Conservation Assessment for the Greater Redhorse (Moxostoma valenciennesi)

Photo: by Konrad Schmidt

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This document is undergoing peer review, comments welcome

This Conservation Assessment was prepared to compile the published and unpublished information on the greater redhorse Moxostoma valenciennesi. It does not represent a management decision by the USDA Forest Service. Though the best scientific information available was used and subject experts were consulted in preparation of this document, it is expected that new information will arise. In the spirit of continuous learning and adaptive management, if you have information that will assist in conserving the subject taxon, please contact the Eastern Region of the Forest Service Threatened and Endangered Species Program at 310 Wisconsin Avenue, Suite 580, Milwaukee, Wisconsin 53203.

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EXECUTIVE SUMMARY

Greater redhorse *Moxostoma valenciennesi* is designated as a Regional Forester Sensitive Species on the Chippewa, Chequamegon-Nicolet, and Huron-Manistee National Forests in the Eastern Region of the Forest Service. The species is documented but not designated as sensitive on the Hiawatha National. The purpose of this document is to provide the background information necessary to prepare Conservation Approaches and a Conservation Strategy that will include management actions to conserve the greater redhorse.

The greater redhorse is a benthic invertivore primarily found in medium to large-sized rivers and occasionally lakes. Although this species is widely distributed, it occurs in small, disjunct populations, and due to specialized feeding and habitat requirements for spawning and rearing, it is particularly sensitive to human alterations of its habitat. As a result of channelization, dam construction, point- and non-point-source pollution, and hydroelectric dam operation, the greater redhorse has likely declined in many areas, even as more occurrence records have been recorded.

In many of the National Forests and states in which the greater redhorse occurs, little or no historic abundance data exist to properly establish population trends and assess viability, therefore surveys are needed to document its present distribution. In addition, research is needed regarding seasonal habitat requirements and the extent to which land use and forest management may impact this species.

ACKNOWLEDGMENTS

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Finally, Chris Bunt, Biotactic, Inc. shared copies of unpublished manuscripts and insight into greater redhorse ecology and aspects of its reproductive biology.

NOMENCLATURE AND TAXONOMY

Scientific name: *Moxostoma valenciennesi* Jordan

Common names: Greater redhorse, others include common redhorse, redhorse

Family: Catostomidae

Synonymy: *Moxostoma rubreques* Hubbs

DESCRIPTION OF SPECIES

The following physical description of greater redhorse is taken from Becker (1983):

> *"Body elongate to moderately stout, almost round in cross section; ventral aspect slightly curved. Adult length about 460 mm (18 in.). TL = 1.23 SL. Depth into SL 3.4-4.2. Head into SL 3.7-4.4 (3.3-3.7 in young up to 76 mm). Snout slightly to moderately rounded, but not overhanging mouth ventrally. Mouth large, ventral and horizontal; lips deeply plicate, folds smooth surfaced except occasionally "wrinkled" on lateral portion of lower lip; lower lip broader than upper lip; lower lip often appearing swollen; lower halves forming an obtuse angle (100-160°). Pharyngeal teeth heavy, about 55 per arch (80 according to Jenkins 1970); crown of each tooth with pronounced cusp on anterior edge; arch moderately strong, symphysis short. Dorsal fin slightly convex (in adults); dorsal fin base into SL 4.9-5.3, length of base about ¾ the distance from back of head to dorsal fin base; dorsal fin rays 13-14 (11-15); anal fin rays 7; pelvic fin rays 9 (8-10); lateral line scales 42-45 (41-45); lateral line complete. Scales around caudal peduncle 16 (14-17).*
>
> *Back brown olive with bronze overcast; sides more golden; belly whitish. Dorsal, caudal, and anal fins red in life (fade to gray in formalin and alcohol); anterior rays o pelvic and pectoral fins whitish, remainder reddish. Scales with dark spots at their anterior exposed bases.*
>
> *Breeding male with minute tubercles on entire dorsal and lateral surfaces of head and on body scales. Large tubercles on rays of lower lobe of caudal fin, fewer rays on upper lobe. Breeding female with small and bluntly tipped tubercles on all fins except dorsal, but less widely distributed and generally smaller than in male; tubercles absent from female body, except on lower caudal peduncle."*

Discrepancies in species identification during historical collections have prevented researchers from obtaining reliable distributional records for the greater redhorse. Similar species which commonly occur with greater redhorse include the shorthead redhorse *Moxostoma macrolepidotum*, and the river redhorse *Moxostoma carinatum*. The trailing edge of the dorsal fin on the river redhorse is usually concave, rather than convex in the greater redhorse. In addition, river redhorse have large molar-like teeth and squared snout. The head of the greater redhorse is also much larger relative to the body (25% of SL), than the head of the shorthead redhorse, in individuals over 10 inches (Page and Burr 1991).

LIFE HISTORY

Reproduction and Dispersal

The life history and reproductive biology of the greater redhorse is among the least studied of the redhorses (Jenkins and Jenkins 1980), but like many fishes in its family (Catostomidae; Jenkins and Burkhead 1993), the greater redhorse is a late maturing, long-lived migratory species that may require large, interconnected river systems to fulfill the needs of all life stages. Only a few studies have addressed these aspects (Cooke and Bunt 1999; Jenkins and Jenkins 1980; Mongeau et al. 1992), but reproductive tactics among catostomids (Page and Johnston 1990), and particularly *Moxostoma* species (Kwak and Skelly 1992), appear to be similar. Generally, stream inhabiting redhorses spawn during spring or early summer over gravel or cobble riffles with higher velocities. However, subtle differences in microhabitat use may allow for segregation of syntopic spawning species and decrease the chance for hybridization among them (for review see Kwak and Skelly 1992). Lake inhabitants may either spawn in shallow areas of lakes, or make mass movements up rivers to reproduce (Kwak and Skelly 1992).

Greater redhorse begin spawning in high velocity riffles or runs when stream temperatures reach at least 13° C between May and July (Jenkins and Jenkins 1980, Cooke and Bunt 1999). However, spawning can occur in temperatures between 13° C and 19° C (Jenkins and Jenkins 1980; Cooke and Bunt 1999). Spawning is stimulated when highly variable spring flows have subsided and stabilized (Jenkins and Jenkins 1980; Cooke and Bunt 1999). Cooke and Bunt (1999) found that spring freshets that occurred after spawning began would cause a delay in spawning activity. A typical spawning bout occurs between a single female and several males over fairly coarse substrates free of silt with large interstitial spaces for egg deposition (Cooke and Bunt 1999). Unlike the river redhorse (*M. carinatum*), greater redhorse do not create or guard nests (Jenkins and Jenkins 1980; Cooke and Bunt 1999). With the completion of reproductive activity, greater redhorse were observed to disperse up to 15 km downstream of spawning areas in an Ontario river (Bunt and Cooke 2001).

Adult greater redhorse do not achieve sexual maturity until a relatively late age. Cooke and Bunt (1999) found age-6 females and age-5 males were the youngest spawning individuals, but Mongeau et al. (1992) reported that males and females did not spawn until age-9. Large-bodied females are highly fecund, with egg counts from seven age 6-9 females ranging from 31,759- 71,920 (Cooke and Bunt 1999). In comparison to several other redhorse species, including the copper (*M. hubbsi)*, river, silver (*M. anisurum)*, and shorthead (*M. macrolepidotum*) redhorses, Mongeau et al. (1992) showed the greater redhorse (egg count, 25,190-51430) was second only to the copper redhorse in fecundity.

Although there is no published information regarding juvenile mortality for this species, hypothesized life history theory predicts that large-bodied catostomids with similar reproductive tactics and biology (i.e. late age of maturation, longevity, high fecundity, seasonal spawning) may experience low juvenile survivorship (near zero) most years, with recruitment relying on a relatively few highly successful spawning bouts by a given individual during its lifetime (Winemiller and Rose 1992). This reproductive strategy takes advantage of seasonal and predictable changes in habitat characteristics, such as spring flooding due to snowmelt. Since year-to-year reproductive success may vary depending on weather and climatic conditions, spawning must be unimpeded annually to take advantage of years with exceptional spawning conditions when juvenile survivorship may be high (e.g. "periodic" strategy; Winemiller and Rose 1992).

Based on this type of life history strategy, repeated unnatural perturbations to stream habitat may impact greater redhorse recruitment. For example, in rivers where flows are regulated or modified by dams, cues required to initiate spawning may be disrupted and larvae may be flushed downstream or stranded year after year, possibly resulting in reduced reproductive success for the entire population. The abundance of larval catostomids has been found to vary greatly among years, and was much lower in abundance in a river regulated by a hydroelectric dam, when compared to a free-flowing river (Scheidegger and Bain 1995). In addition, the year when the highest abundance of larval catostomids was recorded in the regulated river was when the dam was discharging for long periods of time due to high spring river flows rather than regulating flows for maximum energy production (Scheidegger and Bain 1995). Larval catostomids have also been found to occupy specific microhabitats in naturally flowing rivers, which included the shallow, vegetated areas near shore with slow water velocities (Scheidegger and Bain 1995). These habitats are the most effected by fluctuating river flows (Bain et al. 1988), and fish species using them would most likely be depressed in regulated rivers.

Feeding/diet

Moxostoma species possess morphological adaptations conducive to feeding on invertebrates along the stream bottom (i.e. benthic), but that preclude feeding in the water column as generalists. The ventrally positioned mouth with large, sensitive, fleshy lips, and specialized pharyngeal teeth for filtering invertebrates are some examples of benthic-feeding specializations possessed by redhorses (Jenkins and Burkhead 1993). Some species have a robust pharyngeal apparatus designed for crushing mollusks as well (e.g. river redhorse *Moxostoma carinatum*; Jenkins and Burkhead 1993). When several *Moxostoma* species are found in the same stream, a high degree of feeding segregation generally occurs (Mongeau et al. 1992). For example, among five sympatric species of redhorse taken from the Richelieu River, Quebec, there was little diet overlap among them, indicating specialized feeding (Mongeau et al. 1990).

Information about the feeding habits of the greater redhorse is limited, but Mongeau et al. (1990) examined the stomach contents of 57 specimens from a Quebec river and found crustaceans (60%) to be the most numerous, followed by ephemeropterans (21%), trichopterans (8%), and chironomids (6%) in greater redhorse stomachs. Data from a single greater redhorse stomach from New York included mainly aquatic invertebrates and mollusks (Rimsky-Korsakoff 1930, as cited in Becker 1983). The author listed the stomach contents of this 24 cm specimen as 60% crustaceans, 25% mollusks, 10% plants, and 5% midge larvae (Rimsky-Korsakoff 1930, as cited in Becker 1983). Several of these families of invertebrates may be sensitive to siltation or other forms of non-point source and point source pollution, indirectly effecting greater redhorse populations.

HABITAT

Greater redhorse are inhabitants of medium to large-sized (50-150 feet wide) rivers, and large lakes or river reservoirs (Becker 1983). In rivers, it is found mostly in moderate to swift current, in run and riffle habitats with boulder, rubble, and gravel substrates (Becker 1983; Yoder and Beaumier 1986), but may also be found in large river pools.

Habitat suitability curves developed by the Minnesota Department of Natural Resources (DNR), Ecological Services (unpublished data), for greater redhorse indicated relatively specific depth and velocity preferences for different life stages (Fig. 1; see Aadland et al. 1991, Aadland 1993 for methods). Aadland et al. (1991) established six river habitat guilds based on cluster analysis of velocity and depth measurements from several Minnesota rivers, and assigned species-life stages to each guild where densities were highest. Four different greater redhorse life stages (adult non-spawning, spawning, young-of-year, juvenile) belonged to four different habitat guilds (raceway, slow riffle, shallow pool, medium pool; unpublished data, Minnesota DNR, Ecological Services). These results attest to the importance of the availability of diverse habitat types for all life stages.

Higher gradient sections of river with unembedded, coarse substrates are used by spawning greater redhorse. Spawning occurs in riffles or runs in medium to large-sized streams with moderate stream velocities (3.8-116.9 cm/s), shallow depths (10-100 cm), and gravel or cobble substrates (Jenkins and Jenkins 1980; Cooke and Bunt 1999). In the Manistee River, Michigan, greater redhorse were seen spawning in similar habitats as salmonids, in large cobble or gravel substrates below dams (Robert Stuber, USFS, personal communication). Spawning adults sampled from two Minnesota rivers occurred in shallow depths (mean 33 cm) and average velocities of 54 cm/s (range 7-90, Fig. 1), however sample size was low (n = 18; unpublished data, Minnesota DNR, Ecological Services).

Like other juvenile or larval fishes (Scheidegger and Bain 1995, Aadland 1993), shallow, slow velocity pools appear to be important to young-of-year greater redhorse (unpublished data, Minnesota DNR, Ecological Services). Preferred depth and velocity for age-0 greater redhorse was 20 cm and 21 cm/s in Minnesota rivers (Fig. 1). However, juvenile greater redhorse (> age-0, but not sexually mature) were found in greatest densities in slightly deeper pools (60-149 cm) and slightly higher velocities (37 cm/s) than young-of-year (Fig. 1). As larval redhorse develop, they become more mobile and resilient to high flows, which would allow them to occupy slightly deeper habitats with higher velocities (Ruetz and Jennings 2000). Larval fishes are particularly susceptible to downstream displacement from high velocities (Scheidegger and Bain 1995) due to a lack of fin and musculature development. In addition, large predatory fish are less common or absent from shallow pools (Schlosser 1987), indicating habitat use by young greater redhorse may be consistent with predation risk. Therefore, the presence of slow velocity habitats along channel margins is likely vital to maximize survival of age-0 redhorses.

By most accounts, greater redhorse appear to prefer habitats with substrates consisting of coarse materials (e.g. cobble, gravel, boulders), which may be attributed to morphological feeding specializations, food availability, and the need for interstitial spaces for egg incubation. Invertebrate production is greater in unembedded coarse substrates (for review see Allan 1995; crustaceans, Mitchell and Smock 1991), so sedimentation of these areas is detrimental to both food production and to greater redhorse egg viability. Although higher water velocities in stream riffles or runs may require greater energetic costs to maintain position, accumulated fine sediments that might result in low invertebrate density are flushed from between larger materials, resulting in greater food production. In addition, ephemeropterans have been found to comprise a large proportion of greater redhorse stomach contents (Mongeau et al. 1992) and were absent from unstable substrates such as mud or sand in a low gradient river (Benke et al. 1984). Therefore, energetic costs of foraging in high velocity habitats may be outweighed by greater invertebrate food availability. In low-gradient streams where coarse substrates may be less common, large woody debris may be important for invertebrate production. Benke et. al. (1984) showed invertebrate production (biomass) to be 20-50 times higher on woody substrates when compared to sand or mud.

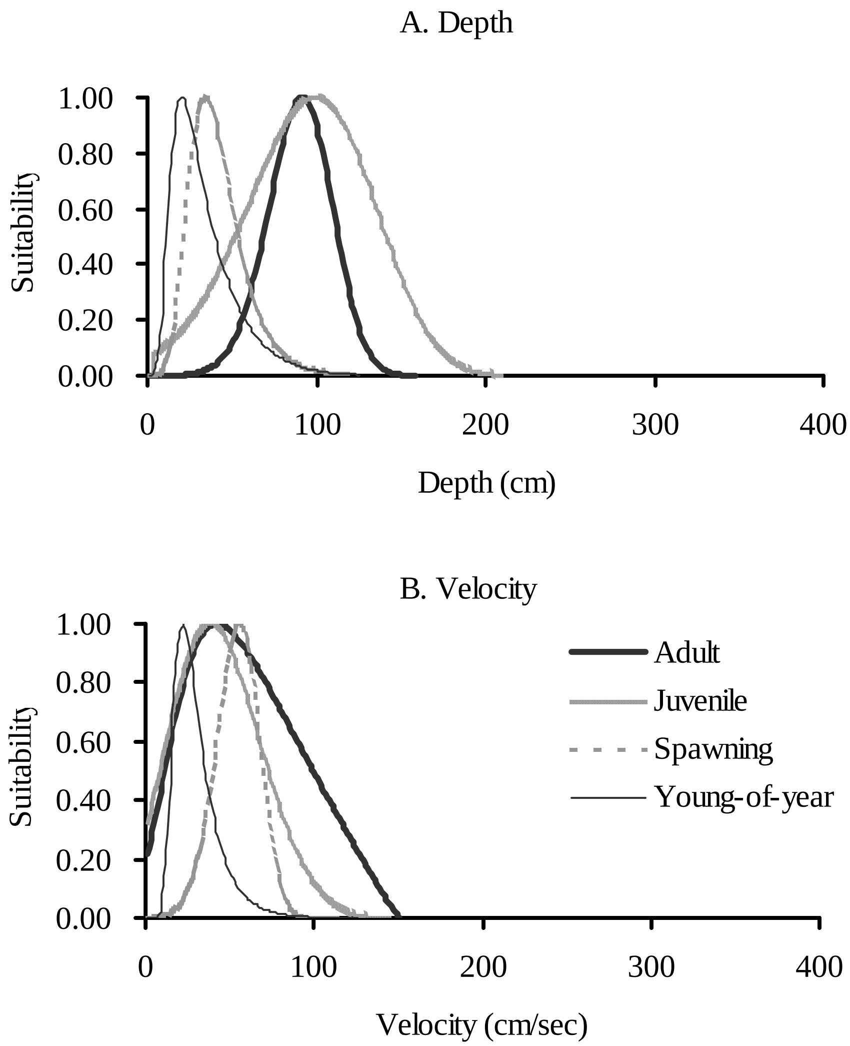

Fig. 1. Habitat suitability curves for depth (A) and velocity (B) preference for different greater redhorse life stages. Curves were developed by the Minnesota Department of Natural Resources, Ecological Services, following methods described in Aadland (1993).

Greater redhorse may prefer rivers with warm to cool water temperatures, but little information concerning temperature preference or physiological tolerance is available. Across streams of varying temperature and catchment area in the lower peninsula of Michigan, Zorn et al. (2002) found the species guild to which greater redhorse belonged (including silver redhorse *M. anisurum*, golden redhorse *M.erythrurum*) was associated with large, warmwater rivers. In addition, fishes common in warm waters such as largemouth bass *Micropterus salmoides*, bluegill *Lepomis macrochirus*, and pumpkinseed *Lepomis gibbosus* have been reported to be associated with greater redhorse in Wisconsin (Becker 1983). In contrast, greater redhorse declined as temperatures increased due to the impoundment of several reaches of the Au Sable River, Michigan, while warmwater species such as centrarchids increased (Zorn and Sendek 2001), indicating a preference for cool temperatures. Other warm or cool water species associated with greater redhorse included golden redhorse, common carp *Cyprinus carpio*, smallmouth bass *Micropterus dolomieu*, northern hog sucker *Hypentelium nigricans*, yellow perch *Perca flavescens*, white sucker *Catostomus commersoni*, rock bass *Ambloplites rupestris*, Iowa darter *Etheostoma exile*, pumpkinseed, and common shiner *Luxilus cornutus*, (see Jenkins and Jenkins 1980; Cooke and Bunt 1999; Bunt and Cooke 2001).

Greater redhorse habitat quality and quantity are difficult to assess with available data, as detailed habitat inventories have not been conducted across their range or within the National Forests covered under this assessment. Nevertheless, rivers of the type inhabited by greater redhorse were historically modified to facilitate river shipping, hydropower production, and to provide a water supply. Few free-flowing rivers remain in the United States (Benke 1990, as cited in Scheidegger and Bain 1995). Low habitat diversity (i.e. few deep pools and shallow riffles), loss of instream cover (e.g. woody debris), and unnatural flow fluctuations are common results of stream channelization that contribute to a loss of fish and invertebrate diversity and abundance. Channelized or dredged reaches do not provide habitat for stream fishes that need shallow runs or riffles for spawning and deep, low-velocity pools to survive harsh winter conditions. Shallow, channel margin habitats required for young greater redhorse, and riffles used by spawning adults would be reduced in channelized streams.

Hydroelectric dams are operated to optimize energy production (i.e. “peaking”), often without regards to fish populations above and below the dams. The highly variable hydrologic regime resulting from this type of operation may impact greater redhorse distribution. During the development of an Index of Biotic Integrity (IBI) to assess the health of aquatic ecosystems in Wisconsin rivers, Lyons et al. (2001) found that sites effected by peaking and scored as “poor” in environmental quality were located in relatively short (mean = 4.3 km, range 3.9-4.5) reaches of river between the dam and the head of the impoundment downstream. Peaking sites rated as “excellent” had significantly longer reach lengths (mean 69.7 km, range 38.8-95.3; Lyons et al. 2001). Sites with more sucker species (including greater redhorse) and higher proportion of suckers in the catch (by weight) had higher IBI scores (Lyons et al. 2001). Therefore, greater redhorse presence and abundance were correlated with longer contiguous river reaches. Higher IBI scores in longer reaches subject to hydroelectric peaking were attributed to the availability of a relatively stable refuge downstream of the dam above the next impoundment where daily flow fluctuations were reduced (Lyons et al. 2001). The impoundments created above dams may also reduce available greater redhorse habitat. Although they may be found in lakes, in the Sandusky River, Ohio, few or no greater redhorse were found in locations near impoundments or where the river was predominately pooled (Yoder and Beaumier 1986). In Michigan’s Au Sable River, greater redhorse may have been extirpated from some reaches where a series of dams converted high gradient riffle habitat into short, predominately impounded areas (Zorn and Sendek 2001). The use of these slow-water habitats may depend on the availability of run or riffle habitat where food and spawning areas may be found, because impoundments contain mostly fine substrates.

Riverine habitats such as shallow pools and riffles, preferred by young-of-year and spawning greater redhorse, respectively, are more susceptible to flow alterations when compared to deeper pools (Aadland 1993; Lobb and Orth 1991). Aadland et al. (1993) found that shallow pool habitats are reduced most by higher flows, while riffles are more sensitive to flow reductions. When considering all fish species, these areas also had the highest life stage and species diversity of the six habitat guilds identified by Aadland (1993).

DISTRIBUTION AND ABUNDANCE

Occurring across a somewhat wide geographical range, the greater redhorse remains in scattered locations in the Mississippi, Hudson Bay (Red River), and Great Lakes-St. Lawrence River Basins (Page and Burr 1991). Currently this species is found in North Dakota (Red River system), Minnesota (Upper and Lower Mississippi, St. Croix, Lake Superior, Minnesota, and Red River drainages), Wisconsin (St. Croix River above St Croix Falls, tributaries of Green Bay, possibly Green Bay and Milwaukee River, Illinois River drainage), and in streams of the Great Lakes drainage in New York, Quebec, and Ontario. In Ohio, the greater redhorse is found in the Sandusky (Yoder and Beaumier 1986), Ottawa, Maumee, Auglaize and St. Joseph Rivers (Great Lakes basin, Clausen et al. 2001). Illinois populations likely occur in the Illinois River, as well as the Fox and Vermillion Rivers (Clausen et al. 2001). In Indiana, greater redhorse was reported from the Eel River (Ohio basin; Robert Jenkins, Roanoke College, personal communication), and eight other rivers (drainages not listed, Clausen et al. 2001). The Eel River population is the only remaining extant population in the Ohio River basin (Robert Jenkins, Roanoke College, personal communication).

In the southern portion of its range, the greater redhorse may be declining (Page and Burr 1991). Historical records, although some unsubstantiated (e.g. Lake of the Woods/Rainy River drainage, Minnesota), indicate that it was found throughout the Great Lakes states, the St. Lawrence River, Red River (Hudson Bay drainage), Ohio River drainage, and the upper Mississippi River from Minnesota and Wisconsin, south to Indiana and Ohio, and including streams in southern Ontario and Quebec, Vermont, Michigan, and North Dakota (Clausen et al. 2001). The greater redhorse occurs in only one known tributary to the Ohio River (Eel River).

In the past 25-30 years, efforts to improve water quality by reducing point-source pollution have increased (e.g. Wisconsin, see Lyons et al. 2001), possibly resulting in increased abundance of greater redhorse and other large-river fishes in some areas (Clausen et al. 2001). New survey data have verified occurrences of greater redhorse in additional rivers, and it is considered abundant in some locations. Several sources indicate this species may be more abundant than was previously believed (Clausen et al. 2001; Lyons et al. 2000), however, in most areas abundance or distributional data needed to assess the status of populations are lacking. Greater redhorse can be locally abundant during spawning runs (Lyons et al. 2000), but are generally rare where they occur. For example, among five *Moxostoma* species collected from the Richelieu River, Quebec, greater redhorse was only collected from 2 of 4 sites surveyed, and occurred in low abundance relative to other redhorses (9% and 2% of total *Moxostoma* collected; Mongeau et al. 1992). In the Sandusky River, Ohio, greater and river redhorse represented 0.3% and 1.3%, respectively, of the total number of fishes (n = 2870) collected (Yoder and Beaumier 1986).

Minnesota – Chippewa National Forest

Few historical occurrences of greater redhorse in Minnesota have been recorded, possibly due to discrepancies in their identification. At one time, the presence of greater redhorse in Minnesota was even listed as "doubtful" by Phillips and Underhill (1971, as cited in Eddy and Underhill 1976). Recently, greater redhorse have been documented in 141 locations in six of ten major Minnesota drainages including the Upper and Lower Mississippi, Red River, St Croix, Minnesota River, and Rainy River drainages. In addition, there were questionable records from the St. Louis (Lake Superior) drainage, however the specimens were not saved and should be disregarded (Robert Jenkins, Roanoke College, personal communication). These were the only records of greater redhorse from the Lake Superior drainage. Less emphasis has been focused on documenting the distribution of this species in Minnesota, possibly because of its unlisted status by the Minnesota Natural Heritage program. Because historical distributional records are incomplete for greater redhorse in Minnesota, it is difficult to establish a clear population trend for this species.

The boundary of the Chippewa National Forest crosses two major drainages: the Mississippi River and Hudson Bay (through the Rainy or Red Rivers). Low-gradient rivers and streams with pool-run morphology are common within the Chippewa National Forest. Although fine substrates dominate most streams, some riffle habitats exist, consisting of gravel, cobble, and mixed sand and gravel substrates. The Mississippi River bisects the Forest, and several dams along the river regulate the water levels in Cass Lake and Lake Winnibigoshish. These dams, for the most part, serve as barriers to fish movement. In addition, Federal Dam, on the Leech Lake River, regulates Leech Lake water levels, and is impassable to fish.

Other than dam operations, extensive draining and ditching of wetlands, clearing of lands and conversion to younger forests may have cumulatively altered the hydrology of rivers (Verry 2001) with suitable greater redhorse habitat. Within the Chippewa National Forest, extensive channelization has occurred on the Willow, Mississippi, and Leech Lake River, where greater redhorse may occur. Many wetlands have been ditched and drained, particularly those within the Mississippi watershed. Channelization of the Mississippi River itself has resulted in greatly decreased sinuosity (range 12 – 49% change) since the late 1800's along all but 1 out of 7 reaches (2 of 32 miles) surveyed downstream of Lake Winnibigoshish (Chippewa National Forest, unpublished data). Due to major changes in the channel pattern and the alteration of river flows by Winnie Dam, floodplain fish habitat may be reduced, and 3050 feet of the Mississippi shoreline is unstable and eroding (Chippewa National Forest, unpublished data).

Greater redhorse have been documented in several watersheds within the Forest boundary, including the Boy River, Willow River, Cass Lake, Turtle River, and Lake Winnibigoshish watersheds (Table 1), but limited sampling has been conducted, and as a result, little is known of their distribution or abundance. In 2000, a juvenile greater redhorse was collected from Cass Lake, providing evidence of natural reproduction within the Mississippi River drainage on the Forest. Although historical records documenting greater redhorse on the Forest are rare, archeological data from a site on the southern shore of Leech Lake suggests greater redhorse existed in Leech Lake (Shane 1996). Greater redhorse have not been documented in Leech Lake recently, but no known surveys have specifically targeted this species.

Several additional lakes and streams connected to the Mississippi River may contain greater redhorse, as appropriate habitat exists. In addition, anecdotal evidence suggests greater redhorse may occur in several other locations on the Chippewa National Forest. For example, large redhorse, which were probably greater redhorse due to their estimated size, were observed spawning in the Mississippi River between Winnie Dam and U. S. Highway 2 (B. Healy and J. Jerry, personal observation), and in the Turtle River upstream of Beltrami County Road 307 (C. Cook, et al. personal observations; Bob Ekstrom, personal observation) by Chippewa National Forest fisheries staff. Further, a 9-10 pound redhorse was caught by an angler in Lake Winnibigoshish, which was identified by a high school biology teacher as a greater redhorse (Jerry Albert, personal communication), but this identification was not verified. Results from a recent (Mortensen and Ringle 2002, unpublished report) survey of tribal members and staff by personnel of the Leech Lake Band of Ojibwe, Division of Resources Management suggests several other potential greater redhorse occurrences. In addition to verified locations, responses indicated large redhorse had been observed by tribal members or DRM staff in the Mississippi River between Winnie Dam and U. S. Highway 2, between Lake Andrusia and Cass Lake (also Bob Ekstrom, personal communication), Turtle River, Bowstring River (Hudson Bay drainage), Leech Lake River below Federal Dam (S. Mortensen, personal observation), and the Ball Club River. The reliability of these reports may vary, however surveys are planned to verify these potential occurrences. In summary, evidence suggests greater redhorse may be found in the Mississippi, Turtle, Leech Lake, Boy, and Willow Rivers, and in Leech Lake, and Lake Winnibigoshish in appropriate habitat.

To further evaluate the distribution and population viability of greater redhorse on the Chippewa National Forest, more surveys specifically targeting this species and their habitat are necessary. The Minnesota DNR performs annual gillnet and electroshocking surveys on many lakes, nevertheless, most efforts have been directed towards gamefishes. Further, surveyors often identified Catostomids only to the genus level during stream or lake surveys, so the presence of greater redhorse may have gone undetected in the past (Cooke and Bunt 1999).

Table 1. Documented greater redhorse occurrence records from watersheds of the Chippewa National Forest. All watersheds where greater redhorse are known to occur on the Chippewa NF are found within the Mississippi River drainage. Source: James Ford Bell Museum of Natural History, University of Minnesota.

Waterbody	County	Watershed	Date	Count
Lake Andrusia	Beltrami	Cass Lake	7/20/1981	1
Lake Andrusia	Beltrami	Cass Lake	Unknown	1
Kitchi Lake	Beltrami	Turtle River	7/27/1988	2
Little Rice Lake	Beltrami	Turtle River	6/18/1990	1
Mississippi River	Beltrami	Lake Winnibigoshish	6/10/2002	13
Big Deep Lake	Cass	Boy River	8/13/1990	2
Boy Lake	Cass	Boy River	8/7/1989	10
Boy Lake	Cass	Boy River	8/1/1992	17
Boy Lake	Cass	Boy River	8/1/1995	35
Child Lake	Cass	Boy River	7/19/1993	1
Inguadona Lake	Cass	Boy River	7/15/1991	6
Inguadona Lake	Cass	Boy River	7/12/1994	10
Little Boy Lake	Cass	Boy River	4/22/1991	1
Rice Lake	Cass	Boy River	7/31/1990	19
Widow Lake	Cass	Boy River	5/26/1994	1
Woman Lake	Cass	Boy River	7/20/1992	2
Woman Lake	Cass	Boy River	7/23/1990	4
Little Thunder Lake	Cass	Willow River	9/14/1964	1

Wisconsin – Chequamegon-Nicolet National Forests

In Wisconsin, greater redhorse has been recorded throughout the Mississippi and Lake Michigan drainage basins in the Chippewa, Mississippi, St. Croix, Red Cedar, Rock, Milwaukee, Menominee, and Wisconsin River tributaries, and several other scattered locations throughout the state (Becker 1983). No known occurrences from the Lake Superior basin in Wisconsin have been recorded. Since Becker (1983), additional occurrences of greater redhorse have been documented in the Upper Chippewa River drainage, tributaries to Lake Michigan (Sheboygan and Twin River drainages), and the first occurrences from the Illinois River drainage in Wisconsin were recorded (Lyons et al. 2000). However, greater redhorse are still considered uncommon in Wisconsin (Lyons et al. 2000), and are listed as “Threatened” by the Wisconsin DNR, Bureau of Endangered Resources.

The Chequamegon-Nicolet National Forest is made up of 2 landbases-including the Chequamegon Landbase in northwest Wisconsin, and the Nicolet Landbase in the northeastern part of the state. The Forest contains land in both the Great Lakes and Mississippi River drainages where a variety of aquatic habitats are present, including both warm and cold-water streams, natural lakes, and numerous impoundments or flowages. Many lakes and rivers are stained, to some degree, due to the presence of acidic bogs in the headwaters.

Much of the Chequamegon landbase is drained by either the Chippewa or the St. Croix River systems (Mississippi River drainage), where greater redhorse are known to occur. Tributaries to the Chippewa River flowing through the Forest include the Flambeau River, the South Fork Flambeau River, and the East and West Fork of the Chippewa River. The Black and the Yellow Rivers flow through the most southern unit of the Chequamegon landbase and drain into the Mississippi River. Habitats in these rivers are diverse, as well, with abundant rock riffles, sluggish pools, and sandy runs, as much of the area was glaciated.

The Chippewa River is a productive, wide (>50 ft.), warmwater river with diverse fish assemblages typical of larger rivers of the Mississippi River drainage. The Chippewa is a native muskellunge river, and contains many characteristic riverine fishes such as sturgeon, catostomids, freshwater drum, and darters, as well as popular game fishes. The Chippewa River and its tributaries have been subjected to a wide variety of degradation, including reach fragmentation by the creation of impoundments and hydroelectric dams. The Federal Energy Regulatory Commission has recently re-licensed several hydroelectric dams along the Chippewa River, however no mitigation for fish passage was included (Sue Reinecke, personal communication). During the height of the logging era in northern Wisconsin, logs were driven down many of the rivers, including the Chippewa and its tributaries, altering their channel morphology, from which some may have not yet fully recovered (Sue Reinecke, personal communication).

Although Lyons et al. (2000) indicated the greater redhorse is distributed widely throughout the Upper Chippewa River drainage, within the Chequamegon landbase, it has only been found in 3 locations within the Chippewa River Watershed (5^{th} code HUC, Table 2). Occurrences have been documented in the East Fork Chippewa River, West Fork Chippewa River upstream to Clam Lake, and the Chippewa Flowage. Additionally, greater redhorse may occur in lakes connected to the West Fork Chippewa River including Lost Land and Teal lakes (Sue Reinecke, personal communication). Several occurrences have also been recorded on the Namekagon River downstream of the Forest boundary, but suitable habitat may not exist in the smaller, coldwater, Namekagon River headwaters within the Forest boundary (Sue Reinecke, personal communication).

Fish surveys have been conducted throughout the Forest, although greater redhorse have not been found in several rivers that may contain suitable habitat. The South Fork Flambeau River, a low-gradient tributary to the Flambeau River, was historically subject to log drives and the effects of which may still be reflected in degraded fish habitats (Sue Reinecke, personal communication). Much of the river contains wetland riparian habitats, which may require more time to recover from impacts related to log drives than rivers flowing through uplands. Habitat in the Flambeau River appears to have recovered from the log drives, but several dams remain in place (Sue Reinecke, personal communication). Fish surveys are performed on the Flambeau River near Park Falls every 3 years, and although several *Moxostoma* species are collected, greater redhorse have not been among them (Sue Reinecke, personal communication). Greater redhorse habitat may also be found in the Yellow River (Taylor County; Sue Reinecke, personal communication).

The Nicolet landbase lies within three major drainages, including the headwaters of the Wisconsin River (Mississippi River drainage), Lake Michigan (Green Bay), and Lake Superior drainages. Most riverine habitats within the Nicolet landbase consist of small, coldwater trout streams, providing little greater redhorse habitat. Although appropriate habitat may exist in the Pine, Peshtigo, and Popple Rivers (Lake Michigan drainage) it is believed redhorses are not native to portions of the rivers within the Nicolet landbase, since natural barriers exist downstream (Oconto Falls and Big Quinnesec Falls), allowing no route for postglacial colonization (Lyons et al. 2001). Lac Vieux Desert is the source of the Wisconsin River, and lies within the Forest boundary, but no greater redhorse have been found in the headwaters. The portion of the Wisconsin River within the Nicolet landbase does not provide suitable greater redhorse habitat, and many tributaries are isolated from the main stem Wisconsin River by dams, so it is unlikely further occurrences of greater redhorse will be documented from Wisconsin River tributaries within the Nicolet landbase (Sue Reinecke, personal communication).

Table 2. Documented greater redhorse occurrence records from the Chequamegon-Nicolet National Forest. Records were obtained from the James Ford Bell Museum of Natural History or Sue Reinecke (USFS, personal communication).

Waterbody	**County**	**Watershed**	**Date**
East Fork Chippewa River	Sawyer	Chippewa River	Unknown
Lower Clam Lake (W. Fk. Chippewa R.)	Sawyer	Chippewa River	Unknown
Chippewa Flowage	Sawyer	Chippewa River	1977

Michigan – Huron-Manistee National Forests

Historically, greater redhorse were found throughout Michigan in the Great Lakes drainage. Before 1960, thirty-nine occurrences of greater redhorse were recorded from Michigan, and sixty-five occurrences have been reported since 1960 (Michigan DNR “Atlas of Fishes” database). Greater redhorse were also collected from Lake Michigan, and Lake Huron (Saginaw Bay). Latta (1998), recently reported greater redhorse from the St. Joseph, Kalamazoo, Grand, Muskegon, Shiawassee, Cass, Black, Manistee, and Au Sable Rivers, and considered this species “widespread and abundant” in the state of Michigan. Several new records of greater redhorse in the St. Joseph, Upper Grand, Thornapple, Maple, and Manistee watersheds have also been documented since 1960. The greater redhorse has been recorded in several locations within the boundaries of the Huron-Manistee National Forest (Table 3), which consists of two land units on the east and west sides of the Lower Peninsula of Michigan, but are administered as one. The distribution of greater redhorse and habitats will be discussed for each unit separately.

The Au Sable River, a tributary to Lake Huron, drains the majority of the Huron National Forest. Prior to the development of six major dams and impoundments on the river, the Au Sable had stable flow and temperature regimes throughout the year due to high inputs of groundwater. This river has relatively high gradient compared to others in Michigan, and most of the high gradient reaches which had well-developed riffles for spawning are impounded (Zorn and Sendeck 2001). Historically, spawning runs of sturgeon, round whitefish, and suckers annually occurred up the Au Sable River from Lake Huron, and arctic grayling were present in the river (Zorn and Sendeck 2001). Presently, the dams have restricted these runs to a short reach below Foot Dam.

The temperature regime throughout the Au Sable River is unique due to its geology, in that temperatures generally decrease as the river gains cold ground-water from the headwaters to the mouth (Zorn et al. 2002). As a consequence of the impoundment of several reaches of the Au Sable, the temperature may be altered to varying degrees among the different reaches, when compared to historic conditions. High-gradient reaches with interspersed pools and abundant woody debris characterized historic habitats along most of the Au Sable River. Much of the river contained coarse substrates, which provided suitable foraging and spawning habitat for greater redhorse. Although greater redhorse remain abundant in some reaches (e.g. below Mio Dam, above Loud Pond, Holly Jennings, personal communication), it is difficult to assess the extent to which they inhabited the river historically due to the alteration of temperature regimes. Greater redhorse appear to be absent or in lower abundance where warmwater fishes (e.g. bass, sunfishes) are common (Zorn and Sendeck 2001), so it is likely that they occurred in greater abundance when temperatures were historically cooler in some reaches. For example, the isolation of the river into a short, mostly impounded reaches with higher temperatures in Foote and Cook ponds (between Five Channels Dam and Foote Dam, Holly Jennings, personal communication) may have resulted in the loss of greater redhorse there. Shoreline erosion and sedimentation of spawning gravels has occurred due to fluctuating flows regulated by dams in some reaches. Past riparian logging activity and associated log drives may have altered channel and bank morphology, as well, exacerbating bank erosion (Zorn and Sendek 2001). In addition to the Au Sable River, greater redhorse have been found in the Pine River, just downstream of the Forest boundary. Suitable greater redhorse habitat may exist in reaches of the Pine River within the Huron National Forest, but surveys have not been conducted (Holly Jennings, personal communication).

The Manistee National Forest contains large portions of three major watersheds, which drain into Lake Michigan, all with known greater redhorse occurrences. These include the Pere Marquette, Muskegon, and the Manistee watersheds. Major rivers in these watersheds with potential habitat for greater redhorse include the Manistee, White, Pere Marquette, and the Muskegon. Although the water quality is generally good in these rivers (O'Neal 1997; Rozich 1998), some types of habitat degradation are common to them. Numerous hydroelectric dams have been built on the Manistee and Muskegon

Rivers, which have impounded high gradient stream reaches, destabilized flow regimes as a result of hydroelectric "peaking", increased water temperatures, and isolated fish populations. Past logging activities, eroding stream crossings, and regulation of the flow regime have reduced amounts of large woody debris and increased sedimentation to these rivers. As a result, several resident (e.g. arctic grayling, muskellunge) and potomadromous (e.g. whitefishes, sturgeon) fishes have been extirpated or are present in low numbers in lower river reaches. River redhorse (*Moxostoma carinatum*), a Michigan state threatened species, is also present below Croton dam on the Muskegon River, where it is limited due to the dam (O'Neal 1997).

Information describing historic fish communities is limited, but it is believed greater redhorse are native to these rivers and are currently present (O'Neal 1997; Rozich 1998). Rozich (1998) indicated the presence of greater redhorse in much of the Manistee River, and O'Neal (1997) documented greater redhorse in the Muskegon River but did not discuss its distribution across river reaches. In several rivers, greater redhorse move upstream from Lake Michigan to spawn, and are locally abundant below dams during spawning runs where they occupy similar habitats as salmonids (Robert Stuber, personal communication). These fish are also found in isolated reaches above impoundments, where they are abundant in runs and riffles with mixed large cobble and gravel substrates (Robert Stuber, personal communication). Although locally abundant, it is likely that variation in temperature and flow, as well as habitat degradation (e.g. dams, sediment), may limit greater redhorse in some river reaches. However, lacking historic and current survey data specifically targeting this species, it is difficult to assess trends in greater redhorse populations. For example, greater redhorse have not been documented since 1960 in the White River of the Manistee National Forest (Atlas of Michigan Fishes data), although they may exist there.

Table 3. Documented greater redhorse occurrence records from watersheds of the Huron-Manistee National Forest. All watersheds where greater redhorse are known to occur on the Huron-Manistee NF are found within the Great Lakes drainage. Records were obtained from the Michigan Atlas of Fishes Database.

Waterbody	County	WATERSHED	Date
	Pre-1960		
Au Sable River (O'Brien Lake)	Alcona	Au Sable	8/9/1939
Au Sable River	Iosco	Au Sable	8/9/1924
Au Sable River	Iosco	Au Sable	8/12/1924
Au Sable River	Iosco	Au Sable	8/10/1924
Au Sable River	Iosco	Au Sable	4/11/1925
Pere Marquette Lake	Mason	Pere Marquette	9/5/1937
Pere Marquette River	Mason	Pere Marquette	7/21/1931
White River	Muskegon	Pere Marquette	8/1/1952
White River	Muskegon	Pere Marquette	8/19/1952
Muskegon River	Newaygo	Muskegon	7/25/1935
	Post-1960		
Au Sable River	Alcona	Au Sable	1990
Au Sable River	Alcona	Au Sable	1990
Pine River	Alcona	Au Sable	9/14/1994
Au Sable River	Oscoda	Au Sable	1990
Au Sable River	Iosco	Au Sable	1990
Manistee River	Manistee	Manistee	4/30/1992
Manistee River	Manistee	Manistee	1990
Manistee River	Manistee	Manistee	1990
Pere Marquette River	Mason	Pere Marquette	2002
Muskegon River	Newaygo	Muskegon	1991

Hiawatha National Forest

The Hiawatha (Michigan) National Forest does not list the greater redhorse as a Regional Forester Sensitive Species, however, there is potential for viable populations of greater redhorse on the Forest. Although occurrences have not been documented on the Hiawatha National Forest recently, greater redhorse were present (pre-1960) in a tributary to Little Bay du Noc, Little Bay du Noc itself, and the Days and Whitefish Rivers in the Tacoosh-Whitefish watershed (Table 4). Further surveys are suggested in the Tacoosh-Whitefish (Hiawatha) watershed to determine whether populations of greater redhorse exist within the Hiawatha National Forests.

Table 4. Documented greater redhorse occurrence records from watersheds of the Hiawatha National Forests. All records listed are from waterbodies within the Great Lakes drainage. Records were obtained from the Michigan Atlas of Fishes database.

Waterbody	County	Watershed	Date	Count
Whitefish River	Delta	Tacoosh-Whitefish	1961	unknown
Days River mouth (Little Bay Du Noc)	Delta	Tacoosh-Whitefish	1965	unknown
Unnamed Tributary to Little Bay Du Noc	Delta	Fishdam-Sturgeon	1959	unknown

Superior National Forest

Several occurrences of greater redhorse were recorded from the St. Louis River drainage (1987-88), however it is unclear whether the localities were within the Superior National Forest (Minnesota) boundaries (James Ford Bell Museum of Natural History, University of Minnesota). These records were the only known occurrences of greater redhorse in tributaries to Lake Superior. However, the voucher specimens collected on the St. Louis River were not saved and should be disregarded (Robert Jenkins, Roanoke College, personal communication).

STATUS

Across its range, greater redhorse occurs in disjunct populations, however over 100 occurrences have been recorded (Clausen et al. 2001). In isolated areas it can occur in abundance, but the status of some populations are unknown. Greater redhorse appear to be stable or increasing in some portions of their range due to pollution control and improving water quality, but are rare or declining in the periphery (Clausen et al. 2001). For example, the only known extant population of greater redhorse in the Ohio River drainage is in the Eel River of Indiana (Robert Jenkins, personal communication). In some cases, the absence of historic abundance data may be due to a lack of sampling, or incorrect identification.

Although the Wisconsin Bureau of Endangered Resources ranks the greater redhorse status as “Threatened,” Minnesota and Michigan Departments of Natural Resources do not apply any special status listing to the species.

U.S. Fish and Wildlife Service: none

U.S. Forest Service: Regional Forester Sensitive Species (region 9)

Global Conservation Status Rank: G4

Species is vulnerable globally because it is rare or uncommon within a restricted range or distribution.

National Conservation Status Rank: N4

Heritage Status Ranks-

States: North Dakota – S2: imperiled
Ohio – S1: critically imperiled
Michigan – S3: vulnerable*
New York – S2: imperiled
Kentucky – SX: extirpated
Illinois – S1S2: critically imperiled-imperiled
Vermont – SU: unrankable, lack of information
Minnesota –no listing
Wisconsin – S2: imperiled**
Indiana – S2: imperiled***

*Michigan just recently de-listed greater redhorse (Ed Schools, personnal communication).
**Considered "Threatened" by the Wisconsin Bureau of Endangered Resources.
***Listed as "Endangered" by the Indiana DNR, Division of Fish and Wildlife.

POPULATION BIOLOGY AND VIABILITY

Lacking few documented examples of local greater redhorse population decline or extirpation, it is difficult to determine former abundance. However, greater redhorse populations are rare and disjunct across their range. Even though more occurrences continue to be documented, greater redhorse population sizes and dynamics are literally unknown. In Minnesota, for instance, the lack of baseline data does not allow biologists to accurately assess population trends statewide. In addition, population age-structure data is unavailable to assess interannual population dynamics (i.e. recruitment, mortality). Therefore, discussions of the viability of greater redhorse populations would be purely speculative.

Although greater redhorse occur across a wide range, unmodified, free-flowing rivers are rare throughout the Midwest. As a consequence of the construction of numerous dams on major river systems where greater redhorse occur, populations are isolated and potentially at risk. Where small, fragmented populations occur, there is a greater likelihood that a significant habitat perturbation could result in extirpation, particularly where no source population for recolonization exists (Brown and Kodric-Brown 1977). Recent work by Lyons et al. (2001) found streams downstream of hydroelectric dams with longer contiguous river reaches before the next impoundment to have a higher IBI score. Although the abundance and number of sucker species (genus *Moxostoma, Mytrema, Hypentelium*, and *Cycleptus*) was used as a metric to determine the score (Lyons et al. 2001), more studies specifically directed towards greater redhorse are needed to evaluate the interactive effects of reach length and dam operations on their populations.

POTENTIAL THREATS AND MONITORING

Commonalities exist among imperiled or extinct fish species. Obligate riverine species that are long-lived, slow-growing, and have specialized benthic feeding adaptations are particularly vulnerable to habitat alterations. For example, when benthic invertebrates decline with increasing sedimentation, fish possessing benthic feeding specializations, such as redhorses, (e.g. ventral position of the mouth) also decline, but those without similar adaptations can exploit drifting invertebrates in the water column (Jenkins and Burkhead 1993). Direct effects to greater redhorse populations are not well documented; however, known effects of habitat alteration to benthic riverine species with similar life history strategies, habitat requirements, and feeding strategies would similarly affect greater redhorse and are discussed below.

PRESENT OR THREATENED RISKS TO HABITAT OR RANGE

Presumably the most significant risk to greater redhorse populations in the past 25 years has been the construction of dams and impoundments. Since greater redhorse are a long-lived species, effects of the isolation of populations by dams and loss of habitat may not be immediately evident. In addition, fewer studies have been conducted to determine the effect of habitat fragmentation on aquatic species viability when compared to terrestrial species (Jager et al. 2001). Although large river fishes may survive in impounded reaches, their abundance is usually lower and riffle or run habitat must be present within the reach (e.g. white sturgeon, Jager et al. 2001). Evidence from Wisconsin rivers points to the importance of long contiguous reaches of river habitat to support catostomids where hydroelectric peaking occurs (Lyons et al. 2001). Highly fluctuating flows reduce specific habitats for certain life stages of greater redhorse, particularly those required for spawning and rearing. Shallow spawning riffles and shallow, vegetated pools along channel margins are the most impacted habitats when flows are regulated (Aadland 1993). These impacts will continue, enhancing the probability of decline in shorter reaches, unless daily flow fluctuations are reduced and fish passage is provided between segments. Dams are present on all National Forests covered under this assessment and greater redhorse populations should be assessed within fragmented habitats.

Greater redhorse are a wide-ranging species, so barriers to fish movements could prevent the completion of its life cycle, particularly if diverse habitats are unavailable in an impounded reach. In addition to dams, poorly constructed road crossings may obstruct greater redhorse movements. Cooke and Bunt (1999) made observations of greater redhorse spawning behavior below a weir in the Grand River, Ontario, and found that greater redhorse were rarely able to pass through a fishway there, while white suckers and smallmouth bass passed about 30-50% of the time (Bunt et al. 1999). Often, greater redhorse attempted to scale the fishway at the weir, but upon failure, returned downstream to spawn on available riffles (Cooke and Bunt 1999). In addition to limiting greater redhorse movement, regulation of flooding by water control structures may not allow fine sediments to be flushed from spawning riffles. Riverine habitat is eliminated in impoundments and slow water velocities result in an accumulation of fine sediments above dams.

The reduction of riparian vegetation along stream corridors may also result in a myriad of detrimental impacts on stream habitats directly and indirectly affecting greater redhorse populations. The reduction of canopy cover can increase daily fluctuations in stream temperatures; however, a change in temperature regime due to canopy cover reduction would be more evident in smaller streams where more shading exists, and may not affect greater redhorse occurring in larger streams. A decline in allochthonous contribution of organic matter (important for invertebrates), destabilized banks and increased siltation and turbidity may also occur as a result of riparian vegetation loss (reviewed by Richards and Hollingsworth 2000). Sediment may fill interstitial spaces required for deposition of eggs, and can result in decreased production of benthic macroinvertebrates, the primary component of the greater redhorses' diet. In addition, the potential for large woody debris recruitment to streams may be reduced. Large wood may function as an important substrate for invertebrate colonization, causes scouring in the formation of pools, and provides complex cover for juvenile fish (Richards and Hollingsworth 2000).

Recent research on the effects of riparian timber harvest practices designed to protect riparian function and water quality in Minnesota (Minnesota Forest Resources Council 1999) indicated mitigations may not be adequate to prevent impacts to aquatic organisms and habitats (Perry et al. 2001). Perry et al. (2001) experimentally evaluated the effects of four riparian timber harvest treatments on riparian systems and water quality attributes, including a control (no harvest), riparian control (uplands harvested, 100 ft. no-cut zone on either side of the stream), cut-to-length thinning or full-tree length thinning (residual basal area of 44 ft^2/acre). Fish community Index of Biotic Integrity scores were lower in thinned riparian treatments when compared to uncut controls (Hemstad and Newman 2001), and intolerant invertebrate taxa declined over four years of study following harvest in streams with thinned riparian zones (Fredrick and Perry 2001). Leaf litter input to streams, which is an important energy source for lower trophic levels (e.g. invertebrates), was significantly lower where timber was harvested from riparian areas (Palik 2001). In addition, percent sand substrate increased in several streams surveyed following riparian thinning, however a high degree of interannual variation in percent sand was present, which the authors believed was due to variation in timber harvest, the presence of road crossings, and timber related road use in other parts of the watershed, confounding site-specific results (Perry et al. 2001).

At the watershed scale, cumulative effects of human land use activities including stream dredging and channelization, historic logging, conversion of forest to agriculture, excessive timber harvest, inaccurately sized culverts or poorly constructed road crossings, and high road densities may alter stream sediment loads and flow regimes leading to changes in fish and invertebrate communities (Verry 2001). Since stream depth, width, and sinuosity (i.e. channel morphology) are balanced to transport specific flows and natural levels of sediment, an increase in either of these can accelerate scouring and channel erosion by altering channel morphology. For example, clearcutting more than

60% of a watershed, and associated soil compaction by logging equipment have been found to increase channel-forming floods in streams of the upper Midwest (Verry 2001; Verry et al. 1983). Higher turbidity and sedimentation as a result of stream scouring can reduce invertebrate and fish production (reviewed by Waters 1995).

Direct and indirect effects of point and non-point source chemical pollution are also harmful to greater redhorse populations, most likely due to a reduction in invertebrate food sources. Benthic macroinvertebrates are particularly sensitive to this type of water quality degradation (Barbour et al. 1999). Although few specific examples of effects to greater redhorse exist, Yoder and Beaumier (1986) found no greater redhorse in several stream reaches sampled where municipal sewage or industrial wastes had degraded water quality.

Commercial, Recreational, Scientific, or Educational Overutilization

Greater redhorse is not a species primarily targeted by anglers in Minnesota, Wisconsin, or Michigan, and impacts of scientific collections are likely insignificant. However, during spring spawning runs, greater redhorse may be susceptible to spearing or netting by humans. Below dams and at road crossings sucker spearing has been observed on the Chippewa National Forest (B. Healy, personal observation). It is unclear how spearing effects populations of greater redhorse, but judging by the number of people participating and the vulnerability of fish below dams, populations may be effected to some degree.

Disease or Predation

The impacts of disease have not been documented in greater redhorse populations, however external anomalies have been observed on individuals in the Sandusky River, Ohio (Yoder and Beaumier 1986). Juvenile and larval greater redhorse are susceptible to predation by aquatic and terrestrial predators, however due to the large size of adults, predation risk is relatively low when larger size is attained. In channelized streams lacking shallow rearing areas, predation on young-of-year or larval greater redhorse may be intensified, since predation risk from aquatic predators may increase with stream depth. Several fishes were observed preying on greater redhorse eggs immediately after spawning bouts, which included the American eel *Anguilla rostrata*, fallfish *Semotilus corporalis*, and yellow perch *Perca flavescens* (Jenkins and Jenkins 1980), but the effects on greater redhorse spawning success are unknown.

Inadequacy of Existing Regulatory Mechanisms

Protection for greater redhorse may be inadequate in Minnesota, because no protection status is listed. However, it is unclear whether harvest by humans has any measurable effect on greater redhorse populations, given the degree of habitat alteration in rivers where it occurs.

Other Natural or Human Factors

The nature of the life history of the greater redhorse appears to exacerbate existing threats attributed to habitat changes. Successful reproduction and recruitment may depend on relatively few exceptional spawning years over a lifetime of an individual (Winemiller and Rose 1992). Since interannual variability in climatic conditions may influence spawning success of species with this reproductive strategy, greater redhorse may be particularly vulnerable to long-term changes in habitat. Evidence suggests that a stable flow regime following spring floods coinciding with warming water temperatures, are required to trigger spawning activity (Cooke and Bunt 1999). In streams with modified flows, due to damming and channelization, spawning may be disrupted, decreasing the chance for successful recruitment. Similarly, when aspen clearcutting results in at least 60% of a watershed in a young forest or open condition, increases in snowmelt and storm flow peaks may occur for years afterwards (Verry et al. 1983). As young forest or open conditions increase in the watershed (up to 50% of the watershed area), snowmelt peaks may be desynchronized in forested and open areas, and as a whole, peak discharge may be lower than in forested watersheds (Verry et al. 1983). These changes to flow regimes perhaps would disrupt or alter the timing of greater redhorse spawning.

SUMMARY OF LAND OWNERSHIP AND EXISTING HABITAT PROTECTION

The lands of many watersheds within National Forest boundaries are under multiple ownership including county, state, and private entities. Although public landholders may be cooperative in efforts to protect watershed integrity, private entities have no obligation to do so. Riparian zones are managed differently than uplands along stream corridors on National Forest lands to reduce impacts of timber harvest on aquatic habitats and biota. Timber harvesting that occurs within the riparian zone on private lands may be detrimental to stream health, despite efforts on public land to protect riparian vegetation. However, as current research suggests, riparian mitigations may not be sufficient to protect stream organisms and habitat (Perry et al. 2001), but more research is needed. Improvement and protection of riparian habitats along rivers designated as Wild and Scenic may afford adequate protection in some National Forests, particularly the Huron-Manistee National Forest in Michigan.

PAST AND CURRENT CONSERVATION ACTIVITIES

It appears that little has been done in the past to conserve this species specifically, mainly because distributional information was limited. However, efforts have been underway to restore stream habitats and riparian vegetation, as well as improve fish passage. Many small dams in the Midwest are in the process of being evaluated for their economic value and viability and potential for removal, and up to 70 small dams have been removed from Wisconsin alone (reviewed by Stanley et. al. 2002). In addition, the Minnesota DNR has removed or modified several dams to allow fish passage (Ann Kuitunen, MN DNR

Ecological Services, personal communication). Although few studies have documented changes in habitat or fish populations after dam removal, Kanehl et al. (1997) found an increase in catostomids and darter abundance, as well as a decrease in tolerant omnivores (common carp) following dam removal on the Milwaukee River. Recently, several hydroelectric dams along the Chippewa River were re-licensed without fish passage mitigations (Sue Reinecke, personal communication), so redhorse populations, if present may continue to be at risk. Since the passage of environmental legislation in the 1970's (e.g. Clean Water Act), water quality has improved, indirectly effecting greater redhorse populations. In addition, the improvement of walleye spawning habitat in National Forest streams (e.g. Chippewa National Forest) may be beneficial to greater redhorse reproduction as well.

MONITORING AND RESEARCH

Existing Surveys, Monitoring and Research

Presently, no known proactive surveys are being conducted specifically for greater redhorse by National Forest personnel. However, in conjunction with state agencies, the Chequamegon-Nicolet National Forest surveys several rivers periodically, and redhorses are identified to species-level if collected. The Michigan Department of Natural Resources recently completed several assessments of Huron-Manistee National Forest watersheds (Au Sable, Manistee, Muskegon River Watersheds), which included fish surveys, however detailed accounts of greater redhorse distribution were not reported in all assessments. The Minnesota DNR actively performs (in combination or alone) gill net, electro-fishing or trawl surveys of many lakes within the Chippewa National Forest, so survey crews should be encouraged to identify the greater redhorse and record habitat data. In addition, Wisconsin DNR provides free access to its Master Fish Database, which includes over 22,000 game and non-game fish collections throughout the state, and is updated regularly. Minnesota DNR Ecological Services recently developed habitat suitability curves for greater redhorse (reported here) that are updated as additional surveys are completed (Ann Kuitunen, MN DNR Ecological Services, personal communication).

Ongoing research regarding aspects of greater redhorse ecology or biology is limited. However, Chris Bunt and Steven Cooke, Biotactic Inc., have recently published the results of their work on greater redhorse post-spawn movements and reproductive biology in the Grand River, Ontario (see Bunt and Cooke 2001; Cooke and Bunt 1999). In addition, they have recently submitted a manuscript for publication describing the larval development of greater redhorse. No other ongoing studies are known.

Survey Protocol

Extensive collections from within the National Forests covered under this assessment have not been completed. Before steps can be taken to conserve the greater redhorse, an accurate inventory must be taken of both streams and lakes within the boundaries of these Forests. Stream channel inventories may be helpful in planning sites to be surveyed for greater redhorse. Since greater redhorse occupy habitats with coarse substrates, efforts should be focused on stream reaches containing those habitat types. Within watersheds where greater redhorse are found, spawning areas also need to be identified and protected. Published information indicates that greater redhorse spawn in similar stream habitats as walleye *Stizostedion vitreum*, although somewhat later in the summer. Artificial walleye spawning reefs in streams of National Forests could be monitored later in the spring, as waters warm to the appropriate temperature for greater redhorse spawning, to determine if these structures are used by greater redhorse. Electro-fishing appears to be the most effective method for sampling greater redhorse, as they are wary and difficult to capture using seines or trap nets (Yoder and Beaumier 1986).

Research Priorities

Further knowledge of greater redhorse movements, habitat use, and diet of all life stages is essential to develop conservation measures for this species. Information of this nature specific to greater redhorse is extremely limited, particularly for juvenile or young-of-year fish. Telemetry studies are needed to pattern migrations and determine habitat use of greater redhorse throughout the year, so essential habitat can be protected or enhanced. Although this species is thought to be an inhabitant of medium to large sized rivers, it has also been found in lakes. However, greater redhorse spawning has never been documented in lentic habitats, so telemetry would provide insight into the importance of lakes as greater redhorse habitat. While conducting fish and habitat inventories, it would be helpful to record whether a given reach is free-flowing or may be isolated by barriers to fish movement. In addition, population data (e.g. age-structure, growth, recruitment) should be recorded for isolated populations. A correlation can then be made between greater redhorse abundance and the patch or reach size required to maintain viable populations. Where greater redhorse are found, temperature regimes should be monitored to further identify appropriate habitat. Finally, relating greater redhorse abundance to land use and watershed conditions would address specifically how land management may impact their populations.

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