Plains Minnow (*Hybognathus placitus*): A Technical Conservation Assessment

Prepared for the USDA Forest Service,
Rocky Mountain Region,
Species Conservation Project

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Authors' Biographies

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Dr. William J. Miller has over 23 years experience in fisheries, instream flow, and aquatic ecology studies. He has worked extensively throughout the western U.S. and is a recognized expert in the areas of Colorado River basin endangered fish species, instream flow, water temperature modeling and habitat assessments. Dr. Miller's experience includes research and evaluations for several threatened, endangered, and candidate aquatic species in the Colorado River and Platte River basins. He has extensive experience in designing and conducting studies using the Instream Flow Incremental Methodology (IFIM), instream water temperature modeling and developing and implementing ecological models for aquatic systems. He has developed habitat suitability criteria for both anadromous and resident salmonids as well as warm-water game and forage species. Dr. Miller is a Certified Fisheries Scientist (No. 2008).

Cover Photo Credit

Plains minnow (*Hybognathus placitus*).

Summary of Key Components for Conservation of the Plains Minnow

Status

The plains minnow (*Hybognathus placitus*) is considered a sensitive species within the USDA Forest Service (USFS), Rocky Mountain Region (Region 2). This species has evolved and adapted to the specific environmental conditions of Great Plains streams that include the eastern portions of Region 2. These conditions include fluctuating stream flows with shifting sand substrates. The abundance and distribution of plains minnows in Region 2 have either declined or become more restricted as a result various anthropogenic impacts.

Primary Threats

Primary threats to this species generally result from anthropogenic activities. Much of the historic change to the aquatic environment and the majority of future threats are related to water management and flow modifications. Diversion of water has resulted in changes in flow regime in both mainstem rivers and tributary streams. Construction of passage barriers, such as diversion dams and reservoirs, have both degraded and fragmented habitat. Introduced non-native species have become both predators and competitors with the plains minnow. Other threats include hybridization, altered flow regimes, disturbance of riparian zones, and landscape scale changes that reduce the natural function of the stream ecosystem. Detailed information concerning the distribution, life history, population trends, and community ecology for this species is relatively limited. Specific local and regional information must be obtained prior to the development of management plans.

Primary Conservation Elements, Management Implications and Considerations

Management plans need to focus on accurate surveys of each basin in the historic range of the plains minnow. The needs of plains minnow are specific to the conditions in which they evolved. The overall objective should be to manage the fluvial system, to the extent possible, in order to emulate historic conditions. These conditions include a natural hydrograph with ample magnitude to maintain suitable habitat for spawning and rearing and a native fish assemblage. Detailed population information along with comprehensive physical and chemical characterizations of each stream will allow biologists to develop range-wide conservation plans and to tailor management plans to individual drainages.

TABLE OF CONTENTS

EDITOR: Richard Vacirca, USDA Forest Service, Rocky Mountain Region

LIST OF TABLES AND FIGURES

Table:

Figures:

INTRODUCTION

This assessment of the plains minnow (*Hybognathus placitus*) is one of many being produced to support the Species Conservation Project for USDA Forest Service (USFS), Rocky Mountain Region (Region 2). The plains minnow is the focus of an assessment because it is considered a sensitive species in Region 2. Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance and/or in habitat capability that would reduce its distribution (FSM 2670.5 (19)). Due to concerns with population viability and abundance, a sensitive species may require special management, so knowledge of its biology and ecology is critical. This assessment addresses the biology, conservation and ecology of plains minnow throughout its range in Region 2.

Goal

The purpose of this species conservation assessment is to provide forest managers, research biologists, and the public with a thorough discussion of the current understanding of the biology, ecology, conservation status, and management of the plains minnow. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. Rather, it provides the ecological background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, it cites management recommendations proposed elsewhere and examines the success of those that have been implemented.

Scope

This assessment examines the biology, ecology, conservation status, and management of the plains minnow with specific reference to the geographic and ecological characteristics of the USFS Region 2. Although some of the literature on the species may originate from field investigations outside the region, this document places that literature in the ecological and social context of the Great Plains in Region 2. Similarly, this assessment is concerned with the reproductive behavior, population dynamics, and other characteristics of the plains minnow in its current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting the synthesis, but it is placed in a current context.

The intent of this assessment was to produce a valuable synthesis of information in a timely manner that could be used by USFS managers and biologists for addressing species needs as well as for revising forest plans. In producing this assessment, we reviewed refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies. Not all publications on plains minnow are referenced in the assessment, nor were all published materials considered equally reliable. The assessment emphasizes refereed literature because this is the accepted standard in science. Non-refereed publications or reports were used when information was unavailable elsewhere, but these were regarded with greater skepticism. Unpublished data (e.g., Natural Heritage Program records) were important in estimating the geographic distribution of this species. These data required special attention because of the diversity of persons and methods used in their collection.

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, strong inference, as described by Platt, suggests that experiments will produce clean results (Hillborn and Mangel 1997), as may be observed in certain physical sciences. The geologist, T. C. Chamberlain (1897) suggested an alternative approach to science where multiple competing hypotheses are confronted with observation and data. Sorting among alternatives may be accomplished using a variety of scientific tools (experiments, modeling, logical inference). In some ways, ecology is like geology in the difficulty in conducting critical experiments and the subsequent reliance on observation, inference, good thinking, and models to guide understanding of the world (Hillborn and Mangel 1997). A problem with using the approach outlined in both Chamberlain (1897) and Platt (1964) is that there is a tendency among scientists to resist change from a common paradigm. Treatment of uncertainty necessitates that a wide variety of hypotheses or experiments by undertaken to test both the true or false nature of the uncertainties at hand (Vadas 1994).

Confronting uncertainty, then, is not prescriptive. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate. While well-executed experiments represent a strong approach to developing knowledge, alternative approaches such as modeling, critical assessment of observations, and inference are accepted as sound approaches to understanding and are used in synthesis for this assessment.

The synthesis of material for the plains minnow included the use of the limited data sets that are available regarding the distribution, abundance, movements, habitat requirements, and life history requisites of the species. Like many non-game native fish, this species has not been extensively studied within Region 2, nor have all the parameters needed for the species assessment been studied extensively. The limited amount of information on key characteristics for the species and our lack of understanding concerning the needs of the species create a great deal of uncertainty pertaining to the assessment for conservation of plains minnow. This species assessment has synthesized a wide range of available data throughout Region 2 and the Great Plains including historical and current distributions, habitat needs, and management requirements. The general lack of precise information regarding species distribution on National Forest System land or near forest boundaries limits the actual data that can be used for this assessment. We have inferred from available data, using a sound scientific approach, to present an understanding of the current needs of the species for the purpose of this assessment.

Application and Interpretation Limits of This Assessment

Information used in this assessment was collected from studies that occurred throughout the geographical range of this species. The greatest emphasis for information regarding life histories and ecology was placed on studies and reports that were specific to Region 2. Although most information should apply broadly throughout the range of the species, it is likely that certain life history parameters (e.g., growth rate, longevity, spawning time) will differ along environmental gradients. Information regarding conservation strategies of the species pertains specifically to Region 2 and does not apply to other portions of the species' range.

Publication of Assessment on the World Wide Web

To facilitate the use of species assessments in the Species Conservation Project, they are being published on the Region 2 World Wide Web site (www.fs.fed.us/r2/projects/scp/assessments/index.shtml). Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More important, it facilitates their revision, which will be accomplished based on guidelines established by Region 2.

Peer Review

Assessments developed for the Species Conservation Project have been peer reviewed prior to their release on the Web. This report was reviewed through a process administered by the American Fisheries Society, which chose two recognized experts (on this or related taxa) to provide critical input on the manuscript. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

The plains minnow is not federally listed as threatened or endangered. The USFS considers it to be a sensitive species in Region 2. The state of Colorado lists the plains minnow as endangered, while Kansas recognizes it as a species need of conservation (SINC). Plains minnow is not recognized as state endangered, threatened, or species of concern in Wyoming, Nebraska, and South Dakota. For states within Region 2, Nature Serve (2003) ranks the plains minnow as follows: Colorado (SH, possibly extirpated), Kansas (S2S3, imperiled/vulnerable), Nebraska (S4, apparently secure), South Dakota (S5, secure), and Wyoming (S3, vulnerable). The species has the following ranks in states outside of Region 2: Arkansas (SX, presumed extirpated), Illinois (S2, imperiled), Iowa (S4, apparently secure), Kentucky (S1, critically imperiled), Missouri (S2, imperiled), Montana (S4S5, apparently secure/secure), New Mexico (S3, vulnerable), North Dakota (unranked), Oklahoma (S5, secure), Tennessee

(S1, critically imperiled), Texas (S4, apparently secure), and Utah (SE, exotic).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

At this time there are no existing conservation or management plans that pertain specifically to the plains minnow in Region 2. In Colorado, plains minnow are considered a "restricted use" species, meaning it is illegal to possess or harvest this species. Regulations in Wyoming are designed to prevent any net loss of habitat for plains minnow. Few other laws directly apply to the management of this species. In much of its range, the plains minnow is commonly used as bait. Fish are harvested from wild populations through seining or other methods. Oklahoma, New Mexico, Texas, Montana, Nebraska, Wyoming, and Kansas currently allow this practice. Although it is understood that recent water use practices are generally responsible for the extirpation of this species from portions of its range and for decline in populations throughout its range, existing survey information is insufficient to assess the adequacy of current laws and management practices for maintaining the viability of existing populations of plains minnow.

Biology and Ecology

Systematics and general species description

The plains minnow (*Hybognathus placitus*) is "a large, silvery, terete minnow with a small head, small subterminal mouth, and small knob on the inside tip of the lower jaw" (Miller and Robinson 1973). It is tan to brown or olive dorsally, silver laterally, and white ventrally with colorless fins. The total length is usually less than 127 mm (5 inches). The plains minnow is a member of the minnow family (Cyprinidae), which is defined by one to three rows of pharyngeal teeth, thin lips, large eyes, abdominal pelvic fins, and usually soft fin rays. This species is similar to the Mississippi silvery minnow (*H. nuchalis*) but with smaller eyes, a wider head, and usually has more than 15 scale rows below the lateral line in contrast to *H. nuchalis* which has less than 15 (Miller and Robinson 1973). The plains minnow shows some predicable sexual dimorphism. Populations in Texas were found to display sexual dimorphism with males having a larger head, longer first dorsal fin ray, longer caudal peduncle, and shorter trunk. The longer first dorsal fin ray was found to be a reliable character for separating males and females (Ostrand et al. 2001).

The systematics of the genus *Hybognathus* has been complicated and confused in the past. The genus has been shown to be a monopyletic taxon, but its relationships to other genera in the family Cyprinidae are still unclear (Schmidt 1994). Nearly every species in this genus has been mistakenly considered a synonym of *H. nuchalis* at some time (Cook et al. 1992, Schmidt 1994). The plains minnow has also been considered a possible sub-species of *H. nuchalis* (Niazi and Moore 1962). Studies of 22 allozyme loci of the Rio Grande silver minnow (*H. amarus*), the Mississippi silvery minnow, the brassy minnow (*H. hankinsoni*), and the plains minnow showed that the latter demonstrated a distinct genetic divergence among all of these taxa which is consistent with the hypothesis that all of these taxa are valid species (Cook et al. 1992). The morphology of the pharyngeal filtering apparatus was shown to be unique in the plains minnow when compared to seven other species of *Hybognathus* (Hlohowskyj et al. 1989). Evidence of the divergence of the plains minnow and the Mississippi silvery minnow was also obtained from studies of the differing structures of the weberian apparatus of each taxon (Niaza and Moore 1962).

The following description of the plains minnow was given by Sublette et al. (1990):

> *"Coloration: Back olivaceous, middorsal stripe present; sides silvery; abdomen whitish; peritoneum black.*
>
> *Head: Bluntly triangular; mouth subterminal. Snout fleshy, rounded; overhanging the mouth. Lower jaw crescent shaped in ventral view, tapering to sharp edge. HL (head length)/Or L (orbital length) = 5.1(4.7-6.0)*[1]*. Sn L(snout length)/Or L = 1.7(1.6-2.0). Pharyngeal dentition 0,4-4,0. Posterior process of basioccipital bone narrow, parallel in the vertebral column with muscle attachments contiguous. SL/HL = 4.0(3.9-4.3).*
>
> *Body: Subterete, slightly compressed. Specimens as long as 95 mm taken in New Mexico. Lateral line complete, with 38(34-42) scales. Scales above lateral line 7(5-8); below 5(4-6). Scales*

[1]Counts are presented with the most common or average number outside the brackets and the range of values that have been reported inside the brackets.

with about 10 radii. Gut long and coiled. Vertebrae 33-35(32-36).

Fins: Dorsal triangular, origin anterior to that of pelvics. Pectorals pointed, second ray longest. Pelvics ovate. Anal triangular. Caudal forked, lobes pointed. Rays: Dorsal 8(7-9) rays 2 and 3 longer than ray 1; pectorals 16(14-18); pelvics 8(7-8); anal 8(6-10); caudal 19(16-21).

Sexual Differences: Male with numerous very fine nuptial tubercules on top of the head, dorsum and on the side of the pectoral fin appressed to the body."

Distribution and abundance

Plains minnows are found in Kentucky, Tennessee, Illinois, Iowa, Missouri, North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Texas, Montana, Wyoming, Colorado, and New Mexico, and they have been introduced into Utah (Lehtinen and Layzer 1988). While this species is doing relatively well in Oklahoma, South Dakota, Montana, Nebraska, and Iowa, its range has been restricted within these states. Populations in most other states in its range are in decline. As streams are desiccated, populations of plains minnows are extirpated from the smaller tributaries leaving only mainstem populations; or in some cases, water regulation on mainstem streams has altered the natural hydrology leaving populations restricted to smaller tributaries.

Within Region 2, the plains minnow was historically distributed in suitable habitat throughout the Arkansas River, Platte River, Kansas River, and Missouri River basins. Due to an absence of distributional data for plains minnow prior to European settlement of the Great Plains, it is impossible to know the entire historical distribution of the species and all of the specific localities where it was once found. Recent collection data are also limited and do not give a complete or accurate description of the plains minnow's current distribution.

Plains minnows are abundant relative to other fish species in the Missouri River along the Kansas border (Cross and Moss 1987). The population in the Missouri River is probably the strongest and most dense population in Region 2. They also inhabit numerous streams in Kansas, Nebraska, and western South Dakota, and streams in the eastern portions of Colorado and Wyoming. A map of USFS lands (**Figure 1**) can be compared to a map of watershed Hydrologic Unit Boundaries (HUB) that identifies where plains minnow have been collected in Region 2 (**Figure 2**). USFS administrative units on, or near, which plains minnows can be found include Cimarron National Grassland (Kansas), Comanche National Grassland (Colorado), Thunder Basin National Grassland (Wyoming), Buffalo Gap National Grassland (South Dakota), Black Hills National Forest (South Dakota), Fort Pierre National Grassland (South Dakota), Samuel R. McKelvie National Forest (Nebraska), Oglala National Grassland (Nebraska), Pawnee National Grassland (Colorado), and Nebraska National Forest (Nebraska).

Population trend

The plains minnow maintains stable populations in many localities, but it has also declined throughout its range. Once the most common fish of the Arkansas River system, its abundance and distribution have decreased substantially in the Arkansas River drainage in Kansas in the last 30 years (Cross and Moss 1987, Taylor and Miller 1990). This species has declined to less than 1 percent of the overall fish population in the Arkansas River from its formerly abundant numbers due to the effects of impoundments, land use, diversion of surface flow for irrigation, and reduction of water table levels in response to mining of groundwater for irrigation (Cross and Moss 1987).

Similarly, the plains minnow was once common and widespread in the Kansas River Basin but has declined dramatically throughout that system (Wenke et al 1993). The species has possibly been extirpated from portions of the western Kansas River Basin, including the Republican, Solomon, Saline, and Smoky Hill rivers, and it is now rare in the lower portion of the Kansas River Basin (Cross and Moss 1987, Wenke et al. 1993).

The plains minnow has gone from being the dominant species in the Canadian River drainage (Oklahoma and Texas) to being very rare in that system (Bonner and Wilde 2000). This is probably due to the reduced occurrence of large floods (Bonner and Wilde 2000). The impoundment of the Double Mountain Fork in the Brazos River (which forms the Lake Alan Henry Reservoir, Texas) was thought to be responsible for the extirpation of the plains minnow from reaches above the dam where it was formerly one of the dominant species in the river (Wilde and Ostrand 1999).

Changes in the Missouri River have resulted in a less severe decline in plains minnow populations. Flood-control programs, navigational developments,

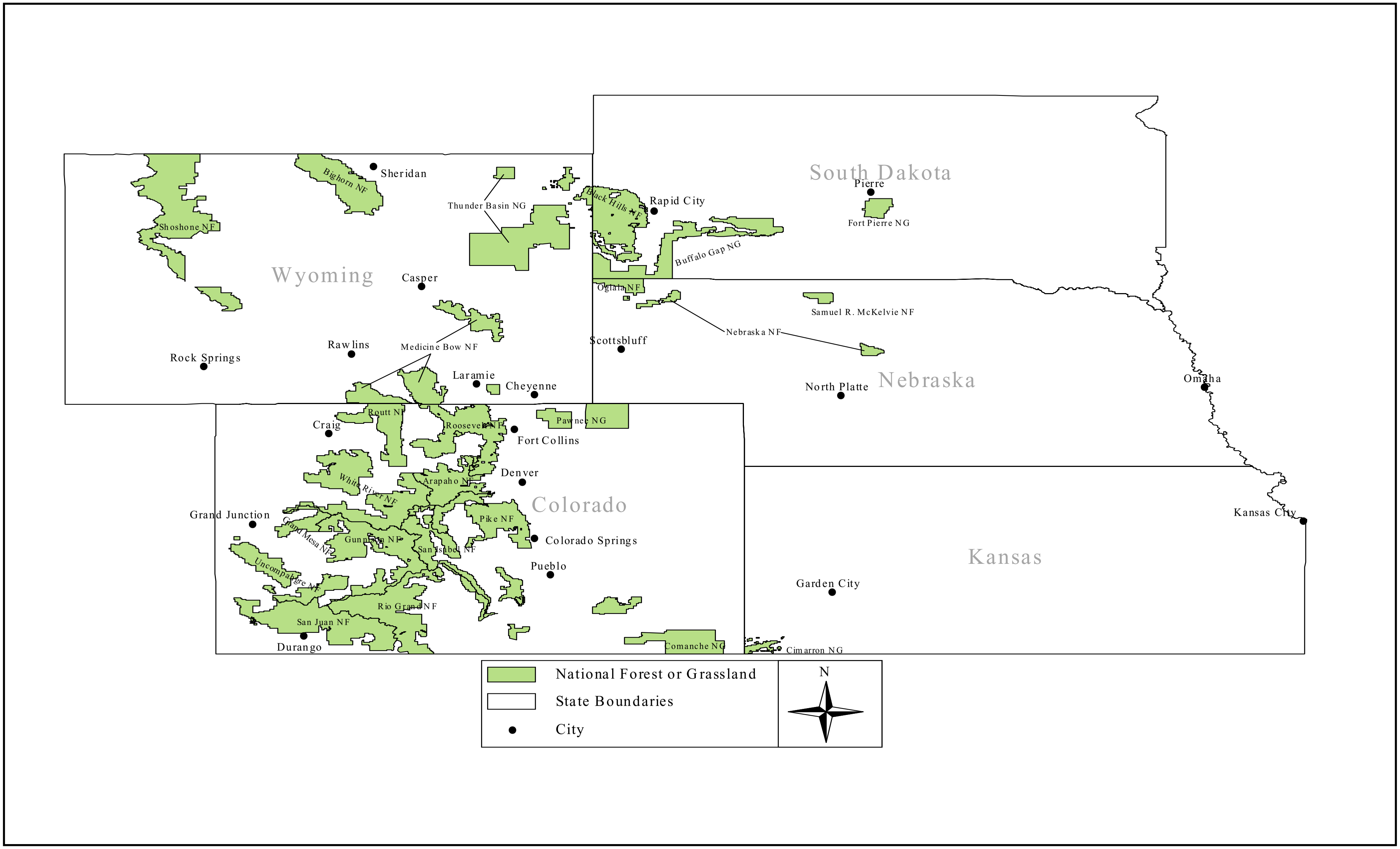

Figure 1. USDA Forest Service Region 2 national forests and grasslands.

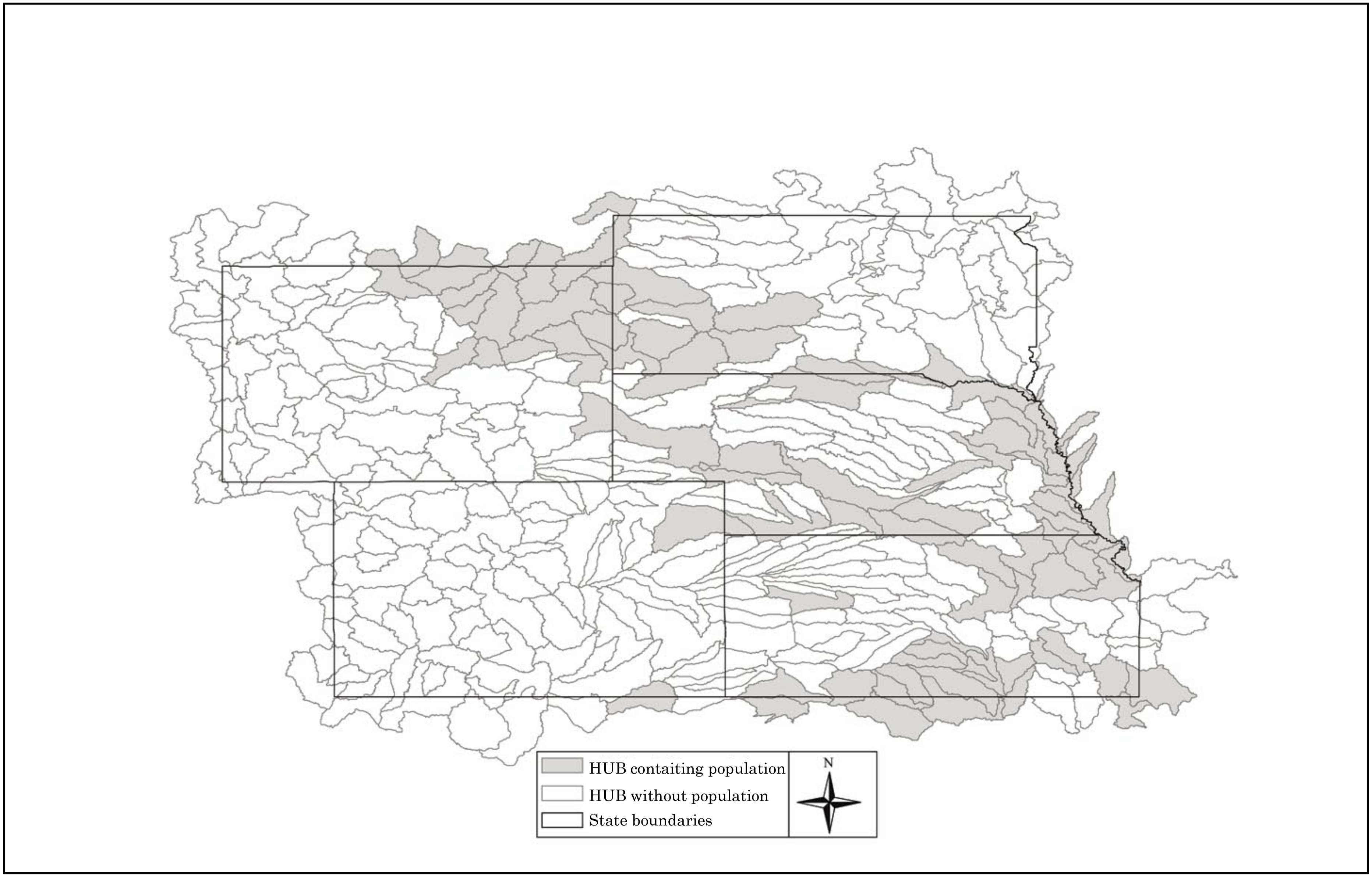

Figure 2. USDA Forest Service Region 2 hydrological unit boundaries (HUB) containing plains minnow populations.

and impoundments have resulted in reduced turbidity and the stabilization of the historically shifting braided channel (Cross and Moss 1987). The elimination of flood events in streams that contain plains minnows has removed the historical cues for spawning and reduced the quality and quantity of available spawning habitat (Wilde and Ostrand 1999).

The expansion in abundance and range of blackstripe topminnow (*Fundulus notatus*), bluegill sunfish (*Lepomis macrochirus*), largemouth bass (*Mircopterus salmoides*), and creek chub (*Semotilus atromaculatus*) was found to correlate with a decline of plains minnow and other native fish populations in the Missouri River (Winston 2002). The mechanism by which the expansion of these species has influenced plains minnow abundance and distribution is not well understood, but it is likely that predation and competition may be important factors.

In streams with meandering channels, the elimination of natural flood cycles leads to a decrease in channel migration rate. This has lead to the reduction in growth of riparian areas in the northeastern portion of the Great Plains. The elimination of natural flood cycles leads to the narrowing of braided stream channels into straighter deeper channels. This has effectively eliminated the shifting sandbar/highly turbid habitat that should occur in this ecosystem. An observed result of this process has been observed as an encroachment on the historically shifting streambed by riparian vegetation in the southwest portion of the Great Plains (Friedman et al. 1998). The degradation of braided channel systems due to highly modified flow regimes (e.g., reduction of peak flows, flow stability, reduced turbidity) in southwestern streams has contributed to the decline in plains minnow populations and possible extirpation from some drainages (i.e., Arkansas River Basin in Colorado) (Cross and Moss 1987).

Cross and Moss (1987) found that the decline in plains minnows in the Arkansas River (Colorado and Kansas) was associated with declining discharge and changes in channel characteristics. The changes are caused by diversion of surface water, impoundments, and land use practices that modify the flow regime, and extensive mining of groundwater. In the western Kansas River Basin, declines in plains minnow was attributed to declining discharge regimes and impoundments (Cross and Moss 1987). These practices involved the withdrawal of water for irrigation accounting for 1/3 of the decline in discharge, and landscape alterations resulting in increased evaporation accounting for 2/3 of the decline in discharge. The decline in plains minnows in the lower Kansas River Basin has been accelerated due to the modification of instream flow in all rivers in the drainage by a system of reservoirs (Cross and Moss 1987).

Activity pattern

Very little information exists regarding the movement and activity patterns of plains minnows. They use various suitable habitats during stable flows but move into concentrated areas (i.e., deeper pools) during stressful times of low or high flows (Matthews and Hill 1980). In the Red River (Oklahoma), plains minnows were found to congregate in pools in large numbers during the autumn and winter (Taylor et al. 1996). Future research will be required to better understand diurnal vs. nocturnal patterns, migration, dispersal and larval drift/movement.

Habitat

The plains minnow typically inhabits channels of shallow, fluctuating streams with shifting sand substrates (Cross and Moss 1987). The species can be found in both turbid and clear streams (Wenke et al. 1993). The plains minnow thrives in harsh environments in the southwest when few competing species are present (Lehtinen and Layzer 1988, Kelsch 1994). It typically inhabits large, often-turbid rivers that have exposed, shallow, sand-filled channels (Taylor and Miller 1990). Preferred habitats include backwaters and gentle eddies (Lehtinen and Layzer 1988). Plains minnows are often collected in areas with aquatic vegetation (Kelsch 1994). Shallow backwaters in braided channels are often used as feeding areas (Wenke et al. 1993). Matthews and Hill (1980) reported that in the Canadian River (where the plains minnow was found to be one of the dominant species), the habitats used were characterized by relatively low oxygen, low temperature, and low current velocity. In contrast to other studies, backwater areas and areas of shallow flowing water were not identified as habitats of importance (Matthews and Hill 1980). Plains minnows were found to use various suitable habitats during conditions of mild flow, but they moved into deeper pools during stressful times of low or high flows (Matthews and Hill 1980). Peters et al. (1988) found that the highest densities of plains minnow in the lower Platte River, Nebraska occurred at depths of 20 to 30 cm (7.9 to 11.8 inches) and current velocities of 10 to 40 cm per second (0.3 to 1.3 ft. per second). They concluded that these were the optimum conditions for the existence of this species.

The headwaters of many plains streams are characterized by cycles of flooding followed by low flows caused by low rainfall. During times of low flow, the streams often become a series of isolated pools. Plains minnow have adapted for survival in these pools as they evaporate and conditions become more extreme. In laboratory experiments, the Critical Thermal Maxima for the plains minnow was found to be 39.7 ± 0.7 °C (103.5 ± 33.3 °F), the salinity tolerance LC50 = 16 ± 1.94 percent, and minimum dissolved oxygen 2.08 ± 0.12 mg per L (Ostrand and Wilde 2001). Experiment results indicate that in oxygen-deficient water, the plains minnow prefers the highest temperature (<30 °C [86 °F]) at which it can operate within the zone of respiratory independence (Bryan et al. 1984). Backwater areas may be important nursery grounds for plains minnows because food is often abundant and available there (Lehtinen and Layzer 1988).

Food habits

Detailed studies on feeding habits of plains minnow are generally lacking. Winston et al. (1991) report that this species feeds on epipsammic algae and detritus. Morphological adaptations that support this feeding behavior include a long, coiled gut and an inferior, crescent-shaped mouth. Plains minnows have also been observed eating their own eggs (oophagy) during spawning (Platania and Altenbach 1998). Research is needed to obtain information regarding feeding preferences and requirements, seasonal differences in feeding, differences in feeding due to fluctuations in flow regime, competition with native and introduced species for food resources, larval feeding habits, and the effects of food availability on population trends, migration, and habitat usage.

Breeding biology

The plains minnow spawns from April to August (Lehtinen and Layzer 1988, Taylor and Miller 1990). Peak reproduction condition of most females examined occurred in June, when mean ovarian weights and mean ova diameters were largest (Lehtinen and Layzer 1988). Other data indicate a bimodal length distribution of young-of-the-year (YOY) in June and July, suggesting that two peaks in spawning activity occurred from April to May 1979 (Lehtinen and Layzer 1988). Plains minnows appear to be well-adapted for the highly variable spring-summer hydrology characteristics of Great Plains stream ecosystems (Platania and Altenbach 1998). Its reproductive cycle is related to the high variable flows typical of Great Plains streams, with spawning commencing at high or receding flows. Typically, flows recede in late May and rise again in early June. These two peaks in the hydrograph correspond with the bimodal distribution of YOY seen in late June. Another strong YOY mode occurred in a July 1986 sample that coincided with a fivefold increase in flow that occurred from 8-9 July (Taylor and Miller 1990). Females begin to mature sexually at different sizes. Females as small as 43 mm (1.7 inches) occurred with maturing ovaries in late April 1986 and 1987. Yet, two 56 mm (2.2 inches) females were immature when collected in May 1987 (Taylor and Miller 1990). Length-frequency distributions indicated that the breeding population was composed of 1 and 2 year old fish (Lehtinen and Layzer 1988). It appears that YOY do not spawn (Lehtinen and Layzer 1988). YOY plains minnows reaching 45 to 50 mm (1.7 to 2 inches) during their first summer had immature ovaries (Taylor and Miller 1990).

Ovaries of plains minnows mature rapidly. All females in a March 1979 collection were undeveloped, but 40 percent of females were sexually mature by April (Lehtinen and Layzer 1988). Maturation of ovaries and ova was positively correlated with increasing day length and temperature (Lehtinen and Layzer 1988). Maturation of ovaries may also be related to fish length (Lehtinen and Layzer 1988). The number of ova and total body weight show a highly significant correlation, with fecundity ranging from 417 to 4134 (mean 817) (Taylor and Miller 1990).

The reproductive strategy of the plains minnow includes semi-buoyant eggs, intermittent spawning, and possibly spawning during only high water. This is a logical adaptation to the highly variable flows of many Great Plains streams (Lehtinen and Layzer 1988). The eggs are scattered over the substrate communally with no nest guarding or territorial behavior (Taylor and Miller 1990). Aggregations of spawning plains minnows have been found in quiet water along sandbars and in backwaters during receding flows, but turbid water prevented direct observation of spawning (Taylor and Miller 1990). Spawning at high or receding flows, differential spawning within the same year-class, fractional spawning, and extended survival of part of the population (age 2) all appear to be adaptive responses to the instability of plains rivers (Taylor and Miller 1990).

The species is short-lived with populations usually composed predominantly of YOY and 1 year old fish (depending on the season) with few fish reaching age 2 (Taylor and Miller 1990). Mortality of adults was assessed from their decline in relative numbers through the reproductive season. By late June, the relative abundance of adult fish had declined substantially, indicating post-spawning mortality (Taylor and Miller 1990).

The plains minnow is part of a reproductive guild defined by a pelagic-broadcast spawning behavior and the production of non-adhesive, semi-buoyant eggs (Platania and Altenbach 1998). Spawned eggs were non-adhesive, dispersed throughout aquaria, and settled to the bottom where they quickly absorbed water and expanded (Platania and Altenbach 1998). Egg diameter was about 1 mm (0.04 inches) on expulsion. The perivitelline space was minimal upon fertilization but expanded within 10 to 30 minutes, causing egg diameters to increase to approximately 3 mm (0.1 inches) (Platania and Altenbach 1998). Eggs sink to the bottom where they may be covered with silt and die if water current is not maintained (Platania and Altenbach 1998). Characteristics of egg development suggest that these fish spawn in the mid- or upper water column during high flows (Platania and Altenbach 1998). The rapid development and hatching of eggs is perceived as a strategy for survival of fishes of the Great Plains or desert ecosystems, which are characterized by extremely erratic spring and summer flows (Platania and Altenbach 1998). Embryos were described as having sharp-angular edges upon fertilization; guild members' embryos were rounded and flattened (saucer-shaped); eggs were spherical; and the chorions were smooth and ornamented with single raised micropyles (Platania and Altenbach 1998).

Generalized spawning behavior of plains minnow was exhibited by males pursuing a single female and nudging her abdominal region. When the female is ready to spawn, a single male wraps around the female, at which time, eggs and milt were simultaneously released (Platania and Altenbach 1998). Often a male would approach a female from below and nudge her near the anal fin or posterior portion of the abdomen, as though to force her upward. Sometimes it was observed that the nudge was violent, frequently leaving a momentarily visible indentation in her abdomen (Platania and Altenbach 1998). After the nudging occurred, the individuals would align themselves laterally head to head. Both would make a series of quick turns while the pursuing male would rapidly undulate the posterior half of his body against the female, nudging her with his snout as though attempting to change her direction. The female then would turn toward the male and away from the male changing directions rapidly and unpredictably (Platania and Altenbach 1998). In some encounters, the male moved from a head-to-head lateral alignment to a bent-vertical position, near perpendicular alignment with head and tail curved slightly with the female. This may have been a precursor to a "spawning embrace" (Platania and Altenbach 1998). The spawning sequence began with a male aligned laterally on the right side of the female in a head-to-head orientation, with his head and abdomen slightly lower and tail slightly higher than the female. Both fish swam in tandem. The male curved his head under vent and wrapped his caudal fin and peduncle over the back of the female, who twisted sideways and curved her body. The male rapidly brought his head toward his tail, appearing to squeeze the female's midsection. Simultaneously, the female released her eggs. The female continued to release eggs as the male returned to normal posture. Duration of the actual spawning event (wrap and release) lasted approximately 66.6 m per second (Platania and Altenbach 1998).

Reproduction usually consisted of several spawning episodes with at least 10-minute intervals between the events (Platania and Altenbach 1998). Pre-spawning male to male interactions in the form of direct contact were infrequent; however, males would chase each other even if neither were adjacent to a female (Platania and Altenbach 1998). If and when direct contact occurred, it was in short duration and consisted of a male individual using his snout to nudge another male in the abdomen or caudal fin (Platania and Altenbach 1998).

Repeatedly, male and female individuals were observed eating eggs (Platania and Altenbach 1998). Egg-eating behavior sometimes occurred immediately after spawning and prior to expansion of the eggs. Fish swam through the concentrated burst of eggs eating an unknown number. Eggs were also consumed after they had fully expanded, but not nearly to the same extent as observed immediately after the spawning event (Platania and Altenbach 1998).

Demography

The plains minnow spawns in the spring and early summer with spawning behavior correlated with a declining hydrograph. Spawning occurs in the water column with non-adhesive demersal eggs being carried along by the current after release. Variations in fecundity between altered and unaltered systems have not yet been investigated. Details of the population genetics of this species have not been well characterized. The effects of isolation on disjunctive populations have not been investigated. Factors limiting population growth have not been characterized, but the loss of useful habitat in many river systems has certainly caused a decrease in potential population size and diversity. Information is also lacking on the extent and effects of hybridization. The plains minnow is known to hybridize with the Rio Grande silvery minnow, a federally endangered species. This was noted as possibly being partially responsible for the decline of the Rio Grande silvery minnow (Bestgen and Platania 1991).

The development of a meaningful life cycle diagram for the plains minnow would require life stage-specific data regarding survival rates, fecundity, and sex ratio. Existing data on plains minnow survival rates and fecundity are sparse or inadequate at this time. The information that is available is highly variable and typically restricted to specific locations. The following life cycle description is presented as a tool to recognize existing data and to identify data needed to refine the model (**Figure 3**).

Input data needed for a population projection matrix model consists of sex ratios, age-specific survival, and age-specific fecundity. These characteristics often depend on location (e.g., stream size, temperature, habitat) and could vary considerably in Region 2. Data specific to the plains minnow are incomplete and restricted to a few site-specific studies. Lehtinen and Layzer (1988) and Taylor and Miller (1990) provided information on sex ratios, growth, age structure, and age of sexual maturity for plains minnow populations. Taylor and Miller (1990) reported sex ratios for a river in central Oklahoma and found a slight dominance by females; however, it was suggested that deviation from a ratio of 1:1 was not biologically significant. Lehtinen and Layzer (1988) and Taylor and Miller (1990) agree that females become sexually mature at age 1, and few fish survive to age 2. Fecundity values used in the life cycle model were based on Taylor and Miller (1990), who reported a mean fecundity of 817 mature ova produced by 31 mature females that were 51 to 87 mm (2 to 3.4 inches) standard length (SL). Fecundity values ranged from 417 to 4,134 and were highly correlated ($P = 0.0001$) to SL. This suggests that the few older fish produce more eggs. Based on this information, a life cycle diagram was constructed using a 1:1 sex ratio and an average fecundity of 800 ova for age 1 fish and 2000 ova for age 2 fish (**Table 1**, **Figure 3**).

The plains minnow is a short-lived species with a high mortality rate from egg through age 1, and a high mortality rate following the first year of spawning. Age-specific survival rates for the life cycle diagram were estimated from population age structure data provided by Lehtinen and Layzer (1988) and Taylor and Miller (1990). Estimates were used for portions of the age structure that were inconclusive or incomplete. Spawning and recruitment likely take place each year but with a high rate of variability. Overall success depends on location and fluctuating environmental conditions.

Community ecology

Plains minnows are part of a guild that typically inhabits channels of shallow, fluctuating streams with shifting sand substrates (Cross and Moss 1987). In the Canadian River, which is highly variable in its discharge,

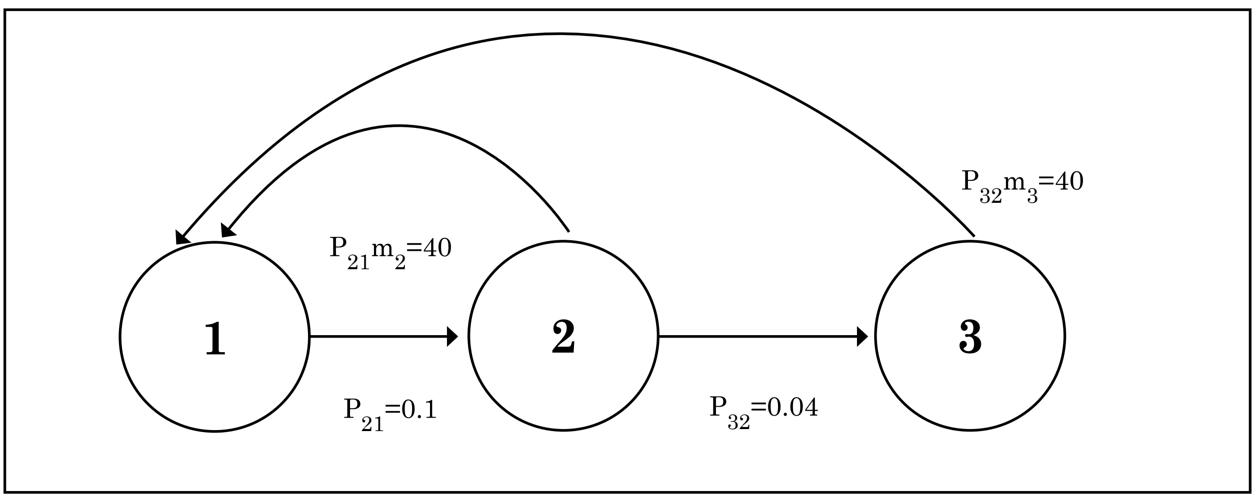

Figure 3. Life cycle graph for the plains minnow. The number of circles (nodes) represent the 3 age-classes. The arrows connecting the nodes represent survival rates. Fertility is represented by the arrows that point back to the first node. Fertilities involve offspring production, m_i, number of female eggs per female as well as survival of the female spawners. Note that reproduction begins after one year of growth.

Table 1. Parameter values for the component terms (P_i and m_i) that make up the vital rates in the projection matrix for plains minnow. Survival rates were estimated from age structure data estimated from Lehtinen and Layzer (1988) and Taylor and Miller (1990). Taylor and Miller (1990) provided data from which fecundity was estimated. The model assumes a 1:1 sex ratio so the egg number used is equal to half the total fecundity.

Parameter	Numeric value	Interpretation
P_{21}	0.1	First year survival rate
P_{32}	0.04	Survival from age 1 to age 2
M_2	400	Number of eggs produced by an age 1 female
M_3	1000	Number of eggs produced by an age 2 female

plains minnows showed a high affinity for sites with cooler water, low velocity flows, and lower dissolved oxygen. This affinity was stronger than any associations with other fish species (Matthews and Hill 1980). Habitat partitioning was evident only when flows were suitable (Mathews and Hill 1980). Fish assemblages in the Red River were also found to respond to temporal variation in habitat, adjusting to flow regimes and habitat availability. In this system, habitat use by plains minnow populations was found to shift rapidly in the spring corresponding to rapid shifts in flow and habitat availability. During the fall, populations were found to be more spatially stable (Taylor et al. 1996).

The most destructive anthropogenic effects on plains minnow ecology are factors such as channelization and the associated habitat modifications that are caused by the elimination of historical hydrological cycles involving flood and drought stages (Cross and Moss 1987). The response of most Great Plains rivers to the construction of dams has been a downstream narrowing of formerly braided channels. This has resulted in changes in the flora present in riparian areas. Consequently, riparian habitat has been established in areas that formerly contained few trees, and trees have been removed from areas that formerly had well-developed riparian flora. These changes could seriously affect habitat availability, habitat quality, habitat usage, and fecundity of the plains minnow (Friedman et al. 1998). Rivers in which braided channels have undergone extensive degradation and presumably a coinciding loss of habitat for plains minnow include the Arkansas River, Canadian River, Platte River (including North Platte and South Platte systems), Republican River, and Washita River. The decline or extirpation of the plains minnow in these rivers has been attributed to this degradation. A reduction in turbidity and moderation of flow regimes favor the survival of fish adapted to clear, slow, stable streams (Cross and Moss 1987). These species are often sight-feeding piscivores that, when allowed to spread into new territory, interact negatively with native fish species adapted to the more erratic flows, turbidity, and shifting channels historically present in plains streams. A reduction in turbidity also allows greater production of periphyton and phytoplankton further altering the ecosystem.

Plains minnow were observed experiencing nearly 100 percent mortality in isolated pools during periods of extremely low flow in the Double Mountain Fork of the Brazos River (Texas) due to lethal levels of dissolved oxygen and ammonia. This species cannot tolerate either oxygen levels lower than 1.2 to 1.5 mg per L or ammonia levels higher than 10 mg per L (Ostrand and Marks 2000). Larvae of plains minnow were found to tolerate Rodeo® herbicide (53.8 percent glyphosphate, active ingredient) at concentrations up to 1,000 mg per L in laboratory experiments (Beyers 1995).

The construction of Altus Dam on the North Fork of the Red River (Oklahoma) caused major changes in fish community structure in the river above the dam. While plains minnows were common elsewhere in the drainage, they were rare or absent above the dam (Winston et al. 1991). This species is otherwise common in southwestern Oklahoma. It appears that as demand for water increases and the likelihood of more impoundments also increases, adverse effects for fish above these impoundments will need to be addressed in the management of the plains minnow (Winston et al. 1991).

Population levels of plains minnow have declined in correlation with increases in populations of blackstripe topminnow, bluegill sunfish, largemouth bass, and creek chub (Winston 2002). This is presumed to be because of negative interactions between these species and plains minnow. No information exists regarding whether these interactions are in the form of predation and/or competition for resources, but these interactions are likely.

Species that are more tolerant of environmental variability and extreme conditions are more likely to occur in upstream reaches; less tolerant species are most likely to inhabit downstream reaches resulting in longitudinal zonation of fish assemblages along an upstream-downstream gradient (Ostrand and Wilde 2001). This trend should lead to the presence of plains minnow in higher, more unstable reaches of the stream where impoundments do not restrict their upstream movement (Ostrand and Wilde 2001).

An envirogram for plains minnow was developed to help elucidate the relationships between existing ecological influences and plains minnow population characteristics (**Figure 4**). Those elements that directly affect the plains minnow are depicted in the envirogram by the centrum, which is further separated into resources, predators, and malentities. Resources elicit positive responses in plains minnow populations whereas predators and malentities produce either negative or neutral responses. Web levels illustrate factors that modify elements within the centrum or within the next lower web level. Andrewartha and Birch (1984) provide further detail into the specific description of all envirogram components. Relative importance of the linkages is poorly understood and warrant further study to validate.

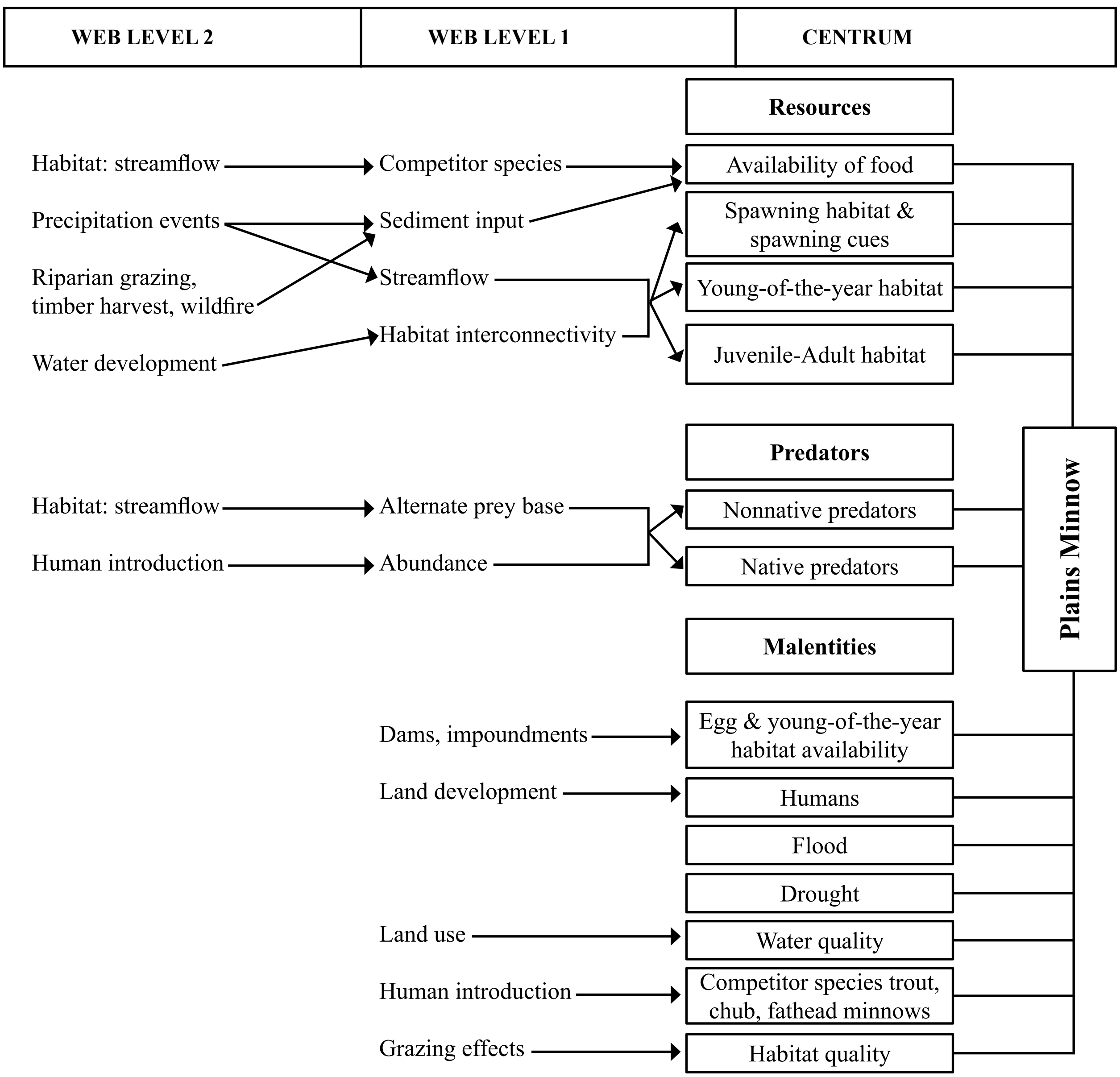

Figure 4. Envirogram for the plains minnow.

Conservation

Threats

The native fish community that evolved within warm-water reaches of Great Plains rivers has been greatly reduced as a result of human activities during the last 100 years. Plains minnow populations have suffered reductions in abundance and distribution from the same mechanisms that have caused the near extinction of other endemic fish. These mechanisms can be separated into two general categories that encompass the majority of the threats to the current and future survival of plains minnow: 1) habitat degradation through loss, fragmentation, or modification, and 2) interactions with non-native species.

These general threats imperil the long-term persistence of plains minnow. Each may work independently or in conjunction with the other to create an environment where plains minnow populations may be reduced or eliminated. The relative importance of each threat and the specific cause-effect relationship usually depends on location.

Habitat degradation includes three areas of concern: habitat loss, habitat fragmentation, and habitat modification. Effects of habitat alteration may not be limited to local areas but may cascade through any given system. Therefore, activities or events occurring on USFS lands may impact populations of plains minnow existing in rivers many kilometers downstream of national grasslands or forests.

Habitat loss typically occurs when streams are dewatered due to water use practices. Habitat fragmentation is often a result of dewatering, but it can also be caused by the creation of barriers to fish passage, such as dams and diversions. Large and small scale water development projects can impact the persistence of plains minnow. Even undersized (or improperly designed) culverts at road or trail crossings can act as barriers, especially at low flows. Irrigation diversions and small capacity irrigation reservoirs reduce streamflow, alter the natural hydrograph, and provide barriers to migration and normal population exchange. Barriers that preclude fish passage can cause population fragmentation and completely prevent or significantly reduce genetic exchange between populations. The fragmented populations in some areas remain viable and maintain population levels at the same density as they were before fragmentation occurred. This currently occurs in small streams that have become isolated from the mainstem rivers due to water diversions. In instances where habitat is fragmented and populations are isolated, the probability that genetic "bottlenecks" will occur becomes more pronounced and single catastrophic events may extirpate populations from entire drainages.

Habitat modification occurs when stream channels are modified due to channelization, scouring, or sedimentation from land use practices, when the natural temperature and flow regimes are altered, or when water chemistry changes due to pollution. Land use practices that can impact stream channels include construction of roads through highly erodible soils, irrigation diversion and return flows, and overgrazing in riparian areas. These can all lead to an increased sediment load in the system and a subsequent change in stream channel geometry (e.g., widening, incision). These modifications alter width:depth ratios, pool: riffle ratios, and other aspects that affect the quality of habitat occupied by plains minnow (e.g., pool depth). In plains streams, the smaller single channel streams may become multiple braided channels with less habitat diversity than the single channel streams.

Stream bank degradation can also result in increased sedimentation. Additional sediment loads (for instance, resulting from high intensity wildland fires) can fill pool and run habitats, cover benthic substrate and smother benthic organisms. The change in sediment load also can result in streams becoming wider and shallower and result in higher than normal water temperatures. Severely reduced stream flows may lead to increased water temperatures, changes in the algal community, and reduced dissolved oxygen levels especially in smaller tributary systems. Although specific tolerances to water quality parameters (i.e., temperature, dissolved oxygen, toxicants) are undefined for this species, it is likely that as water quality is reduced, plains minnow fitness also declines.

Reduction in turbidity caused by impoundment of plains streams is also a threat to plains minnow that can be classified as habitat modification. Channel confinement due to the effects of impoundments in rivers that historically had shifting meandering of braided channels represents a substantial threat to this species. The modification of flow through elimination of flood pulses during the spring and summer has removed cues for the initiation of spawning.

Water development, road construction, oil and gas exploration/extraction, and excessive grazing of riparian areas are likely to continue habitat degradation and to impact plains minnow habitat in the future.

Modification of land use management techniques to decrease the impact to plains minnow habitat may lessen the anthropogenic threats to this species; however, it is unlikely that all impacts or threats could be minimized or halted.

An example of potential threats to plains minnow occurs in the Middle Rio Grande and Middle Pecos River, New Mexico, where guild members immediately downstream of hypolimnetic dam releases are exposed to reduced water temperatures, dampened flow spikes, and prolonged periods of high flow or no flow. Low water temperatures and suppressed flow spikes may inhibit or prevent reproduction of plains minnow (Platania and Altenbach 1998). Conversely, high flow in combination with channel modifications and impoundments can transport eggs and larvae into reservoirs where they may drop out of suspension or perish due to predation or lack of resources. Channel wide diversions fragment the range of plains minnows, entrain drifting eggs and larvae, and prevent upstream movement necessary to maintain populations. The combined effect of the physical structure and altered flow regime that results from mainstream dams and reservoirs appears to be especially detrimental to the continued survival of guild members (Platania and Altenbach 1998).

Competition with and predation by other fish species is another extensive threat to plains minnow population health and viability. Other sympatric species tend to be prolific spawners and well-adapted to a variety of environmental conditions, allowing a competitive advantage on a spatial or temporal scale. Species such as blackstripe topminnow, bluegill sunfish, largemouth bass, and creek chub are known to negatively influence plains minnow populations. The specific mechanism of interaction (predation and/or competition) with these species has not been clearly identified, but the fusiform shape and lack of protecting spines makes plains minnow a potential prey item for predatory non-native species.

The current distribution of plains minnow on or near USFS land creates a unique situation where forest management strategies may cause substantial negative impacts on populations occurring within their boundaries or many kilometers downstream. Certain activities or events that result in excessive erosion or habitat alteration could have detrimental impacts on populations of plains minnow that exist in rivers within USFS boundaries or downstream.

Conservation Status of the Plains Minnow in Region 2

At present, there is concern regarding the status of the plains minnow in Region 2. Although the specific mechanisms of most threats to this species are poorly understood, plains minnow populations have declined in each state in Region 2. Existing research suggests that the decline in both range and populations of this species is due to the combined impacts of habitat alterations and interactions with other species. Changes to the historic temperature and flow regimes are resulting in changes to native fish community assemblages. The shifts in habitat and community structure may create a competitive disadvantage for plains minnow.

Stable populations of plains minnow still exist in various locations within Region 2. These locations include streams in eastern Wyoming, western and central Nebraska, and western Kansas. Specific locations are not readily available due to the lack of specific inventory information, but they do include tributaries of the Missouri, Platte, and Arkansas rivers, as well as some mainstem populations. These locations are usually defined by adequate habitat (as specified in the habitat section of this report), and natural temperature and flow regimes. These areas often maintain healthy populations of other native fish species, including sand shiner (*Notropis stramineus*), red shiner (*Cyprunella lutrensis*), plains killifish (*Fundulus zebrinus*), and other *Hybagnathus* species. These native species have similar habitat needs as the plains minnow.

The plains minnow evolved in a system with a high natural disturbance regime that included a large contrast between annual peak flows and base flows, and considerable sediment transport. Life history attributes and population dynamics allowed this species to persist during (or recolonize after) a disturbance event; however, modifications to the physical and biological environment have reduced its ability to recover after such events. Habitat fragmentation through streamflow reduction, passage barriers, and habitat degradation disconnects metapopulations of plains minnows. Competition and/or predation associated with altered species assemblages can depress plains minnow populations to precarious levels.

Based on the impacts to plains minnow populations and distribution over the past century, the potential for further declines in distribution and abundance is high. Unless alleviated, habitat alterations and non-native species interactions will intensify and jeopardize the existence of the plains minnow.

Potential Management of the Plains Minnow in Region 2

Implications and potential conservation elements

Management plans for plains minnow should seek to maintain stream flows that are sufficiently high enough to maintain water quality levels for the survival of plains minnow (Ostrand and Marks 2000). The estimates according to Platania and Altenbach (1998) suggest that a substantial length of unimpounded river (i.e., 200 to 300 km [124.3 to 186.4 miles]) may be required for successful reproduction.

Plains minnow populations are threatened due to the combined impacts of habitat loss, habitat degradation, habitat fragmentation and interactions with non-native fish species. A brief description of threats is provided here in order to form a basis for the conservation elements; an in-depth discussion of threats to plains minnows can be found in the Threats section of this document.

Management for plains minnow is based on an understanding of specific threats to the species. Habitat loss, modification, and fragmentation due to land and water use practices are primary threats to the persistence of plains minnows in Region 2. Altered flow regimes, and consequently altered sediment transport, can degrade habitat to the extent where plains minnow populations are extirpated from the area. Many of these plains streams have small, easily mobilized particles with lower stream flows leading to channel changes and less sediment transport. The lack of sediment transport can cause the loss of habitat features, such as pools or runs, that provide cover and refuge in winter and periods of drought. Protecting instream flows could assist in the conservation of this species. The degree of influence that population fragmentation has on plains minnow populations is speculative, but it could impact the long-term persistence of this species. Population isolation disrupts the natural exchange of genetic material between populations. Isolated populations are subject to extirpation from catastrophic events because of the unlikelihood of recolonization from other nearby populations. Loss of genetic diversity can also lead to the depression of fecundity and survival rates. The genetic exchange along a metapopulation framework within the plains minnow distribution can provide the required demographic variability and viability.

Other considerations for conservation elements should include protection of riparian areas, minimization of sediment input due to anthropogenic causes (e.g., road building, petroleum and mineral exploration and extraction), and management of non-native fish species. Construction associated with road improvements or development, grazing, and fire activity can result in increased sediment loads to adjacent streams. It is likely that increased sediment loads or deposition at unnatural times (based on historic conditions) could have negatively impact plains minnow populations; however, specific thresholds and mechanisms associated with this impact have not been studied well enough to make precise predictions.

There has been little research to specifically describe the interactions between plains minnow and non-native fish species, but it is likely that non-native fishes threaten plains minnow populations through predation and competition. Management of non-native fish species requires strict adherence to existing regulations regarding the live release of fish. Implementation of management strategies should be designed to restrain the further expansion of non-native fish distribution on USFS lands.

The preservation of stream flows that are adequate to maintain complex habitat, interconnectivity of habitats, and instream cover should be a focal point of management policy or strategy. Conservation elements should address the function of the entire aquatic and riparian ecosystem, with particular attention to downstream populations. Any future plans for the conservation of plains minnow should take into account the entire native fish assemblage that will be affected. This assemblage of species evolved in a system with a high differential between peak spring runoff and fall base flows. Native fish species are likely to benefit from management related to restoration of historical flow regimes and channel maintenance.

Tools and practices

The absence of precise distribution and abundance data for plains minnows in Region 2 (with emphasis toward USFS land) is a concern. This section will deal with techniques intended to gather the missing or needed information outlined in the Information Needs section.

Because adult plains minnow frequent areas with complex instream cover, electrofishing is a feasible means to determine distribution and abundance. The initial priority should be a complete survey of all USFS streams that could contain plains minnows. General stream reach habitat surveys should be conducted concurrently with distribution surveys. Winters and Gallagher (1997) developed a basinwide habitat inventory protocol that would be a cost-effective tool to collect general habitat data.

Once initial distribution and habitat information has been gathered, intensive population estimates would provide baseline information with which the effectiveness of future management strategies could be evaluated. Focus should be on areas where future management strategies may include activities that could possibly impact plains minnow populations. However, the long term monitoring goal should be population estimates and population trend data on all streams containing plains minnow populations on Region 2 lands. Several electrofishing techniques exist that would provide population estimates. The small size of the plains minnow suggests that multiple pass removal estimates would be the most practical method to produce high quality data. Riley and Fausch (1992) recommend that a minimum of three passes be conducted when using the removal method. Use of a single pass method to develop a catch per unit of effort (CPUE) is cost-effective on a time basis, but precision may be sacrificed and the introduction of bias is more likely, especially over long-term monitoring with significant researcher/technician turnover. With removal estimates, researchers are able to calculate confidence intervals, allowing insight into sampling quality.

A large data gap exists in the knowledge of plains minnow movement and use of streams on USFS lands. The implementation of a survey methodology to determine plains minnow distribution and abundance can also provide insight into movement and habitat needs. Habitat selection and preference can be determined through the use a variety of techniques. The simplest technique involves correlating capture locations to specific habitat types. Construction of habitat suitability curves is time intensive, but it could be used in conjunction with hydraulic modeling methodologies to estimate how habitat changes in relation to stream flow. This would allow land use managers to effectively compare the impacts of different altered flow regimes (due to water development projects) on plains minnow habitat. Data obtained could also be used to justify the acquisition of adequate instream flows for the plains minnow and other native fishes.

Defining the relationship between habitat alteration and plains minnow population characteristics is a relatively difficult task. This process may require significant amounts of data, including quantitative analysis of differences in prey base over time, changes in habitat quality/function, and some form of abundance estimates. This type of data could be obtained by sampling multiple locations within streams with known populations and repeated sampling over time. Inclusion of reference sites, if available, would assist in determining how populations and habitat respond to management actions at sites subject to activities such as oil and gas exploration or other land use changes.

To effectively gather data valuable to the conservation of this species, managers need to coordinate with agencies managing portions of streams outside of USFS lands. This will better determine or verify the extent of plains minnow populations that exist off of National Forest System land but that are still affected by USFS management policies and strategies.

The abundance, distribution, and habitat data are needed to gain a better knowledge of the life history, ecology, and habitat requirements (for local and basin scale populations) for the species. Further, determining the response of habitat and populations with change in stream flows would provide data for management decisions on flow regimes required for species conservation. Additional distribution data on National Forest System lands should be regularly monitored. Plains minnow populations exist outside of USFS lands, so coordination and cooperation with federal and state agencies and research efforts would provide forest biologists and managers with information at a broader scale than the limited occurrences on USFS lands. A cooperative federally listed species recovery and habitat restoration program in the central Platte River is one example of such efforts. Under the Central Platte River Basin Endangered Species Recovery Implementation Program, the US Fish and Wildlife Service, Colorado, Wyoming, and Nebraska have agreed to cooperatively conduct habitat restoration efforts (i.e. in-stream flow management), which would help conserve and recover federally listed species associated with the Platte River Basin (http://platteriver.unk.edu/MOA.html).

Information Needs

The current distribution of the plains minnow on National Forest System lands is probably widespread but poorly documented. Specific knowledge of streams and watersheds containing plains minnows on USFS lands is essential prior to the development of management strategies designed to preserve this species. In order to attain the level of understanding that is necessary to properly manage this species at a local level, specific studies must be conducted by drainage. General information needs for plains minnow include a wide range of subjects:

- ❖ distribution
- ❖ habitat requirements and associations
- ❖ general attributes of life history and ecology
- ❖ movement patterns
- ❖ influence of non-native fish
- ❖ effects of human-induced habitat modification.

Temporal changes in abundance and age structure should also be documented prior to implementation of conservation strategies.

The research priority for the plains minnow should be to survey all streams with potential habitat for its presence. Initial focus should be on streams with known populations downstream of USFS lands. During these surveys, information regarding the following physical and chemical characteristics of the habitat should be gathered:

- ❖ elevation
- ❖ water temperature
- ❖ dissolved oxygen
- ❖ dissolved solids
- ❖ discharge
- ❖ depth
- ❖ velocity
- ❖ turbidity
- ❖ substrate
- ❖ habitat type.

This information will provide baseline data regarding habitat requirements and preferences for each physical parameter.

A data gap exists in basic life history information for the plains minnow. In addition to general distribution and abundance information, additional data on seasonal distribution is required. Temporal and spatial changes in abundance, distribution, and age structure should be documented prior to implementation of conservation strategies. Habitat requirements and preferences are poorly understood for most life stages and life history events. Specific scientific evidence that relates the mechanisms in which habitat degradation links to plains minnow population attributes is missing. Habitat requirements and feeding habits at each life stage should also be addressed. Sex ratio, survival rate, and fecundity data should be collected to provide other components missing from the life cycle diagram. It may be important to collect data from several major drainages because much of the specific life history information may vary by basin.

To better understand the community ecology of the plains minnow, future studies should include inventory and monitoring of all fish (adult, juvenile and larvae), macroinvertebrates, and periphyton taxa in the streams where the plains minnow occurs. Stomach content analysis at various life stages will allow for a better understanding of plains minnow feeding habits. Feeding studies on sympatric fish populations need to be conducted to determine potential competition and to understand the impact of introduced and native predators on plains minnow populations.

Genetic testing during future studies on plains minnow populations is important. Tissue samples should be taken from fish from mainstem and isolated populations for analysis of genetic structure. Genetic characterization would allow for studies of population connectivity, migration, population diversity, viability of isolated populations, and the extent and effects of hybridization with native or introduced species.

To ensure the long-term conservation of this species, research must examine techniques to minimize the impact of impoundments and diversion structures on flow regimes, temperature regimes, and movement of native fish. This research should focus on modifying existing impoundments, providing guidelines for construction of future impoundments, and exploring the use of off-channel impoundments. Specific scientific evidence relating the mechanisms in which habitat links to plains minnow populations is missing.

DEFINITIONS

Centrum – any component that directly affects the central organism.

Habitat quality – the physical characteristics of the environment (e.g., soil characteristics for plants or channel morphology for fish) that influence the fitness of individuals. This is distinguished from habitat quantity, which refers to spatial extent.

Hybridization – the production of offspring by crossing two individuals of unlike genetic constitution.

Malentities – all components other than predators that directly affect the central organism and cause a negative response.

Metapopulation – population defined by its expansive presence in accessible habitat whereby its needs for sustainability are met through diversity of habitats, corridors for movement, and interconnection.

Scale – the physical or temporal dimension of an object or process (e.g., size, duration, frequency). In this context, extent defines the overall area covered by a study or analysis and grain defines the size of individual units of observation (sample units).

Species viability – the probability of persistence for a species over some specified temporal scale.

Web Level 1 – any component that affects the centrum.

Web Level 2 – any component that affects Web Level 1.

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