1992**. It appears that mountain sucker are adapted for cool mountain streams and that warm turbid water may limit their distribution; **Brown 1971** does have records in lower Yellowstone R. Check for presence of this species in catches of Montana Fish, Wildlife and Parks. **Decker 1989**. Most important microhabitat factor in Sagehen Cr., California, is cover (root masses, undercut banks, log jams, large boulders). Mountain sucker most often are found in pool-run edges, pools, and runs. **Brown 1971**. Habitat usually clear, cold streams with clean rubble gravel or sand bottoms. Found in a wide range of turbidities. Young prefer the slower side channels or weedy backwaters. **Brown 1971**. Diatoms most abundant food item in stomach, but other algae and higher aquatic plants also present along with a few small aquatic insects, rotifers, and crustaceans. **Hauser 1969**. Mountain sucker that range in size from 20 to 35 mm long are usually found in areas with moderate currents at 15 to 40 cm deep and usually behind an obstruction. Larger fish in this size group found at margins of runs but retreated into deeper water when disturbed—in a tributary of the Yellowstone R. In the Madison R. suckers 35 to 130 mm captured in small intermittent side channels with abundant aquatic vegetation. Fingerlings collected in others area usually associated with deep pools.

Species	Mountain sucker *Catostomus platyrhynchus*
Habitat Use (cont'd)	**Hauser 1969**. Late winter/early spring mountain sucker larger than 130 mm usually found adjacent to pools with bank cover with velocities about 0.5 m/s and depths about 1 to 1.5 m. During spawning, fish are most abundant in riffle areas below pools. After spawning season, mountain sucker are usually in deep pools, using areas associated with bank cover. Often form small schools separate from other sucker spp. Food habits: diatoms, algae, higher plants, Diptera, and other animals.
Egg/Larval Characteristics . Drift . Gravel . Backwaters . Nest	**Campbell 1992**. Eggs are demersal and adhesive. No nest built, but scattered over the substrate. **Hauser 1969**. First fry seen in Flathead Cr. 6/21 and 7/18 in Gallatin R. Spawning season probably June and July. Mountain sucker mature at a younger age, and spawn later in the year than white sucker and longnose sucker.
Migratory Characteristics . None at all . Spawning . Rearing/drifting larvae . Pioneering abilities/colonizing new habitat	**Campbell 1992**. Little information on movements. **Hauser 1969** indicates that adults move from deeper pools in late winter and spring to areas adjacent to the pools in moderate current (0.5 m/s) at 1 to 1.5 m deep with rubble bottoms. Adults found in riffles below pools after spawning. **Decker 1989** in Sagehen Cr., California, found mountain sucker migrated into stream above Stampede Reservoir to spawn. After spawning, they presumably entered reservoir.
Period of peak activity . Nocturnal . Diurnal	**Decker 1989**. Mountain sucker are more active at night. Greatest feeding intensity.
Size of Territory (how much do they move around) . Permanent . Seasonal	

Species	Mountain sucker *Catostomus platyrhynchus*
Location in River . Surface . Substrate . Midchannel . Edges	
Location in Water Column . Surface . Midcolumn . Substrate	**Decker 1989**. Mountain sucker rested on the bottom of Sagehen Cr., California, near some type of cover during majority of daylight hours.
Swimming Performance . Actual measurements . Lifestyle (performance implied by lifestyle) - cruiser - lie in wait predator - scavenger	
Ability to Surmount Passage Barriers . Velocity barriers . Physical obstructions	
Susceptibility to Entrainment . Presence in entrainment study catches	
Fish Passage Studies . Presence in passage studies	
Physical Structure related to Entrainment/Passage	

Species	Mountain sucker *Catostomus platyrhynchus*
Areas literature says don't know anything/much about	**Campbell 1992**. Very little known of the biology of mountain sucker in Canada and elsewhere. Little known of movements and behavior. **Brown 1971**. Spawning process has not been described.
Areas literature says well known/studied	
Threats, Causes of Decline	**Decker 1989**. Stampede Reservoir on Sagehen Cr. inundated habitat. Mountain sucker populations have declined.

Species	Paddlefish *Polyodon spathula*
Habitat Use . Adult . Spawning . Rearing	**Ryckman 1995.** Discussion of three paddlefish snagging sites around confluence of Missouri/Yellowstone R. Fish typically migrate between feeding areas in Lake Sakakawea and spawning areas in the Yellowstone R. and Missouri R. below Fort Peck Reservoir. Most successful spawning takes place in the Yellowstone R. in Montana upstream of the confluence. **Boone and Timmons 1995** discuss importance of bayous, backwaters, oxbows, and subimpoundments for paddlefish feeding and nursery areas—provide zooplankton sources for food. **ODWC 1994.** Paddlefish vulnerable to overharvest because of their schooling tendencies, predictable spawning runs, and winter distribution. **Pitman and Parks 1994.** Paddlefish occupied deeper water when in river or tailwater habitat. Congregate in deep pools during winter when temperatures about 10 ^{0}C, move upstream to spawning habitat as waters warm to 10 to 17^{0}C. **Moen et al. 1992**. Habitat use in Mississippi R. in Iowa: 39 percent tailwaters, 34 percent main channel borders with wing dams, 16 percent main channel borders without borders. **Payne et al. 1990.** In Mississippi R. paddlefish prefer relatively quiet water except during spawning which occurs during spring rises on gravel exposed to flowing water. (**Russell 1986**). Eggs adhere to gravel and other debris. On hatching, larvae immediately entrained in current or swim up into turbulent river currents in which they must survive until they are carried to more quiet water optimal for growth. **Gardner 1990.** Electrofished for adult paddlefish. Only caught one paddlefish in three electrofishing runs of 17 miles each above Intake. In one 20-mile run below Intake caught 20 paddlefish, June 1989. **Crance 1987**. Sufficient water velocities are needed to keep silt from gravel substrate, to move the newly hatched larvae from their hatching site to nursery habitat. Need low nursery velocities so larvae may feed without expending excessive energy.

Species	Paddlefish *Polyodon spathula*
Habitat (cont'd)	**Crance 1987.** Delphi panel came up with SI curves for velocity, depth, substrate, cover, and temperature. Refer to text for details. **Southall and Hubert 1984.** Paddlefish shift to backwater areas post spawning in late spring and into summer - rich in food. Backwaters have more than 3 times the amount of food as main channel. Few fish seen in backwaters (2 percent) or side channels (<1 percent). Paddlefish found in depths/ velocities predicted by HSI curves for optimal conditions. Large paddlefish often found in turbulent currents in tailwaters. **Needham 1983**. In 1962 a large run of paddlefish occurred in the Yellowstone R. which created significant snagging activity. Popular fishing sites now exist at Intake Dam on the Yellowstone R., Missouri R. above Fort Peck Reservoir, and the dredge cut complex below Fort Peck Dam. **Rosen et al. 1982** observed paddlefish using areas of reduced current below sandbars in the Missouri R.— may be able to feed in a refuge from strong currents and to escape into main-channel current. **Rosen et al. 1982.** Paddlefish occupied definite summer and winter habitats in unchannelized river below Gavins Point. Late spring through early fall, most paddlefish are just downstream from submerged sandbars that caused a reduction in velocity (0-0.3 m/s). Velocity in channels adjacent 0.7 to 1.3 m/s). Occasionally found in backwater areas. During late fall through winter, paddlefish occupied deeper habitat >3m. **Berg 1981** documented spawning habitat characteristics in the Missouri R. above Fort Peck— sites contained extensive silt-free gravel bars of a type described by **Purkett 1961**. Berg identified nine critical spawning and staging sites in this part of the river, recommending protection.

Species	Paddlefish *Polyodon spathula*
Habitat (cont'd)	**Carlson and Bonislawsky 1981**. Dams block migratory routes and destroy spawning grounds, but some dams also create many hectares of plankton-rich waters. Paddlefish grow rapidly in such reservoirs and develop sustained populations as long as good spawning areas are maintained. **Rosen and Hales 1981**. Good discussion of feeding ecology. In their study in Missouri R. in South Dakota/Nebraska, found paddlefish were indiscriminant filter feeders. Ingested same ratio of zooplankton species as were in water column. Also discussed ability to selectively feed when insects are in water column drift. Paddlefish YOY are selective feeders, aiming for largest zooplankton present. **Carlson and Bonislawsky 1981**. Three harvest areas in Montana: Yellowstone River, and Fort Peck dredge cuts below the dam and on Missouri R. above reservoir. **Elser (1976)** summarized trends in the Yellowstone R. fishery and documented the development of this population in and above Lake Sakakawea in North Dakota. The population in the Yellowstone and Missouri Rivers not adversely affected by Lake Sakakawea because it created a plankton-rich environment without eliminating spawning areas. **Pflieger 1975.** Habitat requirements are very exacting. During most of its life, it inhabits quiet or slow-flowing waters rich in zooplankton. When spawning, must have access to large, free-flowing river with gravel bars subject to sustained inundation during spring floods. **Brown 1971.** Large numbers observed at Intake on Yellowstone R. and more recently at mouth of Tongue R. **Brown 1971**. It is a detritus and plankton feeder, but may also eat aquatic insects and fish. Swims through water with mouth open, straining out aquatic organisms by gill raker system.

Species	Paddlefish *Polyodon spathula*
Egg/Larval Characteristics . Drift . Gravel . Backwaters . Nest	**Lyons 1993.** Paddlefish reproductive success tends to be highest in years when riverflows are at or near flood levels during and for at least a week after spawning. Specific flows required to provide good spawning conditions at a site depend on the morphometry of the river channel. Paddlefish normally spawn on submerged gravel bars with water velocities >0.4 m/s and depths >2 m. **Booker et al. 1993.** Paddlefish require precise timing of events for successful reproduction. They spawn over gravel substrate in the flowing waters of large rivers. The three most important factors controlling spawning are photoperiod, water temperature, and waterflow. Photoperiod and water temperature (10 to 16 ^{0}C) control the timing of spawning, but an increase in waterflow is triggering stimulus. **Wallus 1986** summarizes collection methods and locations for paddlefish larvae and eggs. Only obliquely towed net and epibenthic sled (designed specifically to collect paddlefish eggs) were successful in collecting eggs. All seven net methods were successful in collecting larvae. Wallus was unsuccessful in locating eggs on Tennessee R., but larvae were present.(i.e., finding spawning areas can be difficult). Behavior and distribution of newly hatched larvae suggest that paddlefish larvae are displaced downstream at a rate similar to that of the water itself. There is evidence that larvae drift downstream in groups. Strong evidence in Tennessee and Cumberland Rivers that paddlefish reproduction is not only affected by temperature, but by waterflows. Highest number of eggs and larvae collected at largest number of sites only with high water (8 of 18 sites). In dry year, only captured from 2 of 10, and 3 of 16 collection sites. **Berg 1981** sampled two paddlefish prolarvae in the Missouri R. In 1978, one at Coal Banks Landing and one at Little Sandy Cr., confirming that paddlefish spawn successfully in the Missouri R. at least as far upstream as Coal Banks Landing. Spawning occurred primarily in June and early July. **Brown 1971.** Spawning probably occurs from June to August. Eggs are demersal and adhesive. Deposited in swift water over gravel at depths to 20 feet. **Purkett 1961.** Paddlefish begin spring spawning movements only when water temperatures reach 10 ^{0}C.

Species	Paddlefish *Polyodon spathula*
Migratory Characteristics . None at all . Spawning . Rearing/drifting larvae . Pioneering abilities/colonizing new habitat	**Pitman and Parks 1994.** Paddlefish mobile and traveled the extent of the Neches and Angelina Rivers available to them (270.4 km). **ODWC 1994** in Neosho R.- Grand Lake paddlefish made several different spawning runs, or pulses: first in late February into March, then late March into early April. Third run 4/21 - 4/26/92. **Lyons 1993**. No evidence of migration below Prairie du Sac Dam in Wisconsin. **Gardner 1990** sampled larval paddlefish at only one station 2 miles upriver from the Confluence 6 sets at 2- to 9-day intervals beginning June 3 and ending June 29. Collected 13 larvae and 4 eggs. 2 larvae 6/7, 2 larvae 6/9, 4 larvae 6/20, and 5 larvae 6/29. 2 eggs 6/7, 1 egg 6/9, and 1 egg 6/1. Discontinued 6/29 but may have been in river longer. Adults were widely distributed in river—no concentration areas. Recommended discontinuing electrofishing. **Dillard et al. 1986.** Population stable and/or recovering most places. Another important breakthrough was preservation and protection of spawning habitat in the Upper Missouri and Yellowstone Rivers—habitat protected specifically for the paddlefish.

Species	Paddlefish *Polyodon spathula*
Migration (cont'd)	**Southall 1984.** Paddlefish in Mississippi R. in Iowa travel extensively within and between navigation pools. It is most mobile in spring when they exhibit upstream movement patterns. Navigation dams are upstream movement barriers if not fully open during spring high water period. Upstream movements led to congregations of fish below dams and extensive use of tailwater habitats during the spring. **Elser 1983.** As in 1981, the 1982 run was slow to develop. Spring was late and the flow pattern of the Yellowstone R. did not reach levels sufficient to encourage paddlefish migrations until mid-May. Traditionally, paddlefish show up at Intake around the first of May. From 1964-80, 4,955 paddlefish tagged at Intake (tagging stopped after 1980). Sixty-five of these tags recaptured elsewhere: 14 in Lake Sakakewea 200 miles downstream; 13 in North Dakota; 3 tagged fish recaptured at mouth of Tongue 114 miles upstream at Cartersville Diversion and in Dredge cuts below Fort Peck Dam. **Elser 1983**. Garrison Reservoir is source of fish caught in the Yellowstone. Change in water temperature and an increase in water level apparently triggers the paddlefish movement out of Garrison into the Missouri. Tag returns show a portion move up Missouri while others move up Yellowstone. Two paddlefish tagged in Van Hook Arm off Garrison Reservoir in 1966 were caught in 1971 and 1973. Fish tagged in Fort Peck Dredge Cuts recaptured at Intake. Elser concludes that paddlefish are not as selective as salmon in choosing spawning streams. **Elser 1983.** Tag returns confirm idea that paddlefish spawning does not occur every year. Highest percentage of tag returns occurred the same year as tagging; falling off the next year; and showing increases the second, fifth and eighth years. **Meyer 1960** concluded also that paddlefish spawn at irregular intervals of 4 to 7 years. Tag returns also confirm the importance of spring rise in triggering spawning movements. **Elser 1983.** River height not as important as length of peak flow. 1973 was a dry year, paddlefish fishery at mouth of the Tongue R. and at Forsyth had only a few fish. But good water in 1974 and fishery at these two areas was good. Elser concludes spring flow is extremely important to the spawning migration of paddlefish. **Rosen et al. 1982** suggested long-distance movements by paddlefish are characteristic of the species and not related solely to spawning. The slow/still waters in which their growth is best may be widely separated and often great distances from suitable spawning areas, which are characterized by gravel substrates in fast-flowing, deep-water streams.

Species	Paddlefish *Polyodon spathula*
Migration (cont'd)	**Berg 1981.** Paddlefish were found seasonally in the Missouri R. from Fort Peck Reservoir upstream to the confluence of the Marias R. They occurred primarily during April, May, and June when they migrated upstream from Fort Peck Reservoir into the Missouri R. to spawn. Most paddlefish return to Fort Peck Reservoir following high water in June. It is not known if any paddlefish reside in the Missouri R. throughout the year. Significant movements of paddlefish to the spawning sites did not occur until flow in the Missouri R. at the Virgelle gage station exceeds 396 m^3/s (14,000 ft^3/s). **Pflieger 1975.** Paddlefish are very mobile and probably do not have a definite home range. Movements of as much as 260 miles in 6 weeks have been recorded by **Robinson 1966.** **Rehwinkel 1975** in trying to find out why paddlefish prefer the Yellowstone R. vs the Missouri R. compared discharge, turbidity, and temperatures on the Yellowstone and the Missouri Rivers the week prior to the arrival of fish at Intake and found the Yellowstone to have the highest discharge, highest suspended load, and warmest water.
Period of peak activity . Nocturnal . Diurnal	**Rosen and Hales 1981.** Appeared to feed throughout 24-h period when food consumption high. Feeding ceased when Gavins Point Dam releases increased—high sand load in river, and during high summer temperatures and low winter temperatures.
Size of Territory (how much do they move around) . Permanent . Seasonal	**Rosen et al. 1982.** No evidence that paddlefish occupy a territory or home range. The ever-shifting bottom profile and constant buildup/breakdown of areas paddlefish preferred to inhabit seems to preclude the establishment of more than a short residence in any one area.
Location in River . Midchannel . Edges	**Pitman and Parks 1994.** Distance to shore in Neches R., Texas, related to season. Closest to shore spring and summer. Move farther from shore when seeking deep winter holes. **Wallus 1986.** Paddlefish larvae widely distributed horizontally between river banks in Tennessee. Larvae often concentrated near the surface. **Gardner 1990.** Comparison of surface vs bottom larval tows revealed that 11 of the 13 (85 percent of paddlefish larvae) were collected in the bottom nets. (contrasts with Wallus).

Species	**Paddlefish** ***Polyodon spathula***
Location in Water Column . Surface . Midcolumn . Substrate	**Rosen et al. 1982.** Floating gill nets usually about 3 m deep were most effective in capturing paddlefish. **Pflieger 1975.** Paddlefish is a fish of open water, swimming about continuously, apparently aimlessly, near the surface or in shallow areas. Frequently leaps clear of surface.
Swimming Performance . Actual measurements . Lifestyle (performance implied by lifestyle) - cruiser - lie in wait predator - scavenger	**Schmulbach et al.** 1982 experimentally determined the critical speed for paddlefish of 73 cm length is >78 cm/s. In comparing habitat preference and swimming performance compatibility, they found that 3 of the 17 species tested (paddlefish, shovelnose sturgeon, and blue suckers) are restricted to large rivers—the "Big River Assemblage" of **Pflieger 1975.** All are relatively good swimmers and have exacting environmental requirements which are evident from their distribution in Missouri R. habitats. The preferred habitat for both paddlefish and sturgeon was the pool where current velocities averaged 30 cm/s. This velocity was well below the sustained swimming speeds of both species: 58.5 and 57.8 cm/s, respectively. Judging from their swimming ability they could have successfully inhabited most Missouri R. habitats but because of other environmental limitations do not. In the unchannelized river, shovelnose sturgeon were common in the main channel and paddlefish in the backwaters. Neither species is found in large numbers in the channelized river.
Ability to Surmount Passage Barriers . Velocity barriers . Physical obstructions	**Pflieger 1975.** Barriers to further upstream movement by spawning migrants provide good areas for snagging—examples: a low dam at Osceola on Osage River is a barrier at most river sages.

Species	Paddlefish *Polyodon spathula*
Susceptibility to Entrainment . Presence in entrainment study catches	**Payne et al. 1990.** Entrainment velocities of 1.5, 3.1, and 4.2 m/s caused 6 percent, 22 percent, and 68 percent mortality. Lab results indicate high tolerance of paddlefish larvae to entrainment in swift water currents. In this case, entrainment simply meant entry into swift water. **Hoyt. 19__?.** First and second year paddlefish impinged on 1 cm^2 traveling screens in Shawnee plant intake canal. Also taken by ichthyoplankton nets set in intake basin of intake canal, Kentucky. **Pasch et al. 1980.** In Osage R., Tennessee, 4,382 paddlefish impinged in intake screens Gallatin Steam Electric Plant, 1974-75. About 9,258 were impinged 1975-76—nearly all impinged were YOY. No evidence such entrainment is reducing populations.
Fish Passage Studies . Presence in passage studies	
Physical Structure related to Entrainment/Passage	

Species	Paddlefish *Polyodon spathula*
Areas literature says don't know anything/much about	**Pitman Parks 1994.** Little known about habitat use of young paddlefish. **ODWC 1994.** Need to identify and protect spawning sites and their various requirements. Need to determine spawning locations and success under various flows and velocities. Movements of paddlefish to various spawning areas, at different flows, need to be understood. Suggests a telemetry study of adults. The suitability of various velocities for larval and age 0 paddlefish remains unknown. The movement of larval paddlefish away from the spawning sites and subsequent dispersal into nursery areas are critical needs. **Lyons 1993.** Need to know more about distribution and abundance of small <5-kg paddlefish. Also need to know if electroshocking is biased against small paddlefish. Effect of flow changes unknown. Effect of snagging injuries unknown. **Booker et al. 1993.** Recovery and management hampered by lack of sufficient information on stock size, movements and distribution, population genetics, harvest and contaminant effects, essential habitat requirements, water quality requirements, and short- and long-term effects of other human impacts. **Jennings and Wilson 1993.** Spawning areas for most paddlefish populations remain unknown. **Crance 1987.** Lack of microhabitat SI because of various constraints—used Delphi to try to estimate. Delphi SI curves need to be verified by data collection especially for spawning habitat, suitability of various velocities for larval and YOY paddlefish, nursery habitat requirements of larvae, and dispersal of newly hatched larvae. **Elser 1983** indicates a paddlefish fishery at mouth of Tongue R. and at Forsyth (Cartersville Diversion); need information on spawning—does it occur at these sites? Can we expect eggs/larvae in drift and hence be at risk of entrainment into irrigation canals? **Rosen et al. 1982.** Much of life history remains a mystery because of difficulty of working in the immense riverine areas inhabited by paddlefish. **Brown 1971.** Specific habitat requirement not known. Spawning has not been described. Small paddlefish rarely witnessed because of turbidity and depth of the water.

Species	Paddlefish *Polyodon spathula*
Areas literature says well known/studied	**Dillard et al 1986.** There is a vast amount of information available about paddlefish. **Graham and Bonislawsky 1978.** Paddlefish studied extensively since 1800. Refer to bibliography for range of studies.

Species	Paddlefish *Polyodon spathula*
Threats/Causes of Decline/Status	**Mero and Willis 1994** documented sauger and walleye predation on paddlefish young in Lake Sakakawea—a result of changing habitat from large river to lake impoundments and stocking of piscivorous game fish. **Birstein 1993.** Sturgeons and paddlefishes are representatives of the Chondrostei, almost all species are endangered or threatened. **Booker et al. 1993.** Primary cause of population declines is loss of spawning and rearing habitat due to environmental alteration. Dam construction eliminated spawning sites, interrupted natural spawning migrations, altered waterflow and eliminated backwaters that were important as nursery and feeding areas. Overharvest also key problem. **Stewart 1987** Paddlefish populations have prospered in Montana. Fishes of Fort Peck Lake and Lake Sakakawea had access to "extensive, intact spawning areas" in upper reaches of the free-flowing Missouri R. and its tributaries such as the Yellowstone R. **Stewart 1987** age structure of the Sakakawea population indicated a mature, healthy population; 7 percent <10 years of age; 42 percent age 20 or older. **Berg 1981.** Paddlefish are native to Montana and are found in both the Yellowstone and Missouri River drainages. Significant numbers of paddlefish are found seasonally. Paddlefish were formerly abundant throughout much of the Mississippi and Missouri River systems but has declined drastically since 1900 (**Pflieger 1975**). A combination of destructive influences, including overharvest and habitat loss in some areas, has contributed to this decline. Only six major, self-sustaining populations of paddlefish remain in the United States currently, including the population in the wild and scenic portion of the Missouri R. above Fort Peck Reservoir. **Pflieger 1975.** Under natural conditions, large free-flowing rivers of the Mississippi Valley, with numerous oxbows and backwaters for feeding and extensive gravel bars for spawning, provided ideal habitat. But stream channelization and drainage of bottom land lakes has eliminated much of the feeding habitat. Now the largest populations are in manmade impoundments that provide favorable feeding habitat. However to support a population, it must be fed by a river that meets the exacting spawning requirements.

Species	Pallid sturgeon *Scaphirhynchus platorynchus*
Habitat Use . Adult . Spawning . Rearing	**Bramblett 1996.** Habitat use by pallid sturgeon is poorly known. It appears that they require large, turbid, riverine habitat with a firm sandy or gravelly substrate (**Bailey and Cross 1954**), who also noted that pallid sturgeon were most closely associated in habitat and distribution with sicklefin chub, a species of large, turbid rivers. **Bramblett 1996.** Speculates that pallid spawning must be similar to shovelnose sturgeon because hybridization has been documented. **Bramblett 1996.** Pallid sturgeon were most often relocated in the lower Missouri R. and the lower 28 km of the Yellowstone, though they were rarely located as far upstream as the Intake Diversion Dam (river km 114.4). Pallid sturgeon were not located above Intake Dam, which may be a partial barrier to upstream movement. **Bramblett 1996.** Pallid sturgeon preferred moderately diverse macrohabitat, sandy substrates, and used greater depths and reaches with greater channel widths than shovelnose sturgeon. Shovelnose sturgeons used a wider variety of macrohabitats, gravel and cobble substrates, and lesser depths than pallid sturgeon. **Bramblett 1996.** Adults in spawning condition were observed at the Missouri/Yellowstone River confluence in late May and early June. **Liebelt 1996** found the following habitat measurements for pallid sturgeon capture sites: minimum and maximum depths averaged 1.7 to 4.1 m and ranged from 0.9 to 6.7 m in 1994; and averaged 2.4 to 5.4 m and ranged 1.5 to 6.7 m in 1995. Current velocities averaged 0.74 m/s and ranged from 0.65 to 0.90 m/s in 1994, and averaged 0.66 m/s and ranged from 0.59 to 0.94 m/s in 1995. All pallid sturgeon captured were associated with sandy substrate. **Krentz 1995** estimated 250 pallid sturgeon inhabit the Missouri R. from Fort Peck Dam to the headwaters of Lake Sakakawea and the Yellowstone R. below Intake Dam **Carlson et al. 1985.** Research in Missouri captured both pallid and shovelnose in gear-sets along sandbars on the inside of riverbends, and in deeply scoured pools behind wing dams, indicating habitat overlap. However pallids were more often caught in swifter currents.

Species	Pallid sturgeon *Scaphirhynchus platorynchus*
Habitat (cont'd)	**Carlson et al. 1985**. Both *S. platorynchus* and *S. albus* were found in main channels of the river, along sandbars at the inside river bends and behind wing dikes with deeply scoured trenches. Tended to catch *S. albus* in swifter water where *S. platyorynchus* was less numerous. **Carlson et al. 1985.** Aquatic invertebrates made up most of diet of both sturgeon species, with a greater proportion of fish in the diet of *S. albus*. Sand composed 24.6 percent of stomach contents of all individuals sampled. **Pflieger and Grace 1985**. Under presettlement conditions, the Missouri R. supported a relatively limited fauna comprised of species adapted for life in an environment characterized by persistent high turbidity, wide seasonal fluctuations in flow and temperature, and an unstable sand-silt substrate. The more distinctive species in this fauna were pallid sturgeon, western silvery minnow, plains minnow, flathead chub, sturgeon chub and sicklefin chub. The pallid sturgeon and flathead chub have declined markedly in abundance from 1940 to 1983 due to increased competition, and reduced habitat diversity. Sicklefin chub and sturgeon have fared better. These species have increased in abundance in the middle and lower sections of the Missouri R. in Missouri. Habitat for them (open channels with swift current and firm substrate) has actually been increased by channelization. This habitat is sparsely inhabited by most other fishes, reducing potential competitors and predators. Their close association with the substrate may result in their being less vulnerable to predation than the midwater flathead chub. The two common species of minnows (western silvery and plains) declined in relative abundance over the period of record. These species typically occur in silty backwaters. These habitats became less prevalent as the river was channelized and its sediment load was reduced. **Pennington et al. 1983** in comparing fish species composition of revetted vs natural banks on the Mississippi R. found that pallid sturgeon, common carp, channel catfish, sauger, and blue suckers were more abundant on revetted banks; and freshwater drum, flathead catfish, bluegill, and skipjack herring were more abundant on natural banks.

Species	**Pallid sturgeon** ***Scaphirhynchus platorynchus***
Habitat (cont'd)	**Cross and Collins 1975.** Pallid sturgeon are restricted to large, muddy rivers with swift current. **Cross and Collins 1975.** Both shovelnose sturgeon and pallid sturgeon are characterized by small eyes, a tough leathery skin and dorsoventrally flattened body, and sensitive barbels which are adaptations to life in large, swift, and turbid rivers.
Egg/Larval Characteristics . Drift . Gravel . Backwaters . Nest	**Liebelt 1996** captured 11 *Scaphirhyncus* larvae in the Missouri R. just below the confluence with the Yellowstone R. indicating possible downstream drift from the Yellowstone R. after hatching. The highest number of larvae were captured during the July 11-13, 1995, sampling period. **Gilbraith et al. 1988.** Adhesive eggs are released in deep channels or rapids and are left unattended. The larvae are pelagic, becoming buoyant or active immediately after hatching (**Moyle and Cech 1982**).
Migratory Characteristics . None at all . Spawning . Rearing/drifting larvae . Pioneering abilities/colonizing new habitat	**Bramblett 1996**. Pallid sturgeon showed a pronounced seasonal shift in locations from the lower 28 km of the Yellowstone R. in spring and summer to the 28 km of the lower Missouri R. below the confluence in fall and winter. Pallids were found grouped in winter, indicating they may have specific wintering areas. **Bramblett 1996**. Movement patterns varied between pallid sturgeon and shovelnose sturgeon. Most pallid sturgeon were located farther upstream in the Yellowstone R. with increasing discharge, but the majority of shovelnose sturgeon were located farther downstream with increasing discharge. **Liebelt 1996** captured and tagged 21 pallid sturgeon in the Missouri R. and 2 in the lower Yellowstone R. Ten were recaptured. An individual tagged in the tailwater of Fort Peck Reservoir was recaptured 312.2 km (194 miles) downstream, exhibiting the greatest movement downstream of all sampled. The other recaptures ranged from 2 to 13 miles from the original capture site. **Erickson 1992**. Pallid sturgeon movements and habitat use were studied in Lake Sharpe, South Dakota. Sturgeon were most often found at 4 to 6 m deep, bottom current velocities from 0 to 0.73 m/s and substrates ranging from mud to gravel and cobble. Pallid sturgeon movement was greater at night and was positively correlated with water temperatures and discharge. Larger fish moved more than smaller fish.

Species	Pallid sturgeon *Scaphirhynchus platorynchus*
Period of peak activity . Nocturnal . Diurnal	
Size of Territory (how much do they move around) . Permanent . Seasonal	
Location in River . Surface . Substrate . Midchannel . Edges	
Location in Water Column . Surface . Midcolumn . Substrate	**Carlson et al. 1985.** Sturgeons were caught on trotlines baited with worms, and fished on the bottom over sandbars. Trammel nets were weighted and set to fish near the bottom behind wing dikes or drifted near the bottom in the main channel.
Swimming Performance . Actual measurements . Lifestyle (performance implied by lifestyle) - cruiser - lie in wait predator - scavenger	
Ability to Surmount Passage Barriers . Velocity barriers . Physical obstructions	

Species	Pallid sturgeon *Scaphirhynchus platorynchus*
Susceptibility to Entrainment . Presence in entrainment study catches	
Fish Passage Studies . Presence in passage studies	
Physical Structure related to Entrainment/Passage	
Areas literature says don't know anything/much about	**Bramblett 1996.** Habitat use by pallid sturgeon is poorly known. Quantitative data on habitat use by pallid sturgeon are limited. (Bramblett's study greatly enhances knowledge of habitat use by both pallid and shovelnose sturgeon in the Missouri R. system). Little information on pallid sturgeon reproduction exists. There is no information on the locations or physical parameters of pallid sturgeon spawning habitat.
Areas literature says well known/studied	
Threats/Causes of Decline/Status	**Bramblett 1996** (summarizing literature): habitat modifications such as dams and channelization are thought to have impacted pallid and shovelnose sturgeon by blocking movements to spawning or feeding areas; destroying spawning areas; altering temperatures, turbidity, and flow regimes; and reducing food supply (**Keenlyne 1989**). These alterations have led to a loss of sediment loads and flood pulses thereby disrupting the processes of meandering, erosion, and accretion. This results in a loss of connection to the flood plain which reduces allocthonous carbon inputs, causing a decline in overall productivity (**Hesse 1987**; **Junk et al. 1989**). Also reduction in habitat diversity and quantity may effectively remove habitat-related reproductive isolating mechanisms, thus leading to hybridization between pallids and shovelnoses. **Carlson et al. 1985** fear that hybridization is a recent phenomenon that may threaten *S. albus*. May be a result of man-caused changes in the big-river environment.

Species	Plains minnow ***Hybognathus placitus***
Habitat Use . Adult . Spawning . Rearing	**Propst and Carlson 1986** found the plains minnow the rarest species in the Platte R. Drainage in Colorado. They were associated with sand-bottomed main channels. This species has been decimated in this drainage due to dewatering and pollution.
Egg/Larval Characteristics . Drift . Gravel . Backwaters . Nest	
Migratory Characteristics . None at all . Spawning . Rearing/drifting larvae . Pioneering abilities/colonizing new habitat	
Period of peak activity . Nocturnal . Diurnal	
Size of Territory (how much do they move around) . Permanent . Seasonal	
Location in River . Midchannel . Edges	

Species	Plains minnow *Hybognathus placitus*
Location in Water Column . Surface . Midcolumn . Substrate	
Swimming Performance . Actual measurements . Lifestyle (performance implied by lifestyle) - cruiser - lie in wait predator - scavenger	
Ability to Surmount Passage Barriers . Velocity barriers . Physical obstructions	
Susceptibility to Entrainment . Presence in entrainment study catches	
Fish Passage Studies . Presence in passage studies	
Physical Structure related to Entrainment/Passage	
Areas literature says don't know anything/much about	
Areas literature says well known/studied	

Species	Plains minnow *Hybognathus placitus*
Threats/Causes of Decline/Status	

Species	River carpsucker *Carpoides carpio*
Habitat Use . Adult . Spawning . Rearing	**Brown and Coon 1994** observed carpsucker and goldeye were found in greater densities in the Missouri R. than in the tributaries. Freshwater drum and common carp also were more abundant in the Missouri R. than in some tributaries. Goldeye and freshwater drum have pelagic eggs and hatched larvae, both of which often are more common in the main channel of large rivers than in backwaters and tributaries (**Holland 1986**). **Brown and Coon 1994** found that common carp, freshwater drum, buffalo, carpsucker, and goldeye were abundant in the deeper tributaries of the Missouri R. and were usually associated with higher turbidity and greater depth. Correspondingly, they found that densities of sunfish, crappie, and nearctic cyprinids were greater in clearer tributaries. **Plieger and Grace 1987** attributed the increased abundance of white crappie and emerald shiner in the Missouri R. over the past 40 years to reductions in turbidity in the main channel. **Hesse et al. 1982** found the dominant species behind wing dikes in the Missouri R. in Nebraska were gizzard shad, river carpsucker, and black and white crappie; while carp, shorthead redhorse, and freshwater drum dominated trail dike habitat. Both the gizzard shad and river carpsucker are reported to inhabit pools and backwater areas of rivers and large streams, which accounts for their abundance along the wing dikes. **Berg 1981** reported that river carpsucker along with 11 other species were the most widely distributed species in the middle Missouri R. **Haddix and Estes 1976** sampled four backwater habitats in the lower Yellowstone R. in 1974. They found carp (67), river carpsucker (62), and goldeye (34) were the most abundant (numbers in parentheses are the fish per run). Sauger was the next most abundant species (16/run). Shovelnose sturgeon and blue sucker were lacking in backwater collections.

Species	River carpsucker *Carpoides carpio*
Egg/Larval Characteristics . Drift . Gravel . Backwaters . Nest	**Beckett and Pennington 1986.** Three principal factors determine ichthyoplankton composition and distribution: larval phenology, habitat characteristics, and river stage. Progeny of early spawners such as goldeye, common carp, buffalo (*Ictiobus* sp.), and sauger dominated spring and early summer ichthyoplankton collections, while freshwater drum, carpsucker (primarily river carpsucker), and *Lepomis* sp. dominated the mid to late summer ichthyoplankton community.[3] The backwaters (*Lepomis* sp) differed markedly from main channel (drum and carpsucker). In general, backwater and slack-water habitats supported much higher ichthyoplankton densities than lotic areas. **Smith and Hubert 1989** found larval flathead chub and river carpsucker in the drift at the mouth of Crazy Woman Cr. Flathead chub was the most abundant spp. (41 percent) followed by river carpsucker (38 percent).

[3] I will only list fish species that are also found in the Yellowstone and upper Missouri Rivers. See citation for the full text of all the species found and discussed.

Species	River carpsucker *Carpoides carpio*
Migratory Characteristics . None at all . Spawning . Rearing/drifting larvae . Pioneering abilities/colonizing new habitat	**Smith and Hubert 1989** found that of 21 spp. collected in the Powder R., Wyoming, and its tributary, Crazy Woman Cr., only 5 showed seasonal spawning movements into Crazy Woman Cr.: goldeye, common carp, river carpsucker, shorthead redhorse, and channel catfish. Eggs and larvae of all five spp. were found in the drift at the mouth of the tributary indicating that they spawned in the tributary. Goldeye eggs appeared to drift downstream out of Crazy Woman Cr. before hatching. At least some common carp, river carpsucker, and channel catfish used the tributary creek as nursery habitat. **Hesse et al. 1982**. There were 610 river carpsucker tagged in the Missouri R. in Nebraska, and 13 tags were recovered. These limited data showed the mean upstream distance traveled was 31.4 km; mean downstream distance was 23.0 km. Two individuals traveled upstream while 11 traveled downstream. **Berg 1981** reported significant spawning runs of river carpsucker along with blue sucker, smallmouth and bigmouth buffalo, shorthead redhorse, longnose sucker, and goldeye in the lower Marias R. during the spring/summer migration period from 1976 through 1979. **Berg 1981** reported that migrant river carpsucker and smallmouth and bigmouth buffalo were conspicuously absent from electrofishing surveys conducted in the lower Teton R. These species usually spawn in the larger streams with backwater areas (**Brown 1971**), and therefore, it is unlikely they spawn in the lower Teton R. Significant spawning runs of these three species were found in the lower Marias R. The lower Marias is a substantially larger stream than the lower Teton R., and it contains more slow-moving and backwater areas.
Period of peak activity . Nocturnal . Diurnal	**Hergenrader et al. 1982** found densities of living freshwater drum and carpsucker (*Carpiodes* sp.) larvae were significantly greater at night in their ichthyoplankton sampling on the Missouri R. in Nebraska.

Species	River carpsucker *Carpoides carpio*
Size of Territory (how much do they move around) . Permanent . Seasonal	
Location in River . Midchannel . Edges	
Location in Water Column . Surface . Midcolumn . Substrate	
Swimming Performance . Actual measurements . Lifestyle (performance implied by lifestyle) - cruiser - lie in wait predator - scavenger	**Schmulbach et al. 1982** experimentally determined the critical velocity of 52.7 ± 21.6 cm/s for river carpsucker. River carpsucker possess modest swimming ability when compared to other native big river species. Among the species with modest swimming abilities, the river carpsucker commonly occurred in more habitats than any other species. The main channel border, spur dike, and revetment habitats would appear to be marginal habitat for this species since its critical speeds are less than the mean current velocities of those habitats. However, the river carpsucker is a good performer on a sustained speed basis so habitats that appear marginal for this species could be used for extended time periods despite having to maintain their position by swimming at a high percentage of their critical speed. **Hesse et al. 1982** found that most of the fish impinged on the traveling screens at two power stations on the Missouri R. in Nebraska were 0 to II age class fish. During the July to December sampling period, the average total lengths of impinged fish were less than 135 mm, indicating that most were YOY. **Morgan and Moore (1972)** reported that maximum maintainable swimming speed of freshwater fish is approximately 10 times their body length. Thus, YOY fish with their smaller body size would be expected to contribute to higher impingement rates during the period they are present in the river.

Species	River carpsucker *Carpoides carpio*
Ability to Surmount Passage Barriers . Velocity barriers . Physical obstructions	
Susceptibility to Entrainment . Presence in entrainment study catches	**Hesse et al. 1982** found that the most common fish impinged on traveling screens in the Missouri R. at the Cooper Nuclear Station in Nebraska included freshwater drum (18.8 percent), river carpsucker (9.3 percent), and gizzard shad (58.0 percent). At the Fort Calhoun Station, the most commonly impinged species included freshwater drum (29.5 percent), gizzard shad (21.1 percent), and channel catfish (9.0 percent).
Fish Passage Studies . Presence in passage studies	
Physical Structure related to Entrainment/Passage	
Areas literature says don't know anything/much about	
Areas literature says well known/studied	
Threats/Causes of Decline/Status	

Species	Sauger *Stizostedion canadense*
Habitat Use . Adult . Spawning . Rearing	**Mero and Willis 1994** found sauger and walleye preyed on paddlefish in Lake Sakakawea. **Crance 1987b**. Delphi method developed HSI curves (see text for curves). Velocities at spawning sites in the Missouri R. below Fort Randall Dam ranged from 54.2 to 143 cm/s; at three spawning sites in Pool 13 of the upper Mississippi R. ranged from 85.3 to 121.9 cm/s at the surface; 85.3 to 109.7 cm/s at 3.0 m depth and 42.2 to 88.4 cm/s near the bottom. In the lab, sauger eggs adhered to rock substrate when subjected to velocities up to 33.5 cm/s. Some velocity needed to aerate eggs. YOY sauger caught at sites with velocities 21.3 to 85.3 cm/s. **Crance 1987b**. Delphi panel agreed all life stages of sauger may use a wide range of depths. Agreed optimal depth is >1 m but no agreement on upper threshold. All felt that turbidity served as cover. **Crance 1987b**, summarizes literature: sauger spawn over substrate mostly of rubble, sand, fine gravel and rubble, pebble-cobble, and rock and cobble. **McBride and Tarter 1983.** Fish comprised the primary food of sauger. In the Ohio R., the dominant species was emerald shiner, followed by gizzard shad and freshwater drum (emerald shiners were the most abundant in the river). Young fish apparently fed on zooplankton, progressing to chironomid larvae to mayfly larvae. **Berg 1981.** Electrofishing surveys indicated that sauger was the most common game fish species in the Missouri R. above Fort Peck Reservoir. The greatest densities of sauger were found in the Missouri R. above the confluence of the Marias R. Tag return data indicated sauger moved extensively in the Missouri R. and tributaries, with movements ranging from 1 to 295 km upstream and from 1 to 246 km downstream. Tributary migrations (Marias, Teton, and Judith Rivers) involve smaller numbers of fish, and the migrations appear to be related only to spawning while the mainstem migration involves significantly more fish, and the migration appears to be related to both spawning and feeding.

Species	Sauger *Stizostedion canadense*
Habitat Use (cont'd)	**Haddix and Estes 1976** sampled four backwater habitats in the lower Yellowstone R. in 1974. They found carp (67), river carpsucker (62), and goldeye (34) were the most abundant. (Numbers in parentheses are the fish per run). Sauger was the next most abundant species (16/run). Shovelnose sturgeon and blue sucker were lacking in backwater collections. **Brown 1971.** Its usual habitat in Montana is the larger turbid rivers and their impoundments. **Scott and Crossman 1963**. Spawning takes place for about a 2-week period in the spring, usually the last week in May or first week in June. It uses the same shoals of gravel to rubble in large turbid lakes or turbid rivers as walleye. During April and May 1974 and 1975, ripe sauger and walleye were taken near the Cartersville diversion section on the Yellowstone R. in water 1 to 4 feet deep, with a sand or gravel substrate and moderate current of approximately 0.5 ft/s. Similar spawning substrate was found in Miles City section of the Yellowstone R. A large partially exposed gravel bar about 1/4 mile below Intake appeared to be suitable spawning substrate for sauger and walleye. Current velocities over the area ranged from 0.35 to 0.87 ft/s. Water depths ranged from 0.90 to 1.4 ft.

Species	Sauger *Stizostedion canadense*
Egg/Larval Characteristics . Drift . Gravel . Backwaters . Nest	**Beckett and Pennington 1986**. Three principal factors determine ichthyoplankton composition and distribution: larval phenology, habitat characteristics, and river stage. Progeny of early spawners such as goldeye, common carp, buffalo (*Ictiobus* sp.), and sauger dominated spring and early summer ichthyoplankton collections, while freshwater drum, carpsucker (primarily river carpsucker), and *Lepomis* sp.dominated the mid to late summer ichthyoplankton community. **Berg 1981** found only 2 larval sauger in the Missouri R. above Fort Peck Reservoir, and 11 larvae in the Marias R. Berg attributes the scarcity of sauger larvae to the time of sampling. Berg believed that the peak spawning occurred in late April and early May, with an estimated incubation period of 13 to 21 days. Most larvae would emerge by the end of May. Intensive larval sampling didn't begin until early June. Most larvae would have emerged prior to this time. **Scott and Crossman 1973**. Spawning begins at 39 ^{0}F (3.9 ^{0}C) and 43 ^{0}F (6.1 ^{0}C). Spawning occurs at night in 2 to 12 ft of water. Eggs are sticky when laid but after water hardening are semibuoyant and non-adhesive. Eggs fall to the bottom where they settle between gravel or boulders. Hatching occurs over a range of 25 to 29 days at temperature ranges from 40 to 55 ^{0}F. After hatching the young spend an additional 7 to 9 days on the bottom absorbing the yolk.

Species	Sauger *Stizostedion canadense*
Migratory Characteristics . None at all . Spawning . Rearing/drifting larvae . Pioneering abilities/colonizing new habitat	**Crance 1987b**. Newly hatched larvae probably are subject to transport by velocities >3.0 cm/s. **Hesse et al. 1982** recovered three sauger tagged in the Missouri R. in Nebraska. Mean distance traveled upstream was 223.7 km; mean distance traveled downstream was 28.2 km. Two of the fish traveled upstream, one traveled downstream. **Fitz and Holbrook 1978.** In Tennessee, saugers (unlike walleye) are seldom caught in vertical gill nets, apparently spawn over large distances of tributary rivers and do not appear to spawn in the reservoir proper. **Hackney and Holbrook 1978**. In Tennessee Valley, sauger congregate in the tailwaters of the next upstream dam beginning in late fall, remaining there through the spring. Fish are scattered throughout the reservoir the remainder of the year. Headwater characteristics may determine the distribution of sauger in Tennessee R. Valley impoundments. Those reservoirs with sauger fisheries all have large rivers flowing into them; in mainstream impoundments these rivers are actually the tailwaters of the dams immediately upstream. Observations there suggest that a large river habitat is required for reproduction and/or early survival. **Nelson 1978**. Catches of larvae in Missouri R. flowing into Lake Sakakawea demonstrate that walleye and sauger spawned primarily if not exclusively in these tributaries. Sauger are only known to spawn in tributary rivers or unaltered reaches of the Missouri R. **Scott and Crossman 1973.** Saugers usually move little in summer, but there are records of individuals moving as far as 100 miles in the Mississippi R.

Species	Sauger *Stizostedion canadense*
Migration (cont'd)	**Haddix and Estes 1976**. Of the 45 sauger tagged and recovered on the lower Yellowstone R., 33 were recaptured at the same location as tagging. Other tag recoveries, however, showed extensive movements. One fish tagged at Intake was recovered at Miles City 114 miles upstream; another tagged at Intake was recovered at the Powder R., 78 miles upstream; and yet another was tagged in Miles City and recovered 52 miles upstream at Forsyth. Eight individuals moved upstream, while three moved downstream. Such downstream movements ranged from Miles City to Intake (114 miles) to a movement from Forsyth to Miles City (52 miles). **Brown 1971.** Spawning occurs in April or May when water temperatures approach 50 ^{0}F. Spawning fish move into backwaters or the mouths of tributaries where depths are 5 feet or less. Eggs are deposited randomly over the bottom and are left without care.
Period of peak activity . Nocturnal . Diurnal	**Swensen 1976** documents increased night feeding by sauger on trout perch in a Minnesota Lake. Found that high light intensity associated with reduced cloud cover, reduced daily food consumption. **Scott and Crossman 1973.** In clearer waters, sauger are most active for short periods in the evening and early morning. In more turbid water, where light intensities are lower, the period of activity is longer. Saugers are sight predators and negatively phototrophic, the light-gathering effect of the *Tapetum lucidum* of the eyes is a definite advantage in their turbid habitat. In very turbid water saugers usually succeed over walleyes.
Size of Territory (how much do they move around) . Permanent . Seasonal	
Location in River . Midchannel . Edges	

Species	**Sauger** *Stizostedion canadense*
Location in Water Column . Surface . Midcolumn . Substrate	**Scott and Crossman 1973.** Although well adapted to turbidity, they do not do well unless temperature characteristics allow them to use the whole depth range.
Swimming Performance . Actual measurements . Lifestyle (performance implied by lifestyle) - cruiser - lie in wait predator - scavenger	**Schmulbach et al. 1982** experimentally determined critical velocity for sustained swimming speed for sauger to be 58.7 ± 21.22 cm/s. Sauger are endemic to the Missouri R. and are more numerous in both unchannelized and channelized river than the walleye. All habitats in the unchannelized river are used by sauger, particularly the tailwaters and confluence of tributary streams. The Cv of 58.7 cm/s for sauger appears too low to allow for their successful use of fast water Missouri R. habitats. **Schmulbach et al**. speculate their results do not reflect actual swimming ability of wild fish.
Ability to Surmount Passage Barriers . Velocity barriers . Physical obstructions	
Susceptibility to Entrainment . Presence in entrainment study catches	**Nelson 1978.** Number of irrigation intakes on the Missouri R. is expanding. These are commonly placed in shallow embayments which greatly increases the potential for entraining or impinging larval fishes, in particular sauger and walleye.
Fish Passage Studies . Presence in passage studies	
Physical Structure related to Entrainment/Passage	
Areas literature says don't know anything/much about	**Crance 1987b**. Available information on habitat suitability is meager and no HSI curves published. Habitats with detectable water velocities are probably used by all life stages of sauger, but preferred velocities unknown.
Areas literature says well known/studied	

Species	Sauger *Stizostedion canadense*
Threats/Causes of Decline/Status	**Nelson 1978.** Sauger were abundant in the Missouri R. prior to closure of Garrison Dam. The increased water clarity and lack of riverine conditions caused the sauger population to decline to a relatively low level.

Species	Shorthead redhorse *Moxostoma macrolepidotum*
Habitat Use . Adult . Spawning . Rearing	**Mongeau and Dumont 1991.** Found shorthead redhorse in Richelieu R., Quebec preferred lowland rivers of medium size characterized by abrupt banks and uniformly deep channels (4 to 7 m) flowing over a solid clay, sand, or gravel bottom. Most populated sections of river have rather slow currents, interspersed by sections of rapids suitable for spawning. **Smith and Hubert 1989** found stonecat along with flathead chub, shorthead redhorse, and longnose dace in both the Powder R. and its tributary, Crazy Woman Cr. The Powder R. is characterized as a meandering, highly braided stream with an unstable sand and silt bottom. The water is naturally turbid. Crazy Woman Cr. has a more confined channel that is stabilized by vegetated banks, and the water is less turbid. It has gravel riffles, pools, cut banks, and large woody debris throughout its entire length. **Sule and Skelly 1985.** In Illinois, preferred habitats were cobble areas in waters 1 to 2 m deep with velocities of 23 to 63 cm/s. **Sule and Skelly** concluded from food eaten that shorthead redhorse feed in riffles and riffle margins. **Pflieger 1975.** Most abundant in Missouri in moderately large rivers having a predominance of gravelly or rocky bottoms and a permanent strong flow. In large streams it frequents the swifter water near riffles; in small streams it is also found in pools without much current. It is very adaptable in its habitat requirements. Food consists of immature aquatic insects. **Brown 1971.** Native and common in Missouri and Yellowstone Rivers. Specific habitat is clear or turbid waters of larger rivers and creeks where temperatures are intermediate and the current is swift. It seems to prefer shallow waters where the bottoms are clean and rocky. Feeds on bottom organisms such as insect larvae, worms, and snails.

Species	Shorthead redhorse *Moxostoma macrolepidotum*
Egg/Larval Characteristics . Drift . Gravel . Backwaters . Nest	**Gale and Mohr 1978.** Of the 18 spp. of larva in the drift sampled on the Susquehanna R., found white sucker, common carp, and shorthead redhorse in large numbers. Nearly all larvae collected at night on the surface, peaking at 2400 h, very few during the day. Of those collected during day, most were near the bottom. Density of drifting larvae captured somewhat higher near either shore than in the channel. But greater volume in main channel thus probably more fish drifting there than along shore. Iron contaminants may have influenced diel patterns. **Sule and Skelly 1985.** Larvae found in drift peaked May 19. No description of location in water column or where in river. **Burr and Morris 19??**. Spawning occurred near edge of a sandbar on a shallow 15- to 21-cm-deep riffle in troughs and circular nests. Over 100 individuals present on spawning area.

Species	Shorthead redhorse *Moxostoma macrolepidotum*
Migratory Characteristics . None at all . Spawning . Rearing/drifting larvae . Pioneering abilities/colonizing new habitat	**Smith and Hubert 1989** found that of 21 spp. collected in the Powder R., Wyoming, and its tributary, Crazy Woman Cr., only 5 showed seasonal spawning movements into Crazy Woman Cr.: goldeye, common carp, river carpsucker, shorthead redhorse, and channel catfish. Eggs and larvae of all five spp. were found in the drift at the mouth of the tributary indicating that they spawned in the tributary. Goldeye eggs appeared to drift downstream out of Crazy Woman Cr. before hatching. At least some common carp, river carpsucker, and channel catfish used the tributary creek as nursery habitat. **Sule and Skelly 1985.** Shorthead redhorse began to gather in a tributary of the Kankakee R., Illinois, in early March and spawned in late April and early May. About 3,000 were present in a single raceway-riffle area. **Curry and Spacie 1979** found that shorthead redhorse entered the mouth of a tributary of the Wabash R. only during the spring spawning period. They were observed spawning 12.8 km up the tributary. They were absent from this tributary in the fall indicating they migrated back to the Wabash R. **Pflieger 1975.** Spawning schools observed on gravelly riffles during late April in Missouri. **Brown 1971.** Spawning seasons occurs in April and May, breeding fish move into smaller tributaries then. Presumably spawning occurs on rocky riffles.
Period of peak activity . Nocturnal . Diurnal	**Burr and Morris 19__?.** In contrast to conjecture that spawning may take place during evening or early morning, they found spawning activities peaked between 11 a.m. and 4 p.m.
Size of Territory (how much do they move around) . Permanent . Seasonal	**Burr and Morris 19??.** No territorial behavior or aggressive displays were observed.

Species	Shorthead redhorse *Moxostoma macrolepidotum*
Location in River . Midchannel . Edges	
Location in Water Column . Surface . Midcolumn . Substrate	
Swimming Performance . Actual measurements . Lifestyle (performance implied by lifestyle) - cruiser - lie in wait predator - scavenger	**Schmulbach et al. 1982** found that experimental critical velocity for sustained swimming performance for shorthead redhorse was 67.6 ± 25.2 cm/s. Shorthead redhorse were considered moderately good swimmers when compared to other native Missouri R. fish. This species had not preferred habitat. It occurred in many habitats with varied current velocities.
Ability to Surmount Passage Barriers . Velocity barriers . Physical obstructions	
Susceptibility to Entrainment . Presence in entrainment study catches	**Hesse et al. 1982** found the dominant species behind wing dikes in the Missouri R. in Nebraska were gizzard shad, river carpsucker, and black and white crappie; while carp, shorthead redhorse, and freshwater drum dominated trail dike habitat. Shorthead redhorse inhabit the swift currents of streams which accounts for its higher relative abundance along the trail dikes.
Fish Passage Studies . Presence in passage studies	
Physical Structure related to Entrainment/Passage	
Areas literature says don't know anything/much about	**Sule and Skelly 1985.** Although redhorses are common in many rivers, original, comprehensive life history studies are few.

Species	Shorthead redhorse *Moxostoma macrolepidotum*
Areas literature says well known/studied	
Threats/Causes of Decline/Status	**Sule and Skelly 1985** - Shorthead redhorse are sensitive to and easily killed by domestic and industrial pollutants.

Species	Shovelnose sturgeon *Scaphirhynchus platorynchus*
Habitat Use . Adult . Spawning . Rearing	**Bramblett 1996.** Pallid sturgeon preferred moderately diverse macrohabitat, sandy substrates, and used greater depths and reaches with greater channel widths than shovelnose sturgeon. Shovelnose sturgeon used a wider variety of macrohabitats, gravel and cobble substrates, and lesser depths than pallid sturgeon. **Bramblett 1996.** Pallid sturgeon showed statistically significant preference for sandy substrates, and individuals were less variable in substrate use than were shovelnose sturgeon. Sand dunes were significantly preferred over general sand substrates. Gravel and cobble substrates were significantly avoided. Shovelnose sturgeon, on the other hand, significantly preferred gravel and cobble substrates and avoided sand; however, individual use varied more than pallids. **Bramblett 1996** found substrate use in his study corresponds to the distribution of the pallid sturgeon and shovelnose sturgeon. Pallid sturgeon are found only in the Mississippi and Missouri Rivers, and their largest tributaries are where sand is predominant substrate. In a database of nation-wide pallid sturgeon captures maintained by the USFWS in Bismarck, 96 percent pallid sturgeon captures with substrate data were over substrates composed at least partially of sand or fines. However substrate use by small pallids ≤5 kg were over substrates larger than sand. In Montana, the Yellowstone and Missouri Rivers change from sand-dominated substrate in their lower reaches to gravel and cobble-dominated substrate in the upper reaches. The majority of pallid sturgeon captures are from the lower, sand-dominated reaches (**Krentz 1994, Tews 1994, Gardner 1995**).

Species	Shovelnose sturgeon *Scaphirhynchus platorynchus*
Habitat (cont'd)	In contrast to pallid sturgeon, shovelnose sturgeon occur in smaller rivers and farther upstream in large rivers such as the Missouri and Mississippi (**Christensen 1975**). In Montana, CPUE for shovelnose is generally higher in the gravel and cobble-dominated reaches than in the sand-dominated reaches of the Yellowstone and Missouri Rivers (**Tews 1994, Bakes et al. 1994**). **Bramblett 1996**. Mean maximum depth in channel cross-sections occupied by pallid and shovelnose were significantly different, with pallids in deeper channels. **Bramblett 1996.** Speculates that pallid spawning must be similar to shovelnose sturgeon because hybridization has been documented. **Hurley et al. 1987.** In spring, in high water with fast currents, shovelnose sturgeon occupied sheltered areas away from main channel. During summer, located most frequently in main channel habitats. Located in water depths between 1 and 10 m. Surface current velocities ranged from 10 to 130 cm/s. Bottom current velocities slower—ranging from 5 to 65 cm/s. Most often found over sand substrates, but regularly associated with high-profile rock substrates. **Carlson et al. 1985.** Both *S. platorynchus* and *S. albus* were found in main channels of the river, along sandbars at the inside river bends and behind wing dikes with deeply scoured trenches. Tended to catch *S. albus* in swifter water where *S. platyorynchus* was less numerous. **Carlson et al. 1985.** Aquatic invertebrates made up most of diet of both sturgeon species, with a greater proportion of fish in the diet of *S. albus*. Sand composed 24.6 percent of stomach contents of all individuals sampled.

Species	Shovelnose sturgeon *Scaphirhynchus platorynchus*
Habitat (cont'd)	**Carlson et al. 1985** caught 4,332 sturgeons in study on Missouri and Mississippi Rivers—only 11 were *S. albus*, 12 were hybrids, and rest were *S. platorynchus*. Unexpectedly caught these hybrids—determined from meristic comparisons. **Carlson et al. 1985**. Research in Missouri captured both pallid and shovelnose in gear-sets along sandbars on the inside of riverbends, and in deeply scoured pools behind wing dams, indicating habitat overlap. However, pallids were more often caught in swifter currents. **Moos 1978**. Goldeye, sauger, redhorse, channel catfish, and carpsucker were the species most frequently captured with shovelnose sturgeon. Only 1 pallid caught, but caught 4,800 shovelnose sturgeons. Channel cat and blue sucker were common associates of shovelnose sturgeon in mid-channel areas and pools adjacent to the channel, while carp, smallmouth and largemouth buffalo, shortnose gar, and gizzard shad were abundant in nets in backwater areas. **Moos 1978.** Gill and trammel nets set in pools behind sand bars and in relatively deep open-water areas adjacent to the main channel were by far the most productive of shovelnose sturgeon. Shovelnose sturgeon most abundant in pools 1.8 to 4.6 m deep. Catches decreased as water depth and velocity increased. **Moos 1978**. Unable to locate spawning grounds in unchannelized Missouri R. below Gavins Point. Concentrations of shovelnose sturgeon in spawning condition were consistently taken adjacent to the main channel. **Moos 1978; Helms 1974.** Shovelnose sturgeon spawn over rocky or gravely substrates in main channel habitats of the Mississippi and Missouri Rivers and their major tributaries. Shovelnose sturgeon spawned in early June to mid-July at temperatures of 17 to 21.5 ^{0}C in the Tongue R.

Species	**Shovelnose sturgeon** ***Scaphirhynchus platorynchus***
Habitat (cont'd)	**Modde and Schmulbach 1977**. During fall and spring in the unchannelized Missouri R., shovelnose sturgeon concentrate in moderately deep water behind sandbars, but disperse during the summer months when water levels and velocities are relatively high. **Haddix and Estes 1976** sampled four backwater habitats in the lower Yellowstone River in 1974. They found carp (67); river carpsucker (62) and goldeye (34) were the most abundant (numbers in parentheses are the fish per run). Sauger was the next most abundant species (16/run). Shovelnose sturgeon and blue sucker were lacking in backwater collections. **Cross and Collins 1975.** Both shovelnose sturgeon and pallid sturgeon are characterized by small eyes, a tough leathery skin and dorsoventrally flattened body, and sensitive barbels which are adaptations to life in large, swift and turbid rivers. **Cross and Collins 1975.** Pallid sturgeon are restricted to large, muddy rivers with swift current. **Brown 1971.** Abundant in mainstem Missouri R. below Great Falls and common in most of the larger primary and some secondary tributaries of this river. Seems to avoid smaller streams. Many collected in Marias R. above Tiber Reservoir. Specific habitat is near the bottom of large rivers over firm, sandy bottoms where current is strong.

Species	Shovelnose sturgeon *Scaphirhynchus platorynchus*
Habitat (cont'd)	**Pflieger and Grace 1985**. Under presettlement conditions, the Missouri R. supported a relatively limited fauna comprised of species adapted for life in an environment characterized by persistent high turbidity, wide seasonal fluctuations in flow and temperature, and an unstable sand-silt substrate. The more distinctive species in this fauna were pallid sturgeon, western silvery minnow, plains minnow, flathead chub, sturgeon chub, and sicklefin chub. The pallid sturgeon and flathead chub have declined markedly in abundance from 1940 to 1983 due to increased competition, and reduced habitat diversity. Sicklefin chub and sturgeon chub have fared better. These species have increased in abundance in the middle and lower sections of the Missouri R. in Missouri. Habitat for them (open channels with swift current and firm substrate) has actually been increased by channelization. This habitat is sparsely inhabited by most other fishes, reducing potential competitors and predators. Their close association with the substrate may result in their being less vulnerable to predation than the midwater flathead chub. The two common species of minnows (Western silvery and plains) declined in relative abundance over the period of record. These species typically occur in silty backwaters. These habitats became less prevalent as the river was channelized and its sediment load was reduced.
Egg/Larval Characteristics . Drift . Gravel . Backwaters . Nest	**Berg 1981** found only two shovelnose larvae in the Marias R., but none in the mainstem Missouri R. above Fort Peck Reservoir. Documented that shovelnose sturgeon spawning in the lower Marias R. occurred at water temperatures ranging from 15.0 to 22.8 ^{0}C, with peak spawning occurring at 16.1 to 20.6 ^{0}C. Optimum temperature for spawning in the lower Tongue R., Montana, was 17.2 to 21.7 ^{0}C (**Elser et al. 1977**). Other citations for optimum temperatures. **Brown 1971.** Eggs are adhesive. **Moos 1978**. Observed phenomenon of hermaphrodite shovelnose sturgeon in upper Missouri. Speculates on influence of environmental changes.

Species	Shovelnose sturgeon *Scaphirhynchus platorynchus*
Migratory Characteristics . None at all . Spawning . Rearing/drifting larvae . Pioneering abilities/colonizing new habitat	**Bramblett 1996.** Potential shovelnose spawning aggregations occurred in the Yellowstone R. from river km 111.0 to 114.3, the reach directly below the Intake Diversion Dam. Shovelnose sturgeon may use this area for spawning, but also may be concentrated in this area because the Intake Diversion Dam may be a partial barrier to upstream movements **(Stewart 1995).** Another potential spawning location for shovelnose sturgeon was from river km 24.9 to 25.6 on the Yellowstone R. **Bramblett 1996.** Both shovelnose sturgeon and pallid sturgeon were capable of rapid, long-range upstream and downstream movements. Pallid sturgeon moved up to 21 km/d; shovelnose moved up to 15 km/d. Most long-range movements occurred in spring and summer. Pallid sturgeon winter movement rates and ranges of activity were significantly smaller than all other seasonal ranges and movement rates. Shovelnose sturgeon were similar. **Bramblett 1996.** Pallid sturgeon showed a pronounced seasonal shift in locations from the lower 28 km of the Yellowstone in spring and summer to the 28 of the lower Missouri R. below the confluence in fall and winter. Pallids were found grouped in winter, indicating they may have specific wintering areas. **Bramblett 1996.** Movement patterns varied between pallid sturgeon and shovelnose sturgeon. Most pallid sturgeon were located farther upstream in the Yellowstone R. with increasing discharge, but the majority of shovelnose sturgeon was located farther downstream with increasing discharge. **Erickson 1992.** Pallid sturgeon movements and habitat use were studied in Lake Sharpe, South Dakota. Pallid sturgeon were most often found at 4- to 6-m-deep bottom current velocities from 0 to 0.73 m/s and substrates ranging from mud to gravel and cobble. Pallid sturgeon movement was greater at night and was positively correlated with water temperatures and discharge. Larger fish moved more than smaller fish.

Species	Shovelnose sturgeon *Scaphirhynchus platorynchus*
Migration (cont'd)	**Hurley et al. 1987.** Average distance traveled downstream 11.7 km; average distance upstream 10.8 km. No significant differences in direction. Average daily movement 339 +/- 33 m. During May and June, most movements occur between activity centers. During spawning season, longer distance movements made. Study confirms that though capable of rapid long-distance movements, shovelnose are generally sedentary. Long-range movements usually characterized by directed progressive movement over several days, shifting to new activity centers or a previously used activity center. Movement between a series of preferred activity centers may be a consistent pattern for shovelnose sturgeon. **Berg 1981** showed shovelnose sturgeon made significant seasonal spawning movements from the lower portion of the middle Missouri R. into the Coal Banks Landing and the Lama Ferry study sections. Distances moved ranged from 3 to 112 km upstream and from 2 to 169 km downstream. Other researchers reported such extensive movements. **Schmulbach (1974)** observed shovelnose sturgeon movements of up to 533.6 km downstream in the lower Missouri R. **Christensen (1975)** reported shovelnose sturgeon movements of up to 17 km upstream and 17 km downstream in the Red Cedar R., Wisconsin. **Helms (1974)** found the maximum distance moved in the upper Mississippi R., Iowa, was 193 km upstream. **Berg 1981** found that the lower Marias R. was important spawning area for shovelnose (importance of tributaries). **Moos 1978.** Shovelnose sturgeon exhibited random movements. The longer at large, the farther away from the original release site. A large-river ecosystem contains a less uniformly distributed fish population than a lake or small stream. Considerable movement might be expected between habitat types and along main axis of river. Some species would be sedentary, others semi-mobile, or mobile. Shovelnose sturgeon probably best characterized as mobile or might also contain both sedentary and mobile groups.

Species	Shovelnose sturgeon *Scaphirhynchus platorynchus*
Migration (cont'd)	**Moos 1978** observed phenomenon of grouped recaptures. Though that suggests schooling, no one has observed schooling in sturgeons. Could be that sturgeon traveling along the river move from pool to pool. Concludes that shovelnose exhibit random movement. Seasonal trends in activity were noted. No territoriality/home range was observed. **Moos 1978**. Shovelnose sturgeon apparently do not move into tributaries in large numbers. **Moos 1978.** Shovelnose sturgeon readily captured by gill nets during April through June and again during October through early December. Very few captured during August and September. Apparently decreasing catches related to increasing water temperatures. Increased movement during the spring spawning season resulted in high June catches. During late November/early December, with water temperature <4 ^{0}C, shovelnose sturgeon concentrated in pools behind sand bars, exhibiting little movement. **Peterman and Haddix 1975.** Sampling above and below Cartersville diversion indicates that the diversion represents the upstream limit of shovelnose distribution in the Yellowstone R. and may represent a barrier to upstream shovelnose sturgeon migration. Limited sampling indicates that shovelnose sturgeon apparently migrate from the Yellowstone into the Powder R. during the spawning season. **Schmulbach 1974,** on the other hand, found shovelnose sturgeon exhibit extensive seasonal movements in the Missouri R.
Period of peak activity . Nocturnal . Diurnal	**Bramblett 1996** observed most pallid sturgeon movements during the day, while shovelnose sturgeon moved at night, but much variability was observed. **Erickson 1992** found pallid sturgeon in the Missouri R., South Dakota, moved more at night; Bramblett speculates that relates to reduced turbidity. Pallid sturgeon may shift to nocturnal activity pattern in the absence of natural turbidity. **Modde and Schmulbach 1977.** Their experience indicated that sturgeon had crepuscular and nocturnal activity peaks.

Species	Shovelnose sturgeon *Scaphirhynchus platorynchus*
Size of Territory (how much do they move around) . Permanent . Seasonal	**Bramblett 1996**. Pallid and shovelnose sturgeon had home ranges of over 300 and 250 linear km of river, respectively, for the two species. **Moos 1978.** Many species which maintain a home range also have the capability to return to the home range if displaced. Moos found no evidence of homing after displacing 23 shovelnose sturgeon.
Location in River . Midchannel . Edges	
Location in Water Column . Surface . Midcolumn . Substrate	**Hurley et al. 1987.** Caught shovelnose sturgeon on bottom drifting trammel net. **Carlson et al. 1985.** Sturgeons caught on trotlines baited with worms and fished on the bottom over sandbars. Trammel nets were weighted and set to fish near the bottom behind wing dikes or drifted near the bottom in the main channel. **Moos 1978.** Opportunistic feeders using macroinverts found in the benthos and drift. Locate food with sensory organs on snout and barbels. Use rostrum to disturb the bottom when feeding. **Brown 1971.** Is a bottom feeder, foraging over substrata and sucking up detritus and any accompanying organisms with its distensible mouth. Fish may occasionally feed pelagically since some plankton such as Daphnia are also found in stomachs.

Species	Shovelnose sturgeon *Scaphirhynchus platorynchus*
Swimming Performance . Actual measurements . Lifestyle (performance implied by lifestyle) - cruiser - lie in wait predator - scavenger	**Schmulbach et al. 1982** determined the experimental critical velocities of shovelnose sturgeon averaged 77 $\pm$ 45 cm/s. The Cv was among the highest of any species used in the experiments. In comparing habitat preference and swimming performance compatibility they found that 3 of the 17 species tested (paddlefish, shovelnose sturgeon, and blue sucker) are restricted to large rivers—the "Big River Assemblage" of **Pflieger 1975.** All are relatively good swimmers and have exacting environmental requirements which is evident from their distribution in Missouri R. habitats. The preferred habitat for both paddlefish and sturgeon was the pool where current velocities averaged 30 cm/s. This velocity was well below the sustained swimming speeds of both species: 58.5 and 57.8 cm/s, respectively. Judging from their swimming ability they could have successfully inhabited most Missouri R. habitats but because of other environmental limitations do not. In the unchannelized river, shovelnose sturgeon were common in the main channel and paddlefish in the backwaters. Neither species is found in large numbers in the channelized river.
Ability to Surmount Passage Barriers . Velocity barriers . Physical obstructions	
Susceptibility to Entrainment . Presence in entrainment study catches	
Fish Passage Studies . Presence in passage studies	
Physical Structure related to Entrainment/Passage	

Species	Shovelnose sturgeon *Scaphirhynchus platorynchus*
Areas literature says don't know anything/much about	**Brown 1971.** Spawning habits unknown. No age and growth studies done in Montana.
Areas literature says well known/studied	**Hurley et al. 1987.** Habitats, movements and foods studied extensively in the unchannelized Missouri R.
Threats/Causes of Decline/Status	**Bramblett 1996**. (Summarizing literature) Habitat modifications such as dams and channelization are thought to have impacted pallid and shovelnose sturgeon by blocking movements to spawning or feeding areas; destroying spawning areas; altering temperatures, turbidity, and flow regimes; and reducing food supply (**Keenlyne 1989**). These alterations have led to a loss of sediment loads and flood pulses thereby disrupting the processes of meandering, erosion, and accretion. This results a loss of connection to the flood plain, which reduces allocthonous carbon inputs, causing a decline in overall productivity (**Hesse 1987; Junk et al. 1989**). Also reduction in habitat diversity and quantity may effectively remove habitat-related reproductive isolating mechanisms, thus leading to hybridization between pallids and shovelnoses. **Carlson et al. 1985** fear that hybridization is a recent phenomenon that may threaten *S. albus*. May be a result of man-caused changes in the big-river environment.

Species	**Sicklefin chub** *Macrhybopsis meeki*
Habitat Use . Adult . Spawning . Rearing	**Grisak 1996**. In sampling for sicklefin chub in the Missouri R. above Fort. Peck Reservoir, found benthic trawling yielded large numbers of sicklefin chub, and very few for seining. Overall sicklefin chub were sampled over sand 70 percent of the time. Mean depth at catch sites was 3.41 m. Found no sicklefin chub upstream of Section 1—which had very little sand. There is a progressive downstream increase in sand substrate and depth. Mean bottom velocity at all sites was 0.66 m/s. **Grisak 1996**. The near absence of sicklefin chub in his seine catches contrasted sharply with observations by **Gardner and Bert 1982** who reported seining 51 sicklefin chubs in the same area between Cow Is. (RM 122) and Turkey Joe (RM 170.5). Major difference between sample periods was peak flows. During the 1979 sample period, the water was much higher and water clarity may have been lower. If sicklefin chub are negatively phototactic, this would influence distribution as **Gould 1994** suggests is true for sicklefin chub. **Pflieger and Grace 1985**. Under presettlement conditions, the Missouri R. supported a relatively limited fauna comprised of species adapted for life in an environment characterized by persistent high turbidity, wide seasonal fluctuations in flow and temperature and an unstable sand-silt substrate. The more distinctive species in this fauna were pallid sturgeon, western silvery minnow, plains minnow, flathead chub, sturgeon chub, and sicklefin chub.

Species	Sicklefin chub *Macrhybopsis meeki*
Habitat (cont'd)	**Pflieger and Grace 1985** (cont'd). The pallid sturgeon and flathead chub have declined markedly in abundance from 1940 to 1983 due to increased competition and reduced habitat diversity. Sicklefin chub and sturgeon chub have fared better. These species have increased in abundance in the middle and lower sections of the Missouri R. in Missouri. Habitat for them (open channels with swift current and firm substrate) has actually been increased by channelization. This habitat is sparsely inhabited by most other fishes, reducing potential competitors and predators. Their close association with the substrate may result in their being less vulnerable to predation than the midwater flathead chub. The two common species of minnows (western silvery and plains) declined in relative abundance over the period of record. These species typically occur in silty backwaters. These habitats became less prevalent as the river was channelized and its sediment load was reduced. **Carter 1981** reports that two sicklefin chub were collected in the Mississippi R. over a sandy bottom in moderate current at depths of 0.5 to 1.5 m. **Brown 1971** does not include sicklefin chub—probably not discovered in Montana at that time.
Egg/Larval Characteristics . Drift . Gravel . Backwaters . Nest	
Migratory Characteristics . None at all . Spawning . Rearing/drifting larvae . Pioneering abilities/colonizing new habitat	

Species	Sicklefin chub *Macrhybopsis meeki*
Period of peak activity . Nocturnal . Diurnal	
Size of Territory (how much do they move around) . Permanent . Seasonal	
Location in River . Midchannel . Edges	
Location in Water Column . Surface . Midcolumn . Substrate	**Liebelt 1996** captured 40 sicklefin chub in the Yellowstone R. between Intake Dam and the confluence with the Missouri R. using a benthic trawl in 1995. This contrasts with only two captured using a beach seine in 1994 and none in 1995 in the same area. A total of 30 sicklefin chub were seined in the Missouri R. primarily from the section below the confluence of the Yellowstone R. Only one was caught by seining in 1995, probably due to the higher water levels than 1994.
Swimming Performance . Actual measurements . Lifestyle (performance implied by lifestyle) - cruiser - lie in wait predator - scavenger	
Ability to Surmount Passage Barriers . Velocity barriers . Physical obstructions	

Species	Sicklefin chub *Macrhybopsis meeki*
Susceptibility to Entrainment . Presence in entrainment study catches	
Fish Passage Studies . Presence in passage studies	
Physical Structure related to Entrainment/Passage	
Areas literature says don't know anything/much about	
Areas literature says well known/studied	
Threats/Causes of Decline/Status	

Species	Stonecat *Noturus flavus*
Habitat Use . Adult . Spawning . Rearing	**Smith and Hubert 1989** found stonecat along with flathead chub, shorthead redhorse, and longnose dace in both the Powder R. and its tributary, Crazy Woman Cr. The Powder R. is characterized as a meandering, highly braided stream with an unstable sand and silt bottom. The water is naturally turbid. Crazy Woman Cr. has a more confined channel that is stabilized by vegetated banks, and the water is less turbid. It has gravel riffles, pools, cut banks, and large woody debris throughout its entire length. **Walsh and Burr 1985.** Stonecat generally inhabit riffles of medium-size to large streams that usually have many large rocks; also present in lakes around limestone reefs and gravel shoals where currents and wave action produce stream-like conditions. Also lives in main channels of Missouri, Ohio, and Mississippi Rivers where individuals are found over sand in swift current. **Walsh and Burr 1985** give habitat characteristics of where larvae collected— a useful table (pg. 88). **Walsh and Burr 1985** food habits found adults ate a variety of benthic organisms, mostly aquatic larval insects and decapod crustaceans. **Pflieger 1975.** Stonecat occurs in varied stream types but avoids those with intermittent flow or extremely high gradients. Most often found on rocky riffles. Also found over sandy bottoms in areas with a swift current. **Scott and Crossman 1973.** The stonecat prefers riffles or rapids of moderate or large streams with bottoms of large, loose rocks. It is present in lakes near sand and gravel bars where there is wave action. It may move into quiet water to feed. In the United States, it is usually absent from streams of low gradient and disappears from streams which are impounded. **Johnson (1965)** found this species in streams near Toronto, Ontario, in numbers per acre ranging from 23 to 164, representing standing crops of 0.3-2.3 pounds per acre. **Carlson 1967.** Food in Vermillion R., South Dakota, included Ephemeroptera nymphs 92.3 percent, Colepoteran larvae 7.7 percent, Notropis sp. (shiners) 7.7 percent; rest were crane fly larvae, wasps, stoneflies, and crayfish.

Species	Stonecat *Noturus flavus*
Egg/Larval Characteristics . Drift . Gravel . Backwaters . Nest	**Smith and Hubert 1989** found larval stonecat in the drift at the mouth of a tributary to the Powder R., Crazy Woman Cr. Stonecat larvae were found during the June 29-July 12 sampling period and during the July 2-August 11 sampling period. **Brown 1971.** Spawn between June and August, peak in late June. Female deposits 200 to 1,200 eggs under stones or other submerged object where both males and females guard them. Hatch in 1 to 2 weeks and young are guarded until they can care for themselves.
Migratory Characteristics . None at all . Spawning . Rearing/drifting larvae . Pioneering abilities/colonizing new habitat	
Period of peak activity . Nocturnal . Diurnal	**Pflieger 1975.** Stonecat most active at night, hiding by day beneath large rocks or other cover. **Scott and Crossman 1973.** Much of its food is searched for along the bottom, probably by means of its sensitive barbels and probably at night. Its food is mostly immature aquatic insects, largely mayflies and secondarily, molluscs, minnows, crawfish, and plant material.
Size of Territory (how much do they move around) . Permanent . Seasonal	
Location in River . Midchannel . Edges	

Species	Stonecat *Noturus flavus*
Location in Water Column . Surface . Midcolumn . Substrate	
Swimming Performance . Actual measurements . Lifestyle (performance implied by lifestyle) - cruiser - lie in wait predator - scavenger	
Ability to Surmount Passage Barriers . Velocity barriers . Physical obstructions	
Susceptibility to Entrainment . Presence in entrainment study catches	
Fish Passage Studies . Presence in passage studies	
Physical Structure related to Entrainment/Passage	
Areas literature says don't know anything/much about	**Brown 1971.** No life history studies made of stonecat in Montana.
Areas literature says well known/studied	
Threats/Causes of Decline/Status	

Species	Sturgeon chub *Macrhybopsis gelida*
Habitat Use . Adult . Spawning . Rearing	**Werdon 1993.** Extant populations: Yellowstone R., Dawson County; Powder R., Custer and Powder River Counties. Extirpated populations in Montana: Tongue R., Custer County; Box Elder Cr., Carter and Fallon Counties; Powder R., Prairie, Custer, Powder River Counties. **Werdon 1993** summarizes collections on lower Yellowstone R.: **Reigh (1978)** collected sturgeon chub in 1976 at four locations on the lower Yellowstone R. **Elser et al. (1980)** made three collections of an unknown number of specimens. (**Werdon 1992**) collected one sturgeon chub on the Yellowstone R. in 1989. USFWS (1992) collected 3 in McKenzie County, North Dakota, in 1992 and 10 in 1993. North Dakota Game and Fish collected 10 in McKenzie County, North Dakota. Tongue R. collections summarized by **Werdon 1993**: **Elser et al. 1980** collected unknown number. **Werdon 1992** collected none on Tongue R. Some also collected on Powder R. Documentation of collections on Missouri R—see **Werdon (1993).** **Werdon 1993** Eyes and optic lobes are reduced and limit vision. **Werdon 1993** believes scale keels may improve hydrodynamic efficiency and may also have a sensory function. **Werdon 1992; Stewart 1981**: Sturgeon chub are found in greatest abundance in gravel riffles. **Smith and Hubert 1989** found sturgeon chub were residents in the Powder R., but not in its tributary, Crazy Woman Cr. The Powder R. is a meandering, highly braided stream with an unstable sand and silt bottom. The water is naturally turbid. Crazy Woman Cr. is less turbid, and has a confined stable channel. **Pflieger and Grace 1985**. Under presettlement conditions, the Missouri R. supported a relatively limited fauna comprised of species adapted for life in an environment characterized by persistent high turbidity, wide seasonal fluctuations in flow and temperature and an unstable sand-silt substrate. The more distinctive species in this fauna were pallid sturgeon, western silvery minnow, plains minnow, flathead chub, sturgeon chub, and sicklefin chub.

Species	Sturgeon chub *Macrhybopsis gelida*
Habitat (cont'd)	**Pflieger and Grace 1985** (cont'd). The pallid sturgeon and flathead chub have declined markedly in abundance from 1940 to 1983 due to increased competition, and reduced habitat diversity. Sicklefin chub and sturgeon have fared better. These species have increased in abundance in the middle and lower sections of the Missouri R. in Missouri. Habitat for them (open channels with swift current and firm substrate) has actually been increased by channelization. This habitat is sparsely inhabited by most other fishes, reducing potential competitors and predators. Their close association with the substrate may result in their being less vulnerable to predation than the midwater flathead chub. The two common species of minnows (western silvery and plains) declined in relative abundance over the period of record. These species typically occur in silty backwaters. These habitats became less prevalent as the river was channelized and its sediment load was reduced. **Reigh and Elsen 1979.** Body is well adapted to conditions of a large, turbid stream. Body is flattened ventrally and curved dorsally to minimize drag and help hold the fish on the bottom in a swift current. The fins are large for better body control in fast water. Scales on upper sides and back are keeled, which may facilitate a smooth flow of water over the body or serve as a current detector (**Pflieger 1975**) to aid the fish in orienting itself. Eyes are reduced. Has sensitive barbels at the corners of the mouth and external taste buds distributed over the head region. The ventral mouth allows fish to feed on the bottom. **Reigh and Elsen 1979**. Sturgeon chub shows marked preference for gravel and rock substrates in area with moderate current. **Reigh 1978**. Collections made in Yellowstone R. at three stations. **Stewart D. 19??**. Sturgeon chub in Powder R., Wyoming, found in habitat composed of moderate current with rocky rubble bottom and water depth from 6 inches to 2 feet. Current needs to be strong enough to remove the heavy silt load of the Powder R. from the bottom thus exposing the rubble. The size of the rocks in the riffle bottom seem to dictate the size of the chubs found. The larger, older chubs prefer rubble sizes ranges from 3 to 6 inches, while smaller chubs are in 1-inch rubble. Even in suitable habitat populations are not large. **Stewart, D. 19??**. Spawning in Powder R., Wyoming, starts in early June, peaking in June and continuing throughout summer. **Pflieger 1975.** In Missouri it inhabits the open channels of large, silty rivers and occurs in swift current over a bottom of sand or fine gravel. Sturgeon chub are adapted for life in turbid waters - its eyes are reduced in size and external taste buds are abundantly developed over the head, body, and fins.

Species	Sturgeon chub *Macrhybopsis gelida*
Egg/Larval Characteristics . Drift . Gravel . Backwaters . Nest	**Werdon 1993.** Sturgeon chub are ripe from mid-June to late July in Wyoming. Guesses that eggs and larvae may be carried downstream. **Reigh and Elsen 1979.** YOY were collected from Little Missouri and Yellowstone Rivers in late July suggesting that the species spawns in spring. All were found over sand bottom.
Migratory Characteristics . None at all . Spawning . Rearing/drifting larvae . Pioneering abilities/colonizing new habitat	**Werdon 1993.** Speculates that sturgeon chub may be forced to migrate as water levels decline in late summer and fall.
Period of peak activity . Nocturnal . Diurnal	
Size of Territory (how much do they move around) . Permanent . Seasonal	
Location in River . Surface . Substrate . Midchannel . Edges	
Location in Water Column . Surface . Midcolumn . Substrate	

Species	**Sturgeon chub *Macrhybopsis gelida***
Swimming Performance . Actual measurements . Lifestyle (performance implied by lifestyle) - cruiser - lie in wait predator - scavenger	
Ability to Surmount Passage Barriers . Velocity barriers . Physical obstructions	
Susceptibility to Entrainment . Presence in entrainment study catches	
Fish Passage Studies . Presence in passage studies	
Physical Structure related to Entrainment/Passage	

Species	Sturgeon chub *Macrhybopsis gelida*
Areas literature says don't know anything/much about	**Werdon 1993.** Historically known populations where current status not known: Yellowstone R., Dawson and Richland Counties. Also Teton R., Chouteau County; Sunday Cr., Custer County; and Sears Cr., Richland County. **Werdon 1993**: Reproductive biology of sturgeon chub is unknown. Need further field studies to determine abundance and distribution of sturgeon chub in the wild and scenic portion of the Missouri R. in Montana, and in Missouri, Yellowstone, and Mississippi Rivers. Need to identify important habitat areas and critical components—especially spawning and rearing requirements. **Reigh and Elsen 1979.** Useful to determine distribution of chubs and other species in Yellowstone R. and Missouri R. below Garrison: flow requirements, seasonal habitat needs, spawning conditions, natural population fluctuations. **Pflieger 1975.** Diet and spawning not known. **Brown 1971.** Life history not known.
Areas literature says well known/studied	
Threats/Causes of Decline/Status	**Rowe 1992.** Impoundments, wing dikes, and revetments resulting in deep, uniform, and narrow channels with decreased turbidity. **Werdon 1993.** Reservoirs flooded riffle habitat, altered temperature and flow regimes and reduced turbidity. Channelization straightened and narrowed the river, reduced habitat diversity and reduced overbank flooding. Additional pressure from introduced fish. Pollution from industry and agriculture may have altered water quality. Sand and gravel operations have removed habitat and restricted fish movements.

Species	White sucker *Catostomus commersoni*
Habitat Use . Adult . Spawning . Rearing	**Brown 1971.** White sucker is in nearly every Montana stream east of the Continental divide, except those with very cold temperatures and high velocities. **Dion et al. 1993.** At many sites in North America, large numbers of white and longnose suckers are under concurrent spring spawning migrations. Hybrids are viable but appear not to reproduce. **Brown 1971.** Habitat extremely varied, being present in both lakes and streams with cold and warm temperatures, high and low turbidities, and fast or slow currents. Reaches maximum abundance in impoundments. **Corbett and Powles 1983.** In 1979, peak spawning of white suckers occurred on 4/20-21 at 9 to 15 °C and 17 to 22 °C at night over a fast riffle in a tributary stream of a lake in Ontario. **Pflieger 1975.** In Missouri, white sucker is a small-creek fish, occurring only rarely in major rivers. It is abundant in high-gradient headwaters streams having gravelly or rocky bottoms and well defined riffles. Habitats with white sucker largely devoid of other suckers—may be competition. Commonly associated with Creek Chub. **Pflieger 1975.** Spawning habitat is gravelly areas near the lower ends of pools in quiet water or where the current begins to quicken. **Chen and Harvey 1995.** This benthivorous species is one of the most widespread and abundant fishes in North America. Feeds on benthic invertebrates and microcrustaceans. Chironomid larvae largest component of diet in lakes. **Dion et al. 1993.** White sucker outnumbered longnose sucker by 20:1 over spawning substrate of large rocks. Longnose suckers outnumbered by 2:1 over gravel substrate. Evidence of behavioral mating barrier. **Barton 1980** found Cladocera, mostly *Daphnia* sp., were major food items for both white suckers and longnose suckers from Paine Lake, Alberta. **Finger 1982** found the white sucker was the most characteristic species in pool habitat in a central New York stream. A few individuals were found in transition and riffle sections, but were much smaller in average length than the overall mean length for the species. The pool habitat supported lower overall fish density than riffle habitat.

Species	White sucker *Catostomus commersoni*
Habitat (cont'd)	**Propst and Carlson 1986** found white sucker was the most widely distributed species in the Platte Basin in Colorado. It occurred in all habitat types but was uncommon or absent at locations lacking flowing water. Large white sucker (>150 mm TL) was found almost exclusively in pools and deep runs of slow water velocity. Small individuals on the other hand were collected from shallow backwaters, riffles of moderate water velocity, and sand-rubble runs. Of fishes inhabiting the basin, it seemed most tolerant of human-induced environmental stress. It was, however, less common at stressed sites than at similar, unstressed locations. The wide environmental tolerance of white sucker was reflected by its occurrence in suitable habitat with all other common inhabitants of the basin. **Reebs et al. 1995** captured white sucker in the shallow backwater of a river in New Brunswick.
Egg/Larval Characteristics . Drift . Gravel . Backwaters . Nest	**Brown 1971.** Eggs are adhesive when laid and stick to and are partially covered by bottom materials. **Corbett and Powles 1993** observed spawning occurred in a tributary stream over a substrate of sand, gravel, and rock. **Gale and Mohr 1978.** Of the 18 species of larva in the drift sampled on the Susquehanna R., found white sucker, common carp, and shorthead redhorse in large numbers. Nearly all larvae collected at night on the surface, peaking at 2400 h, very few during the day. Of those collected during day, most were near the bottom. Density of drifting larvae captured somewhat higher near either shore than in the channel. But greater volume in main channel thus probably more fishing drifting there than along shore. **Geen et al. 1996** found that white sucker and longnose sucker larvae moved downstream almost exclusively between dusk and dawn. They confirmed light intensity was a factor by placing artificial illumination on the river.

Species	White sucker *Catostomus commersoni*
Migratory Characteristics . None at all . Spawning . Rearing/drifting larvae . Pioneering abilities/colonizing new habitat	**Brown 1971.** Spawning fish usually move upstream, or from lakes and impoundments into streams where they seek out gravel beds in fairly swift water. **Barton 1980.** Longnose sucker began migrating upstream from Paine Lake Alberta, first of June continuing for 43 days, while white suckers began earlier in late May, continuing for 51 days. Found correlation between temperature and discharge. **Geen et all 1966** found no such correlation. They concluded that water temperature was most important. **Walton 1979** found discharge most important trigger. **Barton 1980**. Major peak of downstream white sucker movement was in early July, while longnose sucker returned later from mid-June through early July. Barton felt this was correlated with stream discharge alone. **Corbett and Powles 1983.** Newly emerged white sucker prolarvae were found in the substrate for 11 to 13 days before drifting from the spawning ground downstream to the nursery channels. They then migrated from the creek nursery area to the lake, with few observed in the creek by July 4. **Curry and Spacie 1979** found that white suckers resided in the headwaters of a tributary of the Wabash River year round. They showed no strong tendency for nocturnal downstream movements unlike back redhorse and quillback.

Species	**White sucker** ***Catostomus commersoni***
Period of peak activity . Nocturnal . Diurnal	**Chen and Harvey 1995.** In Ontario Lakes, Wisconsin, white sucker are inactive in deep water during daylight and move inshore at night to feed. May reduce metabolic rates by staying in colder hyplimnetic water during non-feeding periods. Unclear if any relation to Yellowstone/Missouri River diurnal activities. **Corbett and Powles 1983** found that white sucker spawning occurred only at night in a tributary stream in Ontario. **Clifford 1972** observed a pronounced diurnal drift pattern of white sucker fry in a Canadian stream. Ninety-eight percent of the fry drifted at night and almost all of this in a 1-hour period. **Reebs et al. 1995** found significant differences between times of day for juvenile suckers caught in unbaited traps; captures at night and dawn were significantly fewer than during the noon and afternoon periods. The pattern was similar for baited traps. They conclude that white sucker appeared to be diurnal. This in contrast to **Scott and Crossman (1973)** who described this species as being mostly crepuscular with moderate activity during the day. On the other hand **Campbell (1971) and Emery (1973)** considered it to be nocturnal. **Reebs et al.** speculate that their minnow trap was selected for juveniles and that there may be temporal segregation between juveniles and adults. They conclude that as yet there is no satisfactory explanation for the plasticity shown in the various activity cycles of this species.
Size of Territory (how much do they move around) . Permanent . Seasonal	
Location in River . Midchannel . Edges	

Species	White sucker *Catostomus commersoni*
Location in Water Column . Surface . Midcolumn . Substrate	**Brown 1971 and Pflieger 1975.** Sucker fry feed on the surface, eating zooplankton, midge larvae, and diatoms. Older larvae feed on the bottom and eat aquatic invertebrates, diatoms, other algae, and debris. **Corbett and Powles 1983.** Post larvae fed primarily on cladocerans and protozoans; rotifers and algae also important. During this period, the mouth was in the terminal position and larvae fed at the surface in the tributary nursery areas. As the mouth changed to the ventral position, diet shifted increasingly to benthic organisms, and position in the water column shifted to the substrate. **Pflieger 1975.** White sucker live in schools near the bottom
Swimming Performance . Actual measurements . Lifestyle (performance implied by lifestyle) - cruiser - lie in wait predator - scavenger	
Ability to Surmount Passage Barriers . Velocity barriers . Physical obstructions	**Dion et al. 1993.** In Quebec, abundances of both white and longnose suckers varied between years. A 5- to 8-fold drop in numbers occurred in the year when reservoir levels were lowered for maintenance, creating rapids that may have blocked upstream movement of reservoir fish.
Susceptibility to Entrainment . Presence in entrainment study catches	
Fish Passage Studies . Presence in passage studies	
Physical Structure related to Entrainment/Passage	

Species	White sucker *Catostomus commersoni*
Areas literature says don't know anything/much about	**Corbett and Powles 1983.** Movements, distribution, and growth of post larval white suckers not documented well for lakes.
Areas literature says well known/studied	**Corbett and Powles 1983.** Extensive studies have been done on homing, spawning behavior, embryogenesis, early development, postlarva feeding, general life history.
Threats/Causes of Decline	**Dion et al. 1993.** The complicated spawning system and low rates of individual spawning of both white and longnose suckers may make them less resilient than they are assumed to be.

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