Plains Topminnow (*Fundulus sciadicus*): A Technical Conservation Assessment

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

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Frank J. Rahel and Laura A. Thel
Department of Zoology and Physiology
University of Wyoming, Laramie, Wyoming 82071

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AUTHORS' BIOGRAPHIES

Frank J. Rahel is a professor in the Department of Zoology and Physiology at the University of Wyoming where he teaches courses in fisheries management, ichthyology, and conservation biology. His research interests are centered around fish ecology and the influence of anthropogenic disturbances on fish assemblages.

Laura A. Thel is a graduate research assistant in the Department of Zoology and Physiology at the University of Wyoming with research interests involving stream ecology, hydrology, and landscape ecology, especially as these are related to the management of native fishes.

COVER PHOTO CREDIT

Plains topminnow (*Fundulus sciadicus*). Photograph by Konrad Schmidt. Used with his permission.

Summary of Key Components for Conservation of the Plains Topminnow

Status

The plains topminnow (*Fundulus sciadicus*) is not considered a federally threatened, endangered, or sensitive species and has a Global Heritage Status Rank of G4 (apparently secure) from the Nature Conservancy. Within Region 2 of the USDA Forest Service (USFS), the species is present on the Pawnee National Grassland in Colorado, the Thunder Basin National Grassland in Wyoming, the Nebraska National Forest in Nebraska, and the Buffalo Gap National Grassland in South Dakota. Plains topminnow is not considered a sensitive species within Region 2 of the USFS, based on the 2003 Regional Forester's Sensitive Species List. However, viability may still be an issue at more localized scales within Region 2. The states of Wyoming and Colorado consider the species to be of conservation concern, but no special conservation status is afforded the species by Nebraska, South Dakota, or Kansas.

Primary Threats

Although the plains topminnow is not a priority for conservation concern at present, there are factors that could become threats in the future. These involve water development activities that alter streamflows, physical/chemical habitat degradation, stream fragmentation, and introduction of nonnative fishes. Reservoirs dampen natural flow fluctuations and reduce sediment loading, leading to channel downcutting and the subsequent loss of shallow, braided channels and backwater areas that are a major habitat for the plains topminnow. Because plains topminnows tend to be located in headwater and naturally intermittent reaches of prairie streams, they are highly vulnerable to losing habitat from activities that divert water from stream channels or that lower water tables. The species is most abundant in spring fed pools having clear water and abundant aquatic plants. Physical/chemical habitat degradation of these habitats can result from sewage discharges, feedlot runoff, intense livestock grazing, and pumping of saline groundwater. Sewage and feedlot runoff can cause eutrophication and lead to low oxygen conditions and high ammonia concentrations, especially at warm water temperatures. Intense livestock grazing can result in increased stream intermittency, increased turbidity (and thus a reduction in aquatic macrophytes that are an important habitat component for plains topminnow), and accumulation of manure in pools. Coalbed methane extraction has the potential to be detrimental to plains killifish populations because the water produced during the extraction process can be highly saline and have concentrations of metals toxic to fish; yet this water is often discharged to surface drainages. Plains topminnows must be able to move throughout a drainage in order to recolonize areas where populations have been extirpated by the periods of intermittency common in many prairie streams. Such movements depend on having connected stream systems and can be hampered by highway culverts, dams, and reaches that have gone dry due to irrigation withdrawals. Another potential threat involves introduction of nonnative fishes that are predators or competitors with plains topminnows. Often these introductions occur in association with impoundments.

Primary Conservation Elements, Management Implications and Considerations

Conservation of the plains topminnow should be considered in conjunction with the conservation of a group of small, warmwater fishes native to streams of the Great Plains The major management actions that would benefit these native fishes are preserving streamflows, maintaining adequate water quality, maintaining stream connectivity, preventing the establishment of nonnative piscivores, and avoiding introductions of nonnative small-bodied fishes. Management actions that help to maintain stream flows, especially in smaller streams that originate on the Great Plains, would be advantageous to native prairie stream fishes. These include securing instream flows, minimizing the drying of stream channels due to irrigation withdrawals, and establishing preserves in perennial stream reaches. In some cases, management of livestock grazing may be needed to avoid trampling stream banks, increasing turbidity, and degrading water quality through accumulation of manure, especially in isolated pools during periods of intermittency. In addition, livestock trampling of stream banks can result in wide, shallow channels that are prone to drying up. Plains topminnow evolved in stream systems subject to disturbances such as floods, winterkill, and occasional intermittency. Thus dispersal and recolonization after local extirpation are likely important mechanisms allowing regional persistence of the species. Therefore, anthropogenic features that impede fish movements such as impoundments or highway culverts may need to be redesigned to facilitate fish passage. Impoundments also provide habitat for nonnative fishes that can be predators or competitors with plains topminnow.

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2), USDA Forest Service (USFS). The plains topminnow (*Fundulus sciadicus*) is the focus of an assessment because there was some level of concern for this species' viability with Region 2 (**Figure 1**) during the Regional Forester's Sensitive Species List revision process in 2001 to 2003. After full examination it was determined that the status of the plains topminnow did not justify listing it as a regional sensitive species. However, it was determined that viability may still be an issue at more localized scales within Region 2. The plains topminnow is a Management Indicator Species (MIS) on the Pawnee National Grassland in Region 2 (**Table 1**).

This assessment addresses the biology of plains topminnow throughout its range in Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of certain species based on available scientific knowledge. 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 when management recommendations have been implemented, the assessment examines the success of their implementation.

Scope

The plains topminnow assessment examines the biology, ecology, conservation status, and management of this species with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region (**Figure 1**). Although some of the literature on this species may originate from field investigations outside the region, this document places that literature in the ecological and social context of the central Rockies. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of plains topminnow in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting the synthesis, but placed in a current context.

In producing the assessment, we reviewed refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies. Not all publications on plains topminnow 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. We chose to use some non-refereed literature in the assessments, however, when information was unavailable elsewhere. Unpublished data (e.g., Natural Heritage Program records) were important in estimating the geographic distribution of the species. These data required special attention because of the diversity of persons and methods used in 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, it is difficult to conduct experiments that produce clean results in the ecological sciences. Often, we must rely on observations, inference, good thinking, and models to guide our understanding of ecological relations. In this assessment, we note the strength of evidence for particular ideas, and we describe alternative explanations where appropriate.

Application and Interpretation Limits of this Assessment

Information about the biology of plains topminnow was collected and summarized from throughout the geographic range. In general, life history and ecological information collected in a portion of the range should apply broadly throughout the range. However, certain life history parameters (such as growth rate, longevity,

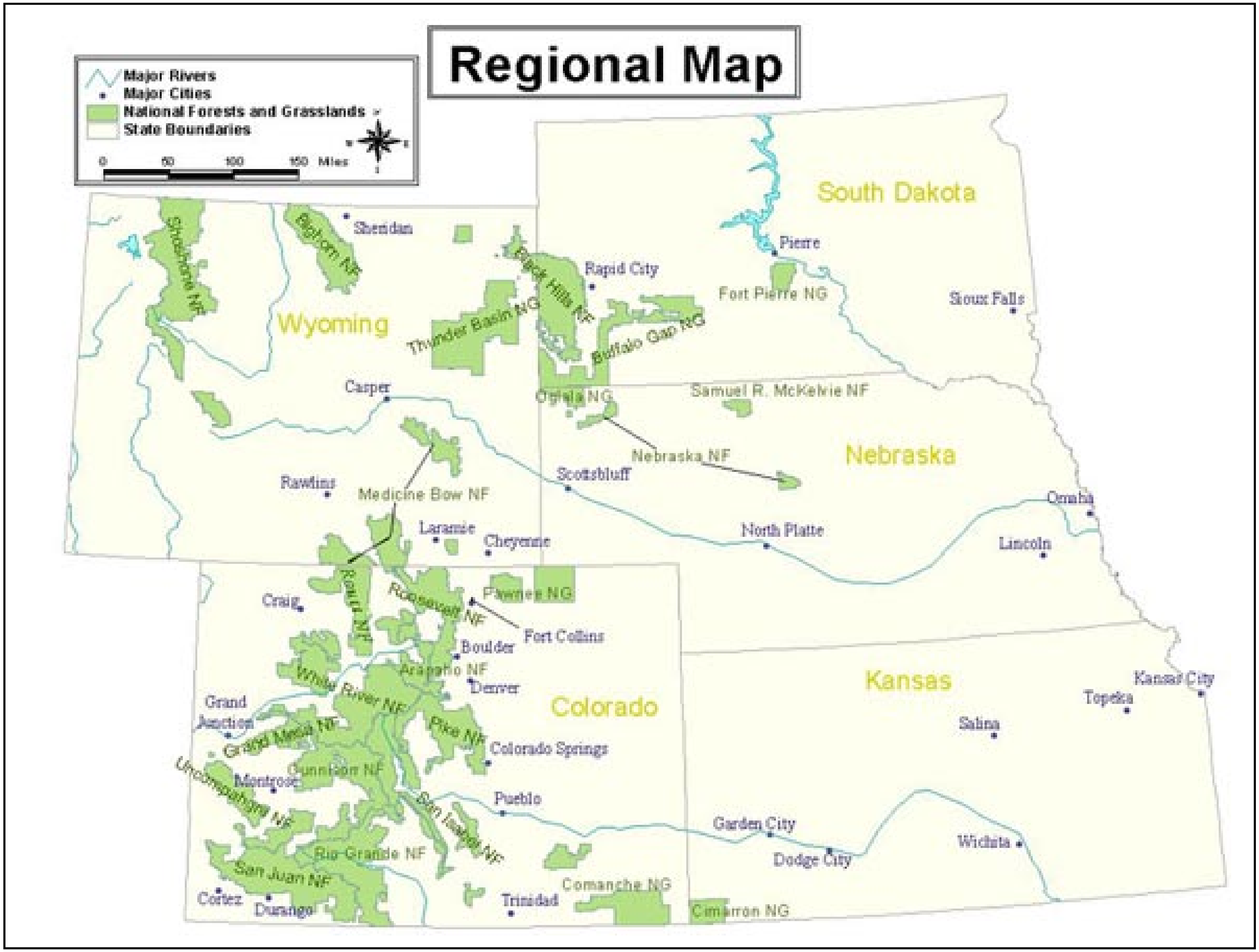


Figure 1. National Forests and Grasslands within the Rocky Mountain Region (Region 2) of the USDA Forest Service.

Table 1. National Forests and Grasslands within the Rocky Mountain Region (Region 2) of the USDA Forest Service.

State	Management Unit	Occurrence	Information Source	ESA/USFS Status	Basis of Status
Colorado	Arapaho National Forest	Absent	Arapaho/Roosevelt National Forests and Pawnee National Grassland Supervisor's Office	Not T,E, or S	Regional Forester's Sensitive Species List, USDA Forest Service, Rocky Mountain Region, 2003
	Comanche National Grassland	Absent	Pike and San Isabel National Forest and Comanche and Cimarron National Grassland Supervisor's Office	Not T,E, or S	Threatened, Endangered and Sensitive Species of the Pike and San Isabel National Forests and Comanche and Cimarron National Grasslands, May 25, 1994.*
	Grand Mesa National Forest	Absent	Grand Mesa, Uncompahgre, and Gunnison National Forests Supervisor's Office	Not T,E, or S	Regional Forester's Sensitive Species List, USDA Forest Service, Rocky Mountain Region, 2003
	Gunnison National Forest	Absent	Grand Mesa, Uncompahgre, and Gunnison National Forests Supervisor's Office	Not T,E, or S	Regional Forester's Sensitive Species List, USDA Forest Service, Rocky Mountain Region, 2003
	Pawnee National Grassland	Present	Arapaho/Roosevelt National Forests and Pawnee National Grassland Supervisor's Office	Not T,E, or S; MIS	Matrix of "Listed" Species in the Great Plains of North America and their Occurrence on National Grasslands**
	Pike National Forest	Absent	Pike and San Isabel National Forest and Comanche and Cimarron National Grassland Supervisor's Office	Not T,E, or S	Threatened, Endangered and Sensitive Species of the Pike and San Isabel National Forests and Comanche and Cimarron National Grasslands, May 25, 1994.*
	Rio Grande National Forest	Absent	Rio Grande National Forest Supervisor's Office	Not T,E, or S	Regional Forester's Sensitive Species List, USDA Forest Service, Rocky Mountain Region, 2003
	Roosevelt National Forest	Absent	Arapaho/Roosevelt National Forests and Pawnee National Grassland Supervisor's Office	Not T,E, or S	Regional Forester's Sensitive Species List, USDA Forest Service, Rocky Mountain Region, 2003
	Routt National Forest	Absent	Medicine Bow/Routt National Forest and Thunder Basin National Grassland Supervisor's Office	Not T,E, or S	Regional Forester's Sensitive Species List, USDA Forest Service, Rocky Mountain Region, 2003
	San Isabel National Forest	Absent	Pike and San Isabel National Forest and Comanche and Cimarron National Grassland Supervisor's Office	Not T,E, or S	Threatened, Endangered and Sensitive Species of the Pike and San Isabel National Forests and Comanche and Cimarron National Grasslands, May 25, 1994.*
	San Juan National Forest	Absent	San Juan National Forest Supervisor's Office	Not T,E, or S	Regional Forester's Sensitive Species List, USDA Forest Service, Rocky Mountain Region, 2003
	Uncompahgre National Forest	Absent	Grand Mesa, Uncompahgre, and Gunnison National Forests Supervisor's Office	Not T,E, or S	Regional Forester's Sensitive Species List, USDA Forest Service, Rocky Mountain Region, 2003
	White River National Forest	Absent	White River National Forest Supervisor's Office	Not T,E, or S	Regional Forester's Sensitive Species List, USDA Forest Service, Rocky Mountain Region, 2003
Kansas	Cimarron National Grassland	Absent	Western Kansas is not considered part of the historic range of plains topminnow.	Not T,E, or S	T,E &S of the Pike & San Isabel National Forest and Comanche & Cimarron National Grassland, May 25, 1994.
Nebraska	Nebraska National Forest	Present	1998 and 1996 Nebraska Department of Environmental Quality, Fisheries surveys. Copies acquired from Nebraska National Forest Supervisor's Office	Not T,E, or S	Regional Forester's Sensitive Species List, USDA Forest Service, Rocky Mountain Region, 2003
	Ogallala National Grassland	Absent	Nebraska National Forest Supervisor's Office	Not T,E, or S	Matrix of "Listed" Species in the Great Plains of North America and their Occurrence on National Grasslands
	Samuel R. McKelvie National Forest	Unknown	No records of plains topminnow occurrence but considered possible by Nebraska National Forest Supervisor's Office	Not T,E, or S	Regional Forester's Sensitive Species List, USDA Forest Service, Rocky Mountain Region, 2003

Table 1 (concluded).

State	Management Unit	Occurrence	Information Source	ESA/USFS Status	Basis of Status
South Dakota	Black Hills National Forest	Absent	Black Hills National Forest Supervisor’s Office	Not T,E, or S	Regional Forester’s Sensitive Species List, USDA Forest Service, Rocky Mountain Region, 2003
	Buffalo Gap National Grassland	Present	Buffalo Gap National Grassland, Wall and Fall River Ranger Districts and Nebraska National Forests Supervisor’s Office	Not T,E, or S	Matrix of “Listed” Species in the Great Plains of North America and their Occurrence on National Grasslands
	Fort Pierre National Grassland	Absent	Fort Pierre National Grassland, District Office and Nebraska National Forests Supervisor’s Office	Not T,E, or S	Matrix of “Listed” Species in the Great Plains of North America and their Occurrence on National Grasslands
Wyoming	Bighorn National Forest	Absent	Bighorn National Forest Supervisor’s Office	Not T,E, or S	Regional Forester’s Sensitive Species List, USDA Forest Service, Rocky Mountain Region
	Medicine Bow National Forest	Absent	Medicine Bow/Routt National Forest and Thunder Basin National Grassland Supervisor’s Office	Not T,E, or S	Regional Forester’s Sensitive Species List, USDA Forest Service, Rocky Mountain Region
	Shoshone National Forest	Absent	Shoshone National Forest Supervisor’s Office	Not T,E, or S	Regional Forester’s Sensitive Species List, USDA Forest Service, Rocky Mountain Region, 2003
	Thunder Basin National Grassland	Present	Medicine Bow/Routt National Forest and Thunder Basin National Grassland Supervisor’s Office	Not T,E, or S	Matrix of “Listed” Species in Great Plains of North America and Occurrence on National Grasslands

*Threatened, Endangered and Sensitive Species of the Pike and San Isabel National Forests and Comanche and Cimarron National Grasslands, May 1994. Compiled by Nancy Ryke, Wildlife Biologist; David Winters, Fish/Wildlife Program Manager; Louanne McMartin, Biological Technician; Steve Vest, Botanist; Barb Masinton Botanist, Ver. 12.19.01.

**Matrix of “Listed” Species in the Great Plains of North America and their Occurrence on National Grasslands, www.fs.fed.us/r2/nebraska/gpng/matrix/fish.html.

spawning activity) could differ along environmental gradients, especially those related to length of growing season. Information about the conservation status was limited to Region 2 of the USFS and should not be taken to imply conservation status in other portions of the species' range.

Publication of Assessment on the World Wide Web

To facilitate use of species assessments in the Species Conservation Project, they are being published on the USFS 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 release on the Web. Peer review for this assessment was administered by the American Fisheries Society, employing at least two recognized experts for this or related taxa. 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 topminnow is not considered a federally threatened, endangered, or sensitive species (U.S. Fish and Wildlife Service; http://endangered.fws.gov/), and it has a Global Heritage Status Rank of G4 (apparently secure) from the Nature Conservancy (http://natureserve.org/explorer/). This fish is generally absent from lands managed by the USFS in Region 2 (**Table 1**). It is present on the Pawnee National Grassland in Colorado, the Thunder Basin National Grassland in Wyoming, the Nebraska National Forest in Nebraska, and the Buffalo Gap National Grassland in South Dakota. However, it is not considered a sensitive species based on the 2003 USFS listing of Endangered, Threatened, and Sensitive Species (http://www.fs.fed.us/r2/projects/scp/sensitivespecies/index.shtml).

There is little information available about the status of plains topminnow on lands administered by the Bureau of Land Management (BLM) in Region 2 of the USFS. The species is listed on the BLM State Director's Sensitive Species list in Colorado but not in Wyoming (**Table 2**). We were unable to obtain information for BLM lands in Nebraska or South Dakota. In Kansas, the BLM manages only subsurface waters.

Table 2. Occurrence and status of plains topminnow on Bureau of Land Management (BLM) lands in Region 2 of the USDA Forest Service.

State	BLM Status	Management Unit	Occurrence	Basis of Status and Occurrence
Colorado	Sensitive	Glenwood Springs Field Office	Absent	BLM Colorado State Director's Sensitive Species List
		Grand Junction Field Office	Absent	BLM Colorado State Director's Sensitive Species List
		Gunnison Field Office	Absent	BLM Colorado State Director's Sensitive Species List
		Kremmling Field Office	Absent	BLM Colorado State Director's Sensitive Species List
		La Jara Field Office	Absent	BLM Colorado State Director's Sensitive Species List
		Little Snake Field Office	Absent	BLM Colorado State Director's Sensitive Species List
		Royal Gorge Field Office	Present	BLM Colorado State Director's Sensitive Species List
		Saguache Field Office	Absent	BLM Colorado State Director's Sensitive Species List
		San Juan Field Office	Absent	BLM Colorado State Director's Sensitive Species List
		Uncompahgre Field Office	Absent	BLM Colorado State Director's Sensitive Species List
		White River Field Office	Present	BLM Colorado State Director's Sensitive Species List

In Wyoming the plains topminnow is not listed a sensitive species by the BLM Wyoming State Director's Office. Information on this species for BLM lands in Nebraska and South Dakota was unavailable. The BLM manages only subsurface waters in Kansas.

The plains topminnow has been given various conservation designations by the five states within USFS Region 2 (**Table 3**). These designations may not be equivalent to the sensitive species category used by the USFS. Definitions for the conservation designations can be found on the state management agency Web sites referenced in **Table 3**. In Nebraska, plains topminnow is not considered a state threatened, endangered, or sensitive species by the Nebraska Game and Parks Commission and has a Nature Conservancy status of S4 (apparently secure). In Colorado, it is considered a species of special concern but is not listed as threatened or endangered by the Colorado Division of Wildlife and has a Nature Conservancy status of S4 (apparently secure). In South Dakota, it is considered a rare species but is not listed as threatened or endangered by the South Dakota Department of Game, Fish, and Parks. The Nature Conservancy status of plains topminnow in South Dakota is S3 (vulnerable). In Wyoming, it is considered to be a species needing conservation attention by the Wyoming Game and Fish Department and has a Nature Conservancy status of S3 (vulnerable). In Kansas, the state Department of Wildlife and Parks does not list the species as threatened or endangered, but the Nature Conservancy gives plains topminnow a status of S1 (critically imperiled). This conflict in status may reflect the fact that the plains topminnow is at the extreme periphery of its range in Kansas and has only been collected from a single site in the southeastern corner of the state (Cross and Collins 1995).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Regulatory mechanisms regarding the harvest or possession of plains topminnow vary among the five states within Region 2. Because of its small size, plains topminnow is not exploited as a game fish but may be collected by anglers for use as bait. We found no studies indicating that overharvest for the baitfish trade was having a negative impact on populations of plains topminnow.

In Colorado, plains topminnow is considered a restricted use species, and it is illegal to possess them or to harvest them. In Kansas, plains topminnow is classified as a bait fish. A fishing license is required to harvest them, and the possession limit is 500 fish per person (Kansas Department of Wildlife and Parks, www.kdwp.state.ks.us). The taking of bait fish is allowed statewide except that seining is prohibited on department-owned waters. In Nebraska, the plains topminnow is not designated as a bait fish and thus would fall into the non-game fish category where there are no harvest limits (2003 Nebraska Fishing Regulations available at http://www.ngpc.state.ne.us/fish/fishguide/fishguide.html). This is somewhat surprising given that most other minnow-like fishes are classified as bait fish in Nebraska and subject to 100 fish bag and possession limits. In Wyoming, the

Table 3. Occurrence and management status of plains topminnow in the five states comprising Region 2 of the USDA Forest Service.

State	Occurrence	State Status	References	State Heritage Status Rank*
Colorado	present	Special Concern, but not listed as Threatened or Endangered	Colorado Division of Wildlife, wildlife.state.co.us	S4 = Apparently Secure
Kansas	present	Not listed as Threatened or Endangered	Kansas Department of Wildlife and Parks, www.kbs.ukans.edu	S1 = Critically Imperiled
Nebraska	present	Not listed as Threatened or Endangered	Nebraska Game and Parks Commission, www.ngpc.state.ne.us	S4 = Apparently Secure
South Dakota	present	Rare	South Dakota Department of Game, Fish and Parks, www.state.sd.us/gfp/division wildlife/diversity/index.htm	S3 = Vulnerable
Wyoming	present	NSS2 = populations are isolated and/or exist at extremely low densities, habitats are stable	Wyoming Game and Fish Department, gf.state.wy.us	S3 = Vulnerable

*State Heritage Status Rank is the status of plains topminnow populations within states based on the ranking system developed by NatureServe, The Nature Conservancy and the Natural Heritage Network, www.natureserve.org.

harvest of plains topminnow is regulated by the general regulations for baitfish harvest. A special license is required to collect bait fish and certain drainages are closed to collecting, but there is no limit to the number of fish that can be collected (Wyoming Game and Fish Department; http://gf.state.wy.us). In South Dakota, the plains topminnow is not designated as a bait fish, nor is it protected by virtue of being designated endangered or threatened (2003 South Dakota fishing regulations; http://www.state.sd.us/gfp). This means it falls under the classification of non-game fish and is not subject to any harvest limits. As with Nebraska, this classification is surprising given that most species in the minnow and sucker families are classified as bait fish and subject to a harvest limit of 12 dozen specimens.

We found no state management plans or conservation strategies that specifically target recovery of plains topminnow within Region 2. At the federal level, the Pawnee National Grassland has designated the plains topminnow as a Management Indicator Species (MIS) for aquatic environments and has initiated a monitoring program for this species and the plains killifish (*Fundulus zebrinus*) (http://www.fs.fed.us/r2/nebraska/gpng/tes_projects/pawneefish.html).

Biology and Ecology

Systematics

The plains topminnow is in the class Osteichthyes, superorder Teleostei, order Cyprinodontiformes, and family Fundulidae. The genus *Fundulus* was moved from Atheriniformes: Cyprinodontidae to Cyprinodontiformes: Fundulidae by Parenti (1981); however, the change was not accepted in the 1991 American Fisheries Society checklist awaiting further confirmation (Comprehensive report on *F. sciadicus*, The Nature Conservancy Natural Heritage database, www.natureserve.org). The Fundulidae family is comprised of five genera with approximately 40 species (Parenti 1981). The genus *Fundulus* has 35 recognized species and three to five recognized sub-genera: *Fundulus*, *Fontinus*, *Plancterus*, *Xenisma*, and *Zygonectes* (Bernardi and Powers 1995).

The plains topminnow was first described by Cope in 1865, as *Fundulus sciadicu*s, in a "Note on fishes brought from the Platte (Kansas) River, near Fort Riley by Dr. W.A. Hammond" in an article on the cold-blooded vertebrates of Michigan (Everman and Cox 1896). The plains topminnow was subsequently assigned other appellations by several workers. In 1891, Jordan referred to plains topminnows as *Zygonectes floripinnis* (Propst and Carlson 1986). Meek (1891) described plains topminnows from the Gasonade and Neosho river systems in Missouri as *Z. macdonaldi* (Hubbs and Ortenburger 1929). Plains topminnows were referred to as *F. floripinnis* by Juday (1904), Cockerell (1908), and Ellis (1914) (Propst and Carlson 1986). Hendricks (1950) used *F. sciadicus*, as did subsequent workers (Propst and Carlson 1986). The current designation of plains topminnow is *F. sciadicus* (Robins et al. 1991).

Species description

Topminnows (Family: Fundulidae) are a small group of species having jaws adapted for feeding at the water surface, heads covered by scales or plates, rounded tail fins, and no line of pored scales along their sides (Cross and Collins 1995). As a group, topminnows are adapted for life at the surface in shallow areas with limited water currents.

Plains topminnows are small, stout fish that are greenish in color and lack distinctive markings (Cross and Collins 1995, Pflieger 1997). The dusky olive color of their back and sides fades to a silvery white on their stomach (Woodling 1985). The head is broad and flat, and the mouth is upturned. The back and sides of topminnows are olive-brown with bronze reflections, faint blue-green cross-hatching, with a narrow golden stripe present on the anterior midline (in front of their dorsal fin) on their back (Pflieger 1997). Fins are colorless or yellowish in immature fish, females, and non-breeding males (Pflieger 1997).

The origin of the dorsal fin base is slightly posterior to the origin of the anal fin base (Pflieger 1997). The number of dorsal fin rays may range from 9 to 12 (Woodling 1985), 9 to 11 (Cross and Collins 1995), or 10 to 11, including rudimentary rays (Pflieger 1997). The anal fin has 12 rays (Baxter and Stone 1995), 12 to 15 rays (Woodling 1985, Cross and Collins 1995), or 12 to 14 rays (Pflieger 1997). Two distinguishing features of topminnows are the rounded caudal fin and the absence of an externally visible lateral line. The scales of plains topminnows are large, and the number of scales along the lateral mid-line range from 33 to 37 (Woodling 1985, Pflieger 1997) or 33 to 39 (Baxter and Stone 1995).

Adults are small, typically 32 to 64 mm (1.5 to 2.5 inches), but they can reach 70 mm (2.8 inches) in length (Cross and Collins 1995, Pflieger 1997). There is little sexual dimorphism except during the breeding season when males have orange-red fin tips (Pflieger 1997).

Males and females in breeding condition exhibit purple-black bands along the median fins (Woodling 1985, Kaufmann and Lynch 1991). Stribley and Stasiak (1982) reported that females were slightly longer (~2 mm) and heavier (~0.2 g) than males of the same age class.

Distribution and abundance

Plains topminnows occur in the Great Plains from southern South Dakota to northeastern Oklahoma and from eastern Wyoming to western Iowa (**Figure 2**). The historic distribution of plains topminnow consisted of two disjunct populations in the Missouri River basin (Lee et al. 1980). One population is centered in Nebraska and extends into eastern Wyoming, northeastern Colorado, southern South Dakota, northeastern Iowa, and the extreme southwest of Minnesota (Comprehensive report on *Fundulus sciadicus*, www.natureserve.org). The other population is centered in Missouri and includes the peripheral regions of southeastern Kansas and northeastern Oklahoma.

The plains topminnow has been introduced to the White River drainage of western Colorado (Woodling 1985), to Utah (Comprehensive report on *Fundulus sciadicus*, www.natureserve.org), and it is suspected to have been introduced into the Cheyenne River drainage in eastern Wyoming and western South Dakota (Brinkman 1994, Baxter and Stone 1995). The plains topminnow may have been introduced to the upper Republican River from the Platte River, but a stream capture event whereby geological changes cause a stream to flow into a new drainage basin has been proposed as an alternate explanation (O'Hare 1985). O'Hare (1985) could not determine the origin of the Republican River population based on a morphological and biochemical analysis of plains topminnows throughout their range.

Current and historic regional distribution and abundance

For the five states comprising Region 2 of the USFS (Colorado, Kansas, Nebraska, South Dakota, and Wyoming) the plains topminnow is most widespread in Nebraska (**Figure 3**). Stasiak (1987) reported plains topminnow in most tributaries of the Platte River in the central and northern part of the state. Plains

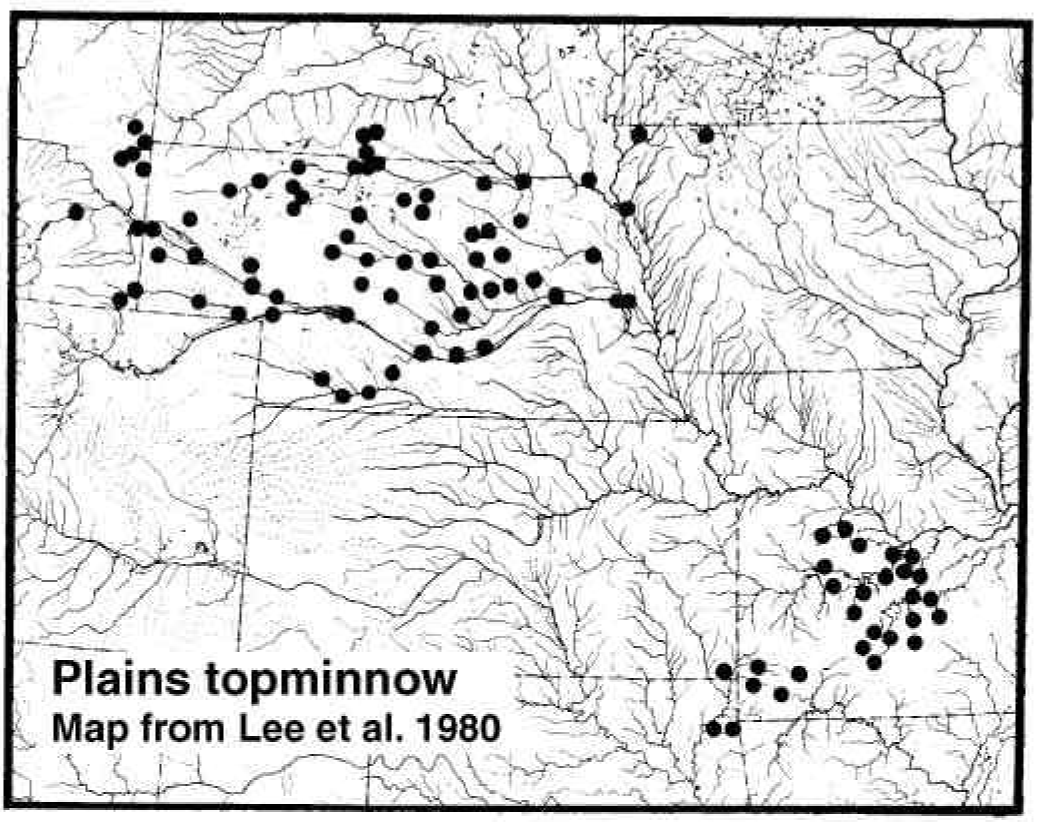


Figure 2. Distribution of plains topminnow in Great Plains. The plains topminnow occurs in two enclaves. One is centered in Nebraska and another one is centered in Missouri.

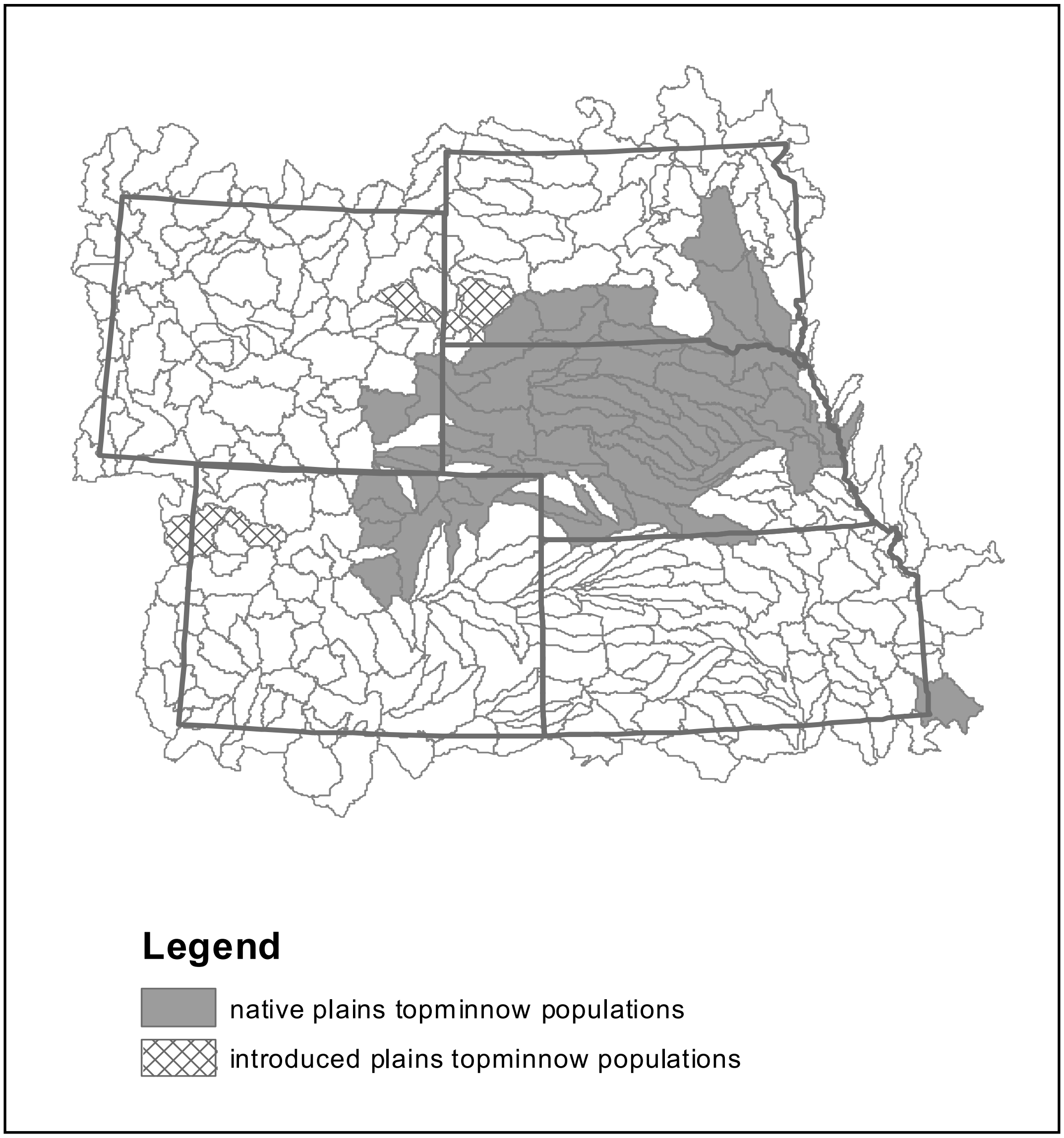


Figure 3. Distribution of plains topminnow by hydrologic units (HUB 4 level) within the Rocky Mountain region (Region 2) of the USDA Forest Service. Sources of information used to produce this map are given in **Appendix B**.

topminnows also occur in the Republican River in the southern part of Nebraska and the Niobrara River basin in the northern part of the state (Lee et al. 1980).

In Colorado, plains topminnows occur throughout the Platte River Basin where they are found in "cool foothill streams, intermittent plains streams and the lower main stem of the South Platte River" (Woodling 1985). The plains topminnow was also introduced into the White River, a tributary of the Colorado River, in western Colorado (Woodling 1985).

Cross (1973) characterized populations of plains topminnow in Kansas as being at the edge of the species' distribution. In Kansas, the single record of plains topminnows is from a backwater of Shoal Creek, Cherokee County in the extreme southeast corner of the state (Cross and Collins 1995).

In South Dakota, plains topminnows occur in the Vermillion and James river drainages and in eastern and southwestern tributaries of the Missouri River (Brinkman 1994). Plains topminnows are also found in the Cheyenne River; however, the population is thought to have been accidentally introduced since Bailey and Allum (1962) did not collect this species during their survey (Brinkman 1994).

The plains topminnow has been collected in southeastern Wyoming in the tributaries of both the North and South Platte rivers as well as from the Niobrara River basin (Patton et al. 2000). Plains topminnows have been collected in the headwaters of the Cheyenne River, as discussed above, where it is believed to have been introduced (Baxter and Stone 1995).

Pflieger (1997) stated that "because of specialized habitat requirements, the plains topminnow appears to occur as isolated colonies but is rather common in its preferred habitat." Lynch and Roh (1996) described plains topminnow as "widely distributed but rare" in a study of the ichthyofauna of the Platte River. Similarly, Propst and Carlson (1986) described plains topminnow in the South Platte River basin in Colorado having a widely scattered distribution, and when collected, generally found in low numbers. Plains topminnow populations have a tendency of occurring in relatively isolated patches. Although plains topminnows may be abundant at some locations and scarce in others, the isolated nature of their populations suggests that the connectivity of streams and the preservation of source populations may be important to the long term persistence of the species

Population trends (local, regional and range wide)

At the local level, there have been no long-term, intensive monitoring studies tracking the population trends of plains topminnow. The assessments of the population status of this species have been based on synoptic surveys usually taken at widely separated points in time. At the regional level, two such surveys have commented on trends in the occurrence of plains topminnow. In the Missouri River drainage within Wyoming, Patton (1997) sampled fish populations at 42 stream sites that had been previously surveyed in the 1960's. He found plains topminnows at five of the six sites where they had been collected in the earlier survey, but after adjusting the data for differences in capture probabilities between the surveys, he concluded that this species was declining in its distribution within Wyoming (Patton et al. 1998). The Platte River Basin Native Fishes Work Group (1999) compared fish species distributions pre-1980 to post-1980 and recommended that the plains topminnow be considered a "species of concern" in the Platte River basin in Colorado, Nebraska, and Wyoming. This designation was based on the facts that in Colorado, populations were considered stable but habitats were highly vulnerable to development along the Front Range; in Wyoming, populations were considered to have declined based on the survey of Patton (1997) discussed earlier; and in Nebraska, historically abundant populations were considered to be declining due to competition with introduced mosquitofish (*Gambusia affinis*).

In terms of the range-wide status of plains topminnow, the Nature Conservancy has given the species a Global Heritage Status Rank of G4 (apparently secure). This ranking was based on the species being considered common in Nebraska. However, the Nature Conservancy noted that some range retractions have occurred in Missouri and on the periphery of the northern portion of the species' historic range (www.natureserve.org/explorer).

Activity patterns

Little is known about the activity patterns of plains topminnows. There has been one behavioral study describing the breeding behavior of plains topminnows. However, there have been no observations of feeding behaviors. Brinkman (1994) reported that plains topminnow colonized an intermittent drainage of the James River in South Dakota during an unusually wet period and persisted in an isolated pool for several years. This suggests that movement to colonize new habitat may be an important part of the life history of this species. Also, the patchy distribution of plains topminnows (Lynch and Roh 1986, Propst and Carlson 1986, Pflieger 1997) further suggests that movements to recolonize habitats after local extirpation may be important to the long-term regional persistence of the species.

Topminnows are thought to be most active in the daytime (Cross and Collins 1995). The morphology of topminnows indicates that they are adapted to live near the surface, in shallow water. The preference of topminnows for shallow waters enables them to avoid low dissolved oxygen conditions and predation from larger fish (Brinkman 1994, Cross and Collins 1995). The predilection of plains topminnow for inhabiting the shallows was noted by Pflieger (1997) who observed them alone or in "small groups near the surface of the water." Brinkman (1994) reported observing young-of-year plains topminnows foraging in the shallow, vegetated areas of a stream. Baxter and Stone (1995) remarked that schools of plains topminnows could be found occupying the shallow habitats of streams margins, sloughs, and backwaters. Propst (1982) reported that plain topminnows were always collected in low densities in the Platte River drainage of Colorado and that most were found alone. He suggested that the pugnacious temperament of plains topminnow may explain their typical occurrence in low numbers.

Kaufmann and Lynch (1991) collected plains topminnows and transferred them to laboratory tanks to study their courtship behavior and breeding biology. The fish were initially wary and sought cover whenever the tank was approached until they became accustomed to the activity of the keeper. Breeding activity was observed in the vegetation and filamentous algae in the aquaria. It is unlikely that plains topminnows are required to make significant spawning migrations since they occupy heavily vegetated waters. Because plains topminnow eggs become entrained in the vegetation and are deposited in slow current areas, eggs are unlikely to be dispersed downstream by currents.

Habitat

Plains topminnows are most often found in heavily vegetated, shallow, slow water habitats in small, clear streams. Some descriptions indicate they also occupy habitats with moderate to fast current (e.g., Lee et al. 1980). However, most researchers have reported that plains topminnows exhibit a preference for quiet water habitats (e.g., Branson 1967, Propst and Carlson 1986, Baxter and Stone 1995, Pflieger 1997).

Propst and Carlson (1986) stated that in the South Platte drainage of Colorado all sites where the plains topminnow was collected had aquatic vegetation and little, if any, current. Baxter and Stone (1995) noted that plains topminnows in Wyoming thrive in sloughs and backwaters with prolific vegetation. Similarly, Lynch and Roh (1986) noted that plains topminnows were abundant in the lentic microhabitats of many tributaries of the North and South Platte rivers in Nebraska. Maret and Peters (1980) remarked that plains topminnows in a Nebraska stream were most abundant in "backwaters and ditches bordering the stream". In Kansas, the single collection of plains topminnow was "from a small weedy pool alongside the channel of a creek" (Cross and Collins 1995). Pflieger (1997) described the habitat of plains topminnow in Missouri as quiet pools of small creeks, backwaters, and overflow pools of larger streams in clear waters with little current and abundant submergent vegetation. Branson (1967) described plains topminnow habitat in northeastern Oklahoma as clear, heavily vegetated waters with little or no current. Branson (1967) also remarked that plains topminnows were fairly abundant in small spring-fed tributaries of Spring Creek in Missouri.

Kazmierski (1966) found that plains topminnows had the most limited distribution of all the fish species collected in an intermittent stream in southeastern South Dakota. Most of the individuals (98 percent) were collected at one of the five sampling stations. This station was characterized as a small stream, with slight current, abundant aquatic vegetation, and clear water. Kazmierski (1966) suggested that the profuse growth of *Potamogeton* spp. at the station accounted for the abundance of plains topminnow there compared to the other four sampling sites.

In Griffith's (1974) study of the salinity tolerances of *Fundulus* species, plains topminnows were found to have moderate salinity tolerance. The mean salinity tolerance of plains topminnow was 24 parts per thousand (ppt). The salinity of seawater is 35 ppt. For comparison, the freshwater *Fundulus* species with the least tolerance, *F. notti*, had a mean tolerance of 19 ppt whereas the most tolerant species tested, *F. zebrinus*, had a maximum salinity tolerance of 89 ppt. Most freshwater *Fundulus* species had a maximum salinity tolerance around 29 ppt.

Smale and Rabeni (1995a) tested 35 fish species common in Missouri streams for hypoxia tolerance and 34 species for hyperthermia tolerance. Plains topminnows ranked 20th for hypoxia tolerance, indicating that they were more tolerant of low dissolved oxygen concentrations than 19 other species. They ranked 25th for hyperthermia tolerances, again indicating they were among the most tolerant species. The researchers remarked that although laboratory determinations of critical temperature and dissolved oxygen concentrations rarely correspond with those observed in the field, relative tolerances of species indicated by rank could be help to explain observed assemblage patterns. The authors noted in a companion study (Smale and Rabeni 1995b) that hypoxia tolerance was a good predictor of species distribution patterns at a regional scale. Jester et al. (1992) characterized the tolerance of Oklahoma fishes to water quality and habitat degradation and classified plains topminnows as moderately tolerant.

Brinkman (1994) noted that plains topminnow were well adapted for survival in shallow isolated pools because they were able to survive high temperature and low dissolved oxygen conditions that eliminated other fish species. Brinkman (1994) reported a population of plains topminnow that survived and reproduced in a small isolated pool in an intermittent tributary of the

James River, South Dakota. Plains topminnow persisted for four years whereas other fish species (including fathead minnows, creek chubs, darters, and green sunfish) that were initially present in the pool were absent by the following summer. Such isolated pools may provide refuges that allow plains topminnows to survive periods of drought and then recolonize areas when water flows return.

Plains topminnows deposit their eggs on aquatic vegetation and filamentous algae. Unlike many other fish species, they do not appear to seek out a different habitat for spawning but reproduce in the same areas of abundant aquatic vegetation that they occupy throughout the year.

Food habits

The food habits and feeding behaviors of plains topminnow have not been well studied. Cross and Collins (1975) characterized the diet of topminnows as varied and composed of most organisms in the plankton as well those in the surface film. Pflieger (1997) remarked that although the food habits of plains topminnow have not been studied, insects were likely an important part of their diet. Stribley and Stasiak (1982) reported plains topminnows "preyed primarily on Ostracod crustaceans, snails of the genus *Physa*, and larval forms of the Dipteran insect families Chironomidae and Simuliidae."

Breeding biology

Plains topminnows spawn in spring and early summer (Cross and Collins 1995, Pflieger 1997). Timing and length of reproductive season likely vary in accordance with temperature variations throughout the species' range. Observations of reproductive condition have primarily been from the center of their range in Nebraska. Kazmierski (1966) observed male fish in breeding coloration for approximately one month from June 20 to July 21 in Nebraska. However, variation in size of young-of-the-year indicated that the breeding season extended from mid-June to early August. Kinney and Lynch (1991) determined that spawning by plains topminnow in Nebraska occurred from late March to late July. Pflieger (1997) considered the plains topminnow spawning season to occur in May and June in Missouri, whereas Ellis (1914) reportedly collected gravid plains topminnows in mid-July in Colorado. Kinney and Lynch (1991) suggested that the onset and completion of the reproductive season were approximately three weeks earlier in Missouri than in Nebraska due to differences in latitude, but the duration of the breeding season was approximately 60 days in both states.

Kaufmann and Lynch (1991) suggested the spawning season of plains topminnows is regulated by water temperature. They cited work by Mayer (1931) indicating that plains topminnows held in captivity did not spawn at 65 °F (18 °C) but started to breed when the water temperature was raised to 70 °F (21 °C). Kaufmann and Lynch (1991) found that plains topminnows bred from 18° to 22 °C (64.4° to 71.6 °F). They suggested that at higher temperatures egg deposition ceases and eggs in the ovaries regress since few eggs were found in the wild when water temperatures reached 25 °C (77 °F). Absence or low numbers of mature eggs in females collected in mid-June through July coupled with the presence of all classes of eggs in female specimens collected in late March suggested that the spawning season of plains topminnows began in spring with water temperatures around 19° to 20 °C (66.2° to 68 °F) and ended by early summer (Kinney and Lynch 1991). Non-gravid females with only immature eggs were collected in late March when water temperature was 15 °C (59 °F), further indicating temperature strongly influences breeding season.

Kaufmann and Lynch (1991) observed the courtship behavior of plains topminnows in aquaria with gravel substrates and abundant vegetation. Adult specimens were collected from the wild in autumn and late winter. After a few days of acclimation to the warmer water conditions in the lab, the plains topminnows exhibited brighter colors. The fins of males became red, and a black border on the median fins of both sexes developed. Males engaged in a combat ceremonial that resulted in the establishment of a few dominant males in the aquarium. The combative behavior consisted of two males aligning themselves head to tail and circling. The males would attempt to align perpendicular to one another, and if possible bite each other on the dorsal fin or anterior to the dorsal fin. Interactions lasted as long as 90 minutes. Male-female interactions were initiated by a male enlarging his gular region and lowering his jaw. Following this display a female would swim to the male and the two would align head to tail and wiggle vigorously. The researchers described the ovipositing behavior as a vigorous wiggling by a male-female pair occurring in the filamentous algae. The researchers did not observe eggs and milt being released, but eggs were found attached to filamentous algae only after this behavior was observed.

Kaufmann and Lynch (1991) described plains topminnow egg size and color and development from specimens at the University of Nebraska State Museum. Egg size ranged from 0.1 to 0.3 mm (0.004 to 0.01 in.), to approximately 1.6 to 1.8 mm (0.06 to 0.07 in.) in diameter. Egg color was described as yellow to orange, and eggs were noted to contain many oil droplets. Oil droplets are a characteristic common to the eggs of all cyprinodontiforms (Able 1984). Kaufmann and Lynch (1991) also examined eggs deposited by captive plains topminnows and reported that the eggs had thin filaments on the chorion that became entangled with algal filaments. Kinney and Lynch (1991) reported that mature eggs ranged from 1.6 to 2.0 mm (0.06 to 0.08 in.) in diameter. This is larger than the egg sizes reported by Kaufmann and Lynch (1991); however Kinney and Lynch (1991) only measured the largest of the immature eggs from each specimen. Kaufmann and Lynch (1991) suggested that because females developed abdominal swelling within a week of improving their diets and because females collected in April contained only small eggs, egg development from the immature to mature state probably occurs rapidly in plains topminnows.

Kinney and Lynch (1991) estimated the fecundity of plains topminnow from preserved specimens collected in Nebraska. Females containing mature eggs were age 1, 2, or 3. The largest number of mature eggs found in a female was 88; however, the mean number of mature eggs was 22. Eggs in two intermediate stages of development were also counted, and the means reported for these states were 20 and 50 eggs. Immature eggs were not counted. The authors suggested that females produced 30 to 50 eggs per year for each of their three reproductive years.

Kaufmann and Lynch (1991) studied the development of eggs and larvae in the laboratory. Embryos hatched in 13.5 to 14 days at 21 to 23 °C (69.8 to 73.4 °F). This is a longer development period than the 8 to 10 days at 21 °C (69.8 °F) reported by Mayer (1931) (cited in Kaufmann and Lynch 1991). Kaufmann and Lynch reported that plains topminnow larvae were 6.2 to 7.7 mm (0.2 to 0.3 in.) in total length, averaging 6.7 mm (0.3 in.). Newly hatched larvae were not observed to feed despite depleted yolk reserves. Able (1984) noted that the oil droplets in the yolk are thought to provide nutrition late in embryonic development. Jerky swimming movements were observed for larvae on the first day after hatching if disturbed, but undisturbed larvae were described as hanging at the water's edge (Kaufmann and Lynch 1991). Kaufmann and Lynch (1991) did not indicate when larvae began to feed. The diamond killifish (*Adinia xenica*), which Kaufmann and Lynch (1991) indicated had embryonic development similar to plains topminnow, reportedly began feeding the day they hatched. Plains topminnow larvae swam away from observers two to four days after hatching (Kaufmann and Lynch 1991).

Demography

Genetic characteristics and concerns

Plains topminnows have been found to vary morphologically and biochemically among disjunct localities. O'Hare (1985) measured 24 meristic and morphometric characteristics of 112 plains topminnows from throughout their current range. There was variation among populations for 61 percent of the morphological characteristics in males and 83 percent of the morphological characteristics in females. However, there were no consistent patterns of variation among populations or groups of populations. O'Hare (1985) concluded that variation in morphological characteristics of plains topminnow did not warrant subspecies designation of the disjunct Nebraska and Missouri populations and that none of the characteristics could be used to distinguish individuals from different states. O'Hare cautioned about the difficulty of interpreting genetic variation from morphological variation as the number and types of genes involved in morphological characters are unknown and environmental factors are known to affect fish morphology during development. O'Hare (1985) also suggested that sexual dimorphism and environmental factors should be considered when investigating morphological variation among populations of the species, since these factors could mask small differences between populations.

O'Hare (1985) also assessed genetic variation in plains topminnow populations using a biochemical analysis. All the Nebraska populations were similar whereas the two Missouri populations had diverged from the Nebraska populations and from one another. O'Hare cautioned that the results were likely affected by the small sample sizes (10 to 15 fish) and small number of loci (6) used in the analyses.

Life history characteristics

There is limited information regarding the life history of the plains topminnow. It is a short-lived species, having a lifespan of four years and reaches a maximum total length of around 75 mm (3 in.). Both males and females become sexually mature in their second summer of life, at age 1 (Stribley and Stasiak 1982). The sex ratio has not been determined. Females are reported to be slightly larger than males of the same age class (approximately 2 mm longer and 0.2 grams heavier). No information regarding recruitment or survival rates from one age class to another have been reported. Stribley and Stasiak (1982) used scale annuli to age 346 plains topminnows from two streams in Keith County, Nebraska. Mean total lengths were 23 mm (0.9 in.) at age 0, 47 mm (1.9 in.) at age 1, 53 mm (2.1 in.) at age 2, and 62 mm (2.4 in.) at age 3.

Kinney and Lynch (1991) used scale annuli to age female plains topminnows from the University of Nebraska State Museum. The majority of specimens were ages 3 and 4 with no age 0 or age 1 and only one age 2 female. The single age 2 specimen measured 37 mm (1.5 in.) standard length. The mean standard length of age 3 females was 43 mm (1.7 in.) (n = 33), and the range was 35 to 51 mm (1.4 to 2.3 in.). The age 4 females had a mean standard length of 52 mm (2 in.) (n = 17), with a range of 45 to 58 mm (1.8 to 2.3 in.).

Maret and Peters (1980) collected 77 plains topminnows from a tributary of Salt Creek in Nebraska and reported specimens ranged in size from 23 to 65 mm (0.9 to 2.6 in.). The authors did not age the fish or provide length-frequency distributions.

Life cycle graph diagram and analysis of demographic matrix. A life cycle graph (**Figure 4**) was constructed and used as the basis for an analysis of how population demographics might influence the long-term persistence of plains topminnow populations. Details of the analysis are given in **Appendix A**. The approach was to use a stage-based variation of a Leslie matrix to project population sizes under various scenarios of environmental and demographic stochasticity. A major reason for doing a matrix demographic analysis is to identify which age-specific vital rates (such as the probability that a fish of a given age survives during the next year or the number of eggs produced by a female of a given age) are likely to be most influential in determining population growth rate. Population growth rate, in turn, is critical in allowing plains topminnow populations to recover from low-points in abundance and thus avoid going extinct.

Input data needed for a population projection matrix model consist of age-specific survival and fecundity rates. We assembled the sparse data available in the literature on these rates for plains killifish (**Table 4**). The model has two kinds of input terms: P_i describing survival rates and m_i describing fertilities (**Table 4**). Fecundities are given as female offspring per female based on a 1:1 sex ratio. In contrast to fisheries terminology, the convention here is ordinal numbering beginning with 1 (first, second, third and fourth age-classes). Thus, age-class 0 in fisheries terminology corresponds to age class 1 in the matrix model. Each age-class describes a one-year census interval period, such as the age-class that begins with an egg at the census and proceeds to the birthday of that egg as a yearling as described by the survival arc P_{21} in **Figure 4**.

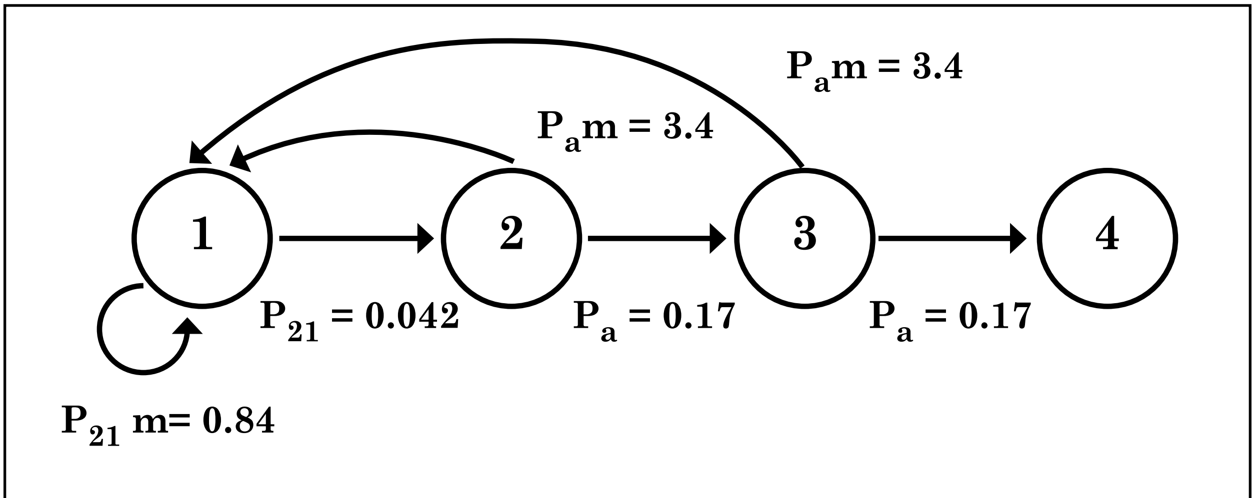


Figure 4. Life cycle graph for plains topminnow. The numbered circles (nodes) represent the four age-classes – first year through fourth year females. The arrows (arcs) connecting the nodes represent the vital rates — transitions between age-classes such as survival (P_{ji}) or fertility (the two arcs $P_{ji} * m_i$ that point back toward the first node). Note that reproduction begins in the second year. Fertilities involve offspring production (m_i, the number of female eggs per female) as well as survival of the mother (P_{ji}) from the time of the census just after breeding until the next breeding season one year later. Self-loop on the first node indicates that females can reproduce as yearlings.

Table 4. Parameter values for the component terms (P_i and m_i) that make up the vital rates in the projection matrix for plains topminnow. The egg production rates described by Kinney and Lynch (1991) provided the basis for calculating fecundity. We found no data on annual survival rates for adult plains topminnow and thus used values for a related species, the plains killifish, presented by Minckley and Klaassen (1969), Brown (1986), and Schemeidler and Brown (1990).

Parameter	Numeric value	Interpretation
m	20	Number of female eggs produced by a female
P_{21}	0.042	First-year survival rate
P_a	0.17	Annual survival rate of adults

Sensitivity analysis. Sensitivity is the effect on population growth rate (λ) of an absolute change in the vital rates (a_{ij}, the arcs in the life cycle graph, **Figure 4**). Sensitivity analysis can show how important a given vital rate is to λ or fitness. One can use sensitivities to assess the relative importance of survival versus reproductive transitions. Sensitivities also can be used to evaluate the effects of inaccurate estimation of vital rates, to quantify the effects of environmental perturbations, and to identify stage-specific survival or fertility rates that are most critical to increasing λ of an endangered species. The major conclusion from the sensitivity analysis is that first-year survival is overwhelmingly important to population viability (details are given in **Appendix A**). Plains topminnow shows large sensitivity (80 percent of total) to changes in survival, with first-year survival alone accounting for 77 percent of the total sensitivity. The sensitivity to changes in reproduction is just 20 percent of the total.

Elasticity analysis: Interpreting sensitivities can be somewhat misleading because survival rates and reproductive rates are measured on different scales. For instance, a change of 0.5 in survival may be a big alteration, e.g., a change from a survival rate of 0.9 to 0.4 corresponds to a reduction in survival from 90 percent to 40 percent. On the other hand, a change of 0.5 in fertility may be a small proportional alteration, e.g., a change from an average clutch size of 100 eggs to 99.5 eggs. Elasticities are the sensitivities of λ to proportional changes in the vital rates (a_{ij}) and thus largely avoid the problem of differences in units of measurement. Details of the elasticity analysis for plains topminnow are given in **Appendix A**. Population growth rate (λ) is most elastic to changes in first-year reproduction ($P_{21}m$ in **Figure 4**) followed by first-year survival (P_{21}) and then second-year reproduction ($P_a m$). The sensitivities and elasticities for plains topminnow do not correspond in rank magnitude. The first and third most elastic transitions involve reproduction, in contrast to the first-year survival so heavily emphasized by the sensitivity analysis. The summed reproductive elasticities account for fully 84 percent of the total (compared to 16 percent for the summed survival elasticities). Thus, survival and reproduction in the first year and to a lesser extent survival and reproduction in the second year are the data elements that warrant careful monitoring in order to refine the matrix demographic analysis.

Other demographic parameters. The stable age distribution (**Appendix A**, **Table A1**) describes the proportion of each age-class in a population at demographic equilibrium. For plains topminnow at the time of the post-breeding annual census (just after the end of the breeding season), eggs and age 0 fish represent 95 percent of the population, second-year individuals (age 1 in fisheries terminology) represent another 4 percent, and older fish are extremely rare. Reproductive values (**Appendix A**, **Table A2**) describe the "value" of a stage as a seed for population growth relative to that of the first (in this case, egg) stage. The reproductive value of the first stage is always 1.0. A female individual in age-class 2 is "worth" 3.95 eggs, and so on. The peak reproductive value (3.95) occurs at the second age-class, and these females are an important stage in the life cycle (though they represent only 4 percent of the population). It is important to remember that the second age-class in the demographic matrix analysis corresponds to age 1 fish using conventional fisheries terminology.

Stochastic model. We conducted a stochastic matrix analysis for plains topminnow. We incorporated stochasticity in several ways, by varying different combinations of vital rates or by varying the amount of stochastic fluctuation (details in **Appendix A**). The stochastic model produced two major results. First, varying first-year reproduction had a greater effect on λ than varying all the survival rates (**Appendix A**, **Table A3**). Second, the magnitude of stochastic fluctuation largely determines the negative effect on population dynamics. These results indicate that populations of plains topminnow are vulnerable both to stochastic fluctuations in production of newborns (due, for example, to climatic fluctuations or to human disturbance) and, to a far lesser degree, to variations in survival.

Summary of major conclusions from matrix projection models:

- ❖ First-year survival accounts for 84 percent of total "possible" sensitivity. Any absolute changes in this rate will have major impacts on population dynamics.
- ❖ First-year reproduction accounts for 70 percent of the total elasticity, compared to 14 percent (next highest value) accounted for by first-year survival. Proportional changes in first-year reproduction will have a major impact on population dynamics.
- ❖ The contrast between the conclusions from the sensitivity and elasticity analyses suggests that survival and reproduction in the first year of life are both critical to the population dynamics of plains topminnow.
- ❖ Where the potential exists for survival through to the third year, reproductive values of females in that age-class will be high. Such populations may be important sources of recolonization for other sites or in periods when local conditions improve.
- ❖ Stochastic simulations echoed the elasticity analyses in emphasizing the importance of variation in first-year reproduction to population dynamics. In comparison to life histories of other vertebrates, the plains topminnow appears to be vulnerable to local extinction. Management will need to take account of the potential for considerable variability in population trajectories and the need for multiple habitat sites as a buffer against the likelihood of reasonably frequent local population extinctions.

Ecological influences on survival and reproduction

There is little information that would allow mortality of plains topminnow to be partitioned among different causes (e.g., predation, competition, parasitism, abiotic stressors) for the various life history stages. As with most fish species that provide little or no parental care, the mortality rate of early life history stages is high. Survival from egg through the first year of life was estimated to be only 0.042 percent, based on the matrix population analysis (see section Life cycle diagram and analysis of demographic matrix). Because the eggs have thin filaments that become entangled with plants and because plains topminnow spawn in backwater areas with little or no current, stranding of eggs and larvae in unsuitable habitat as they drift downstream is not likely to be a major source of mortality (Kaufmann and Lynch 1991). However, mortality of these early life history stages would occur if backwater habitats dry up. Predation on eggs and larvae may be an important source of mortality although this remains to be investigated. Owen et al. (1981) remarked that plains topminnows were likely a prey item of various species of piscivorous fishes and birds. For example, green sunfish (*Lepomis cyanellus*) and creek chubs (*Semotilus atromaculatus*) are potential predators occasionally found in pools of small streams inhabited by plains topminnows, but no studies have quantified the impact of predation on plains topminnow population dynamics.

Plains topminnows primarily consume aquatic insects, but the extent to which competition with other fishes limits population size is unknown. It has been speculated that introduced western mosquitofish may negatively impact plains topminnows through aggressive behavior including bodily attacks (Lynch 1988a). Although this appears reasonable based on observations of mosquitofish-plains topminnow interactions in aquaria, the extent to which mosquitofish have caused declines in populations of plains topminnow in nature has not been documented. There is no evidence to suggest that disease or parasites are major factors impacting survival or reproduction.

The side channel and backwater habitats inhabited by plains topminnows are prone to severe abiotic conditions, including desiccation, anoxia or high temperatures in summer, or complete freezing and anoxia in winter. Although plains topminnows are tolerant of low oxygen and high temperatures, populations are likely decimated by periodic drought conditions common in the Great Plains region. For example, Brinkman (1994) reported that a population of plains topminnows survived and reproduced in a small isolated pool in an intermittent tributary of the James River, South Dakota. Although the population persisted over four years under harsh environmental conditions, it ultimately went extinct when the pool dried completely.

Social pattern for spacing

The plains topminnow is not a schooling species and often only a few individuals are captured in a given area. However, the degree to which the species is territorial and whether territoriality plays a role in population regulation has not been examined in wild populations. Neither sex appears to defend a nest site during the reproductive period.

Patterns of dispersal of young and adults

Dispersal patterns of plains topminnow have not been investigated. Many fish species characteristic of prairie streams are broadcast spawners whose eggs and larvae drift downstream during development (Bonner and Wilde 2000). When coupled with upstream migrations by adults prior to spawning, this strategy would provide a mechanism to allow the species to disperse throughout a drainage. However, plains topminnows spawn in vegetated, slow water areas where dispersal by water currents would occur only during sporadic floods and then only in a downstream direction. Plains topminnows live in backwater habitats that are prone to conditions such as summer desiccation or winter anoxia that would cause local population extirpations. This suggests that recolonization of habitats is an important feature of the life history of this species. Furthermore, such recolonization must entail active dispersal in an upstream direction in addition to the passive dispersal in a downstream direction that likely accompanies flood events.

Spatial characteristics of populations

Spatial characteristics of populations such as sources and sinks, or metapopulation dynamics, have not been studied in plains topminnow. Although there is considerable variation in morphological characteristics among populations, genetic studies do not support subspecies designation for the disjunct Nebraska and Missouri populations (see Systematics and Species Description section). Plains topminnows naturally exist in widely separated populations because of its specialized habitat requirements. This suggests that problems associated with fragmentation, such as reduced genetic variation in isolated populations, increased risked of extirpation due to demographic or environmental stochasticity, and lack of recolonization following extirpations, could become an issue as surface and groundwater development jeopardize backwater and headwater habitats in prairie streams.

Limiting factors

The main factors limiting population growth for specific populations or the species in general have not been identified but likely involve habitat availability. The species is generally limited to still, clear water areas with abundant macrophytes and sand-gravel substrate in warmwater streams. This type of specialized habitat is relatively rare in the arid Great Plains region where stream turbidity levels often are high. Another probable limiting factor is desiccation of the shallow, backwater habitats and intermittent streams favored by this species (Brinkman 1994). Although desiccation is a natural process in the arid Great Plains region, lowering of ground water levels through irrigation pumping has increased the magnitude of stream dewatering (Fausch and Bestgen 1997, Dodds et al. 2004).

The role of native predators or competitors in limiting populations of plains topminnow has not been determined. However, three nonnative fish species can have detrimental effects on plains topminnows: green sunfish and largemouth bass (*Micropterus salmoides*), which are potential predators, and the mosquitofish, which is a potential competitor.

Community ecology

Predators

Little is known about the predators of plains topminnows or the effect of predation on their population dynamics. Owen et al. (1981) remarked that plains topminnows were likely a prey item of various species of piscivorous fishes and birds. Piscivorous fish, such as green sunfish and creek chubs are potential predators that are commonly found in the pools of small streams inhabited by plains topminnows. Carlander (1969) reported plains topminnow were a prey species of black bullheads (*Ameiurus melas*) (cited in Weitzel 2002).

Competitors

Plains topminnows are well known for their pugnacious temperament. Pflieger (1997) stated the plains topminnow was known as a "hardy and attractive aquarium fish but is difficult to keep with other species because of its aggressive disposition." Propst and Carlson (1986) noted that plains topminnow were rarely collected with other fishes and suggested that it was likely a "consequence of its pugnacious disposition". In

Propst's (1982) survey of the South Platte River drainage in Colorado he reported collecting a brook stickleback (*Culaea inconstans*) with one plains topminnow and an Iowa darter (*Etheostoma exile*) with another. Propst (1982) observed that plains killifish "intermingled" with plains topminnows in a pothole of one creek, but generally found plains topminnows without associates. In Nebraska, Maret and Peters (1980) also reported that plains topminnow was most commonly associated with brook sticklebacks. In Oklahoma, plains topminnow was commonly found with the least darter (*Etheostoma microperca*) (Branson 1967).

Patton (1997) found plains topminnows in streams with creek chubs, common shiners (*Luxilus cornutus*), fathead minnows (*Pimephales promelas*), brassy minnows (*Hybognathus hankinsoni*), longnose dace (*Rhinichthys cataractae*), sand shiners (*Notropis stramineus*), central stonerollers (*Campostoma anomalum*), white suckers (*Catostomus commersoni*), plains killifish, Johnny darters (*Etheostoma nigrum*), orangethroat darters (*E. spectabile*), green sunfish, and stonecat (*Noturus flavus*). However, the degree to which plains topminnow overlapped in microhabitat use with these species was not indicated.

Lynch and Roh (1996) attributed the apparent decline in plains topminnow abundance in Nebraska to competition with the introduced mosquitofish, but they did not elaborate on the possible mechanisms involved.

Plains topminnow males engage in intra-specific competition for breeding dominance (Kaufmann and Lynch 1991), but how this competition may affect population dynamics has not been ascertained. The typically low abundance of adult plains topminnows suggests that intra-specific competition for food items is limited. However, the sparse occurrence of plains topminnow may result from their pugnacious nature manifested as competition for territories. Behavioral studies of plains topminnows in their natural habitats are needed to evaluate the role of territoriality in regulating populations of this species.

Parasites and disease

The role of parasitism or disease in regulating the population dynamics of plains topminnow is unknown. There has only been one report of the parasites of this species. Ferdig (1990) studied the ecology of parasites in disjunct populations of plains topminnows from three streams in eastern Nebraska and characterized the parasite assemblage of plains topminnows as depauperate. Ferdig (1990) described the gill monogenean *Salsuginus yutanensis* as having a high degree of host specificity for plains topminnow. Two other worm-like species were found on plains topminnows: *Gyrodactylus* spp. on the gills and fins and *Phyllodistomum* spp. in the ureter and bladder. Several protozoans, including two ciliated gill protozoans (*Trichodina* spp. and *Scyphidia* spp.) were found. *Trichodina* spp. occurred regularly and in large numbers on the host gills while *Scyphidia* spp. was not so ubiquitous. Ferdig (1990) also observed *Myxosoma funduli*, a protozoan that forms cysts on the gill filament tissues.

Symbiotic and mutualistic interactions

No symbiotic or mutualistic interactions have been documented for the plains topminnow.

Envirogram of ecological relationships

An envirogram depicts the ecological relationships that influence the survival and reproductive success of a species (Andrewartha and Birch 1984). An envirogram is built around a centrum of four components that together encompass all the major ecological relationships important to the species. These four components are termed resources, malentities, predators, and mates. Environmental (including biotic) factors that modify the four components form a web extending to several levels of indirect causation. For example, aquatic invertebrates may be important as food for a fish species and thus constitute one of the major categories for the resource component of the centrum. The abundance of aquatic invertebrates, in turn, is determined by a hierarchy of environmental factors that constitute the web. For example, invertebrate abundance is influenced by algal production, which, in turn, is determined by water fertility, which, in turn, is determined by watershed geology and land-use.

An envirogram depicting the centrum and web for plains topminnow is presented in **Figure 5**. The major resource needed by plains topminnow is food, which consists largely of aquatic invertebrates. The abundance of aquatic invertebrates depends on their food sources (e.g., algae and detritus), and these, in turn, depend upon a series of abiotic factors and human modifications of the watershed. The major malentities are considered to be summer heat stress, habitat desiccation, poor water quality, and nonnative competitors. These are often exacerbated by human modification of the environment due to surface and groundwater withdrawals for agricultural and municipal uses, livestock grazing, or fish species introductions for sportfishing. These factors

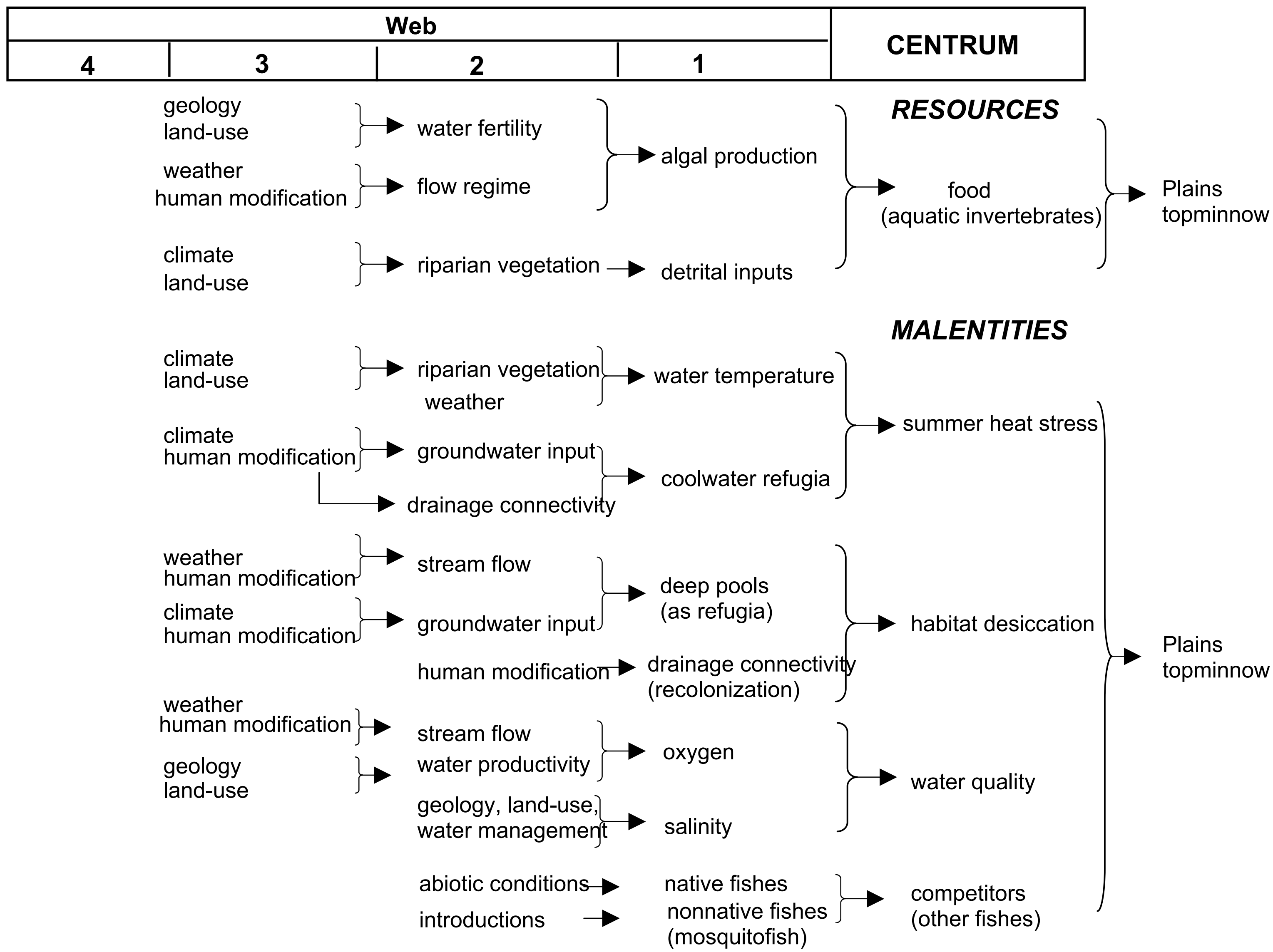
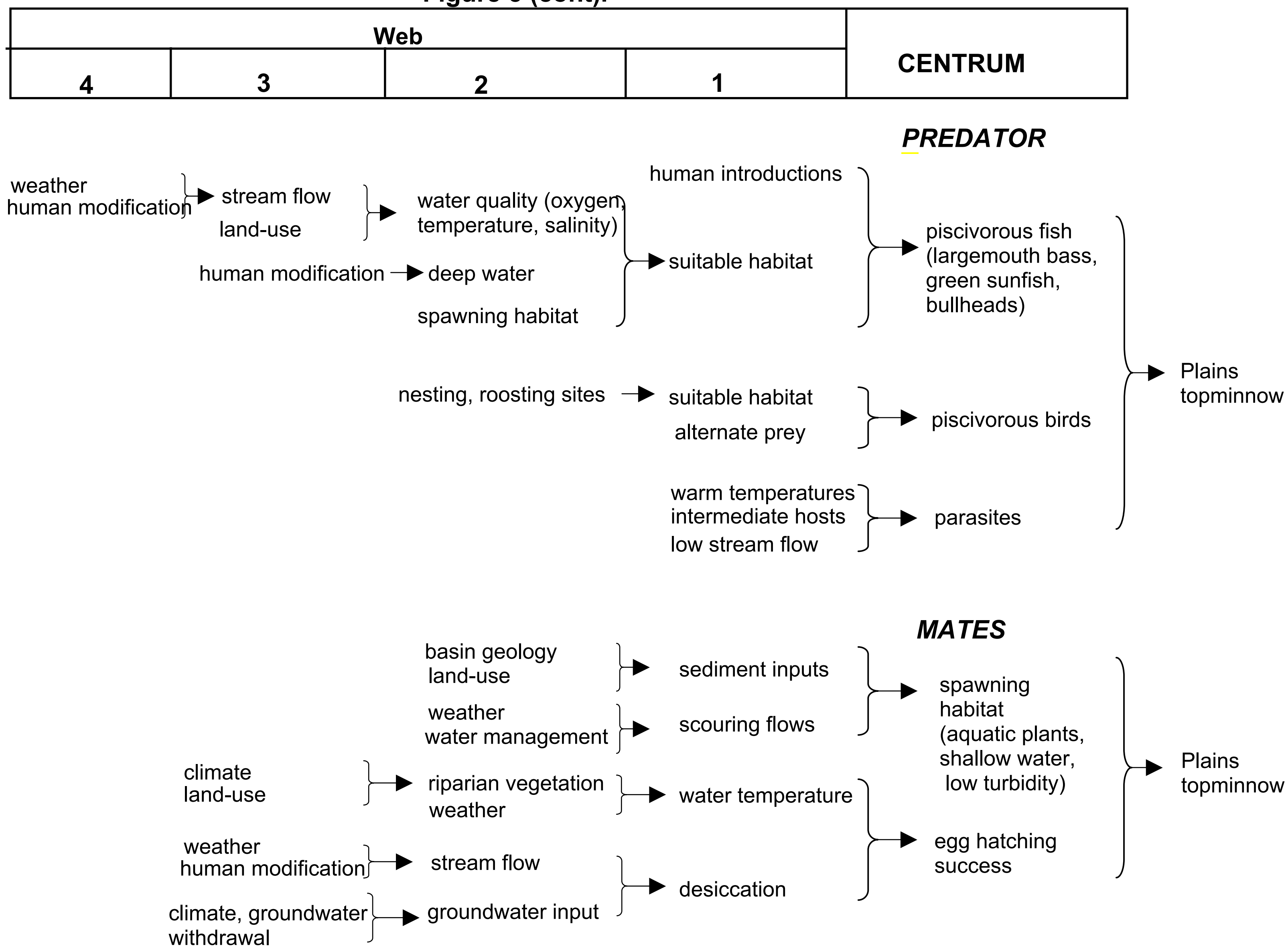


Figure 5. Envirogram for plains topminnow.

Figure 5 (cont).



are discussed in the Potential Threats section of the conservation assessment.

Piscivorous fish and piscivorous birds are considered the major predators for plains topminnow. Under mates, suitable spawning habitat and egg hatching success are major determinants of reproductive success. The web indicates how the components of the centrum are modified by a host of abiotic factors, species interactions, and human modifications of the environment.

CONSERVATION

Potential Threats

Although the plains topminnow is considered to be globally secure by the Natural Heritage Program, populations in some areas appear to have declined (see Population Trends section). These declines are likely the result of several factors that will continue to be threats in the future. These involve water development activities that alter streamflows, physical/chemical habitat degradation, stream fragmentation, and introduction of nonnative fishes.

Water development activities are a dominant feature of Great Plains watersheds. For example, in the Kansas River system of northeastern Colorado, northern Kansas, and southern Nebraska, eighteen large reservoirs and 13,000 small impoundments now control discharge from more than 80 percent of the drainage area (Sanders et al. 1993). For streams fed by snowmelt, reservoirs dampen natural flow fluctuations and reduce sediment load, making prairie streams less turbid and more confined in narrower, deeper channels. This leads to downcutting of the main channel and the subsequent loss of shallow, braided channels and backwater areas that are a major habitat for native prairie stream fishes including the plains topminnow (Patton and Hubert 1993). In the lower Kansas River system, clear water releases below reservoirs have resulted in channel downcutting by as much as 3 m (9.8 ft.) within 12 years of operation (Sanders et al. 1993).

Although reservoir releases may enhance summer stream flows in downstream reaches, other water development activities tend to have the opposite effect. Withdrawal of surface water for irrigation can result in dewatering of large stretches of prairie streams. Also, pumping of groundwater can lower water tables and cause streams to become intermittent or dry up completely (Limbird 1993, Sanders et al. 1993 Dodds et al. 2004). Cross and Moss (1987) reported that a 160 km (99.4 miles) stretch of the main stem Arkansas River in Kansas goes dry in the summer due to upstream water use and lowering of the water table by irrigation pumping. Because plains topminnows tend to be located in headwater and naturally intermittent reaches of prairie streams, they are highly vulnerable to losing habitat from activities that divert water from stream channels or lower the water tables.

Physical/chemical habitat degradation is another potential threat to plains topminnow populations. Nesler et al. (1997) noted that habitat loss was a threat to plains topminnow populations in Colorado because much of the best habitat for this species was within the rapidly urbanizing Front Range corridor where development was resulting in stream channelization along with additions of nutrients and contaminants. Water quality degradation can result from sewage discharges, feedlot runoff, intense livestock grazing, and pumping of saline groundwater. Sewage and feedlot runoff can cause eutrophication and lead to low oxygen conditions and high ammonia concentrations, especially during periods of warm water temperature. Intense livestock grazing can result in increased stream intermittency, increased turbidity (and thus a reduction in aquatic macrophytes), and accumulation of manure in pools (Platts 1991). The increased interest in extracting coalbed methane in the Rocky Mountain region has the potential to be detrimental to plains killifish populations, especially in the Thunder Basin National Grassland of Wyoming (Freilich 2004). Water produced during the methane extraction process can be highly saline and have concentrations of metals toxic to fish; yet this water is often discharged to surface drainages. While plains topminnows tolerate moderate salinities – surviving at salinities up to 24 ppt in laboratory tests (Griffith 1974) – some of the water produced during coalbed methane exceeds this level of salinity.

The reduction of connectivity in a drainage network exacerbates the loss of plains topminnow populations caused by drought, winterkill, or channel dewatering due to irrigation (Dodds et al. 2004). Factors that reduce connectivity involve barriers to fish movement such as highway culverts, dams, and intermittent reaches. Plains topminnow populations have a tendency to occur in relatively isolated patches across a watershed (Propst and Carlson 1986, Lynch and Roh 1996, Pflieger 1997). This patchy distribution probably reflects the fact that appropriate habitat in headwater stream reaches and backwater areas is patchily distributed across the landscape, especially during periods of low streamflow (Labbe and Fausch 2000, Scheurer et al. 2003). Habitat patches are periodically created and lost, thus recolonization of depopulated stream reaches was probably a common phenomenon in the evolutionary history of plains topminnow. Source-sink population dynamics have not been examined for the plains topminnow but have been shown to be important in the survival of other prairie stream fishes such as the Arkansas darter (*Etheostoma cragini*). Labbe and Fausch (2000) noted that the persistence of the Arkansas darter in two intermittent Colorado streams depended on deep pools refuges and the ability of darters to colonize new habitat during high streamflow periods. Of course, such colonization depends on having connected stream systems, which often is not the case for Great Plains streams now. Instead, recolonization is hampered by fragmentation of watersheds through construction of dams and reservoirs that block fish movement. In some cases, populations of stream fishes have been extirpated after stream reaches became isolated from the rest of the watershed by construction of a dam. Winston et al. (1991) reported that four minnow species were lost due to the damming of a prairie stream in Oklahoma. The species were cut off from downstream populations by the reservoir that formed behind the dam, and when the upstream populations were extirpated due to natural disturbances, repopulation from downstream sources was no longer possible.

Another potential threat to plains topminnow populations involves introduction of nonnative fishes. Plains topminnows are seldom found in association with larger, piscivorous fish. Historically, piscivorous game fish such as largemouth bass, green sunfish, and black crappie (*Pomoxis nigromaculatus*) were absent or rare in prairie stream drainages because of the paucity of deepwater habitat. However, construction of stock watering ponds and irrigation reservoirs has created such habitat and lead to widespread stocking of piscivorous game fish. Although the impact of such stockings on native fishes has seldom been evaluated, it is likely that an abundant population of predators would be detrimental to small prey species such as the plains topminnow. For example, Labbe and Fausch (2000) noted that nonnative northern pike (*Esox lucius*) were detrimental to the Arkansas darter in the Arkansas River drainage of Colorado. Schrank et al. (2001) found that the number of impoundments per ha in a watershed was positively related to the likelihood that the endangered Topeka shiner (*Notropis topeka*) had been extirpated from sites in Kansas. The likely mechanism was that impoundments promoted an abundance of largemouth bass that eliminated the shiner through predation.

Whether introduction of nonnative species that could act as competitors poses a threat to plains topminnow is unclear. The most likely nonnative competitor would be the mosquitofish, which has become established in riverine habitats favored by plains topminnow in Nebraska (Lynch 1988b, Lynch and Roh 1996). Because mosquitofish are aggressive toward other fishes, there is the potential for a negative effect on plains topminnow. Meffe (1985) reported that introduced mosquitofish extirpated populations of Sonoran killifish (*Poeciliopsis occidentalis*) in the southwestern U.S. Although Lynch (1988a) speculated that mosquitofish would have negative impacts on native killifishes, we found no studies documenting the extirpation of plains topminnow populations following establishment of mosquitofish in Region 2 of the USFS. Nesler et al. (1997) believed that the lack of negative effects of mosquitofish on native killifishes in Colorado and Wyoming may reflect the fact that mosquitofish have remained relatively uncommon in most habitats in those states. Mosquitofish populations appear to be limited by their intolerance to cold winter water temperature.

Conservation Status of Plains Topminnow in the Rocky Mountain Region

Within Region 2 of the USFS, the plains topminnow is not considered a federally threatened or endangered species and has Global Heritage Status Rank of G4 (apparently secure). It is present on the Pawnee National Grassland in Colorado, the Thunder Basin National Grassland in Wyoming, the Nebraska National Forest in Nebraska, and the Buffalo Gap National Grassland in South Dakota where it is not considered a sensitive species based on the 2003 USFS listing of sensitive species. The five states comprising Region 2 have different conservation rankings for the plains topminnow. Both Wyoming and Colorado consider the species to be of conservation concern, but no special conservation status is afforded the species by Nebraska, South Dakota, or Kansas.

Although the species remains widespread throughout much of its historical range, it is unknown if remaining populations are stable or if the species is continuing to decline. Thus, further monitoring of remaining populations is warranted. The USFS and the State of Colorado have started a monitoring program for plains topminnow on the Pawnee National Grassland in Colorado (http://www.fs.fed.us/r2/nebraska/gpng/tes_projects/pawneefish.html). This monitoring follows designation of the species as a Management Indicator Species (MIS) of aquatic environments on the Pawnee National Grassland. Aquatic environments occur in small isolated pockets on the Pawnee National Grassland, and thus plains topminnow populations are vulnerable to local extinctions due to natural and anthropogenic disturbances such as drought, water table drawdown, and blockage of migration pathways via road culverts or dams. Monitoring populations will allow managers to evaluate land-use practices that may be detrimental to the long-term survival of this species.

Potential Management of the Species Region 2

Implications and potential conservation elements

Although the plains topminnow is not considered to be critically imperiled in most of its range, continued water development in the naturally arid Great Plains region coupled with natural or climate-change associated drought would be detrimental to this species. The major management actions that would benefit native prairie stream fishes such as the plains topminnow are preserving streamflows, maintaining adequate water quality, maintaining stream connectivity, preventing the establishment of nonnative piscivores, and avoiding introductions of nonnative small-bodied fishes from other Great Plains watersheds (Fausch and Bestgen 1997).

Management actions that would help to maintain stream flows, especially in smaller streams that originate on the Great Plains, would be advantageous to this species. The plains topminnow is part of a group of small-bodied, warmwater fishes native to streams of the Great Plains, and management actions aimed at preserving entire assemblages prior to severe imperilment are considered the best approach to conservation of native species (Nesler et al. 1997, Rahel 1997, Nesler et al. 1999). Securing water rights to maintain instream flows in mountain streams has benefited native salmonids in the Rocky Mountain region (Annear and Dey 2001), and similar actions would be of obvious benefit to native fishes in prairie streams. For example, Moyle et al. (1998) described how the return of a more normal flow regime in a California stream benefited an entire assemblage of native fishes. The case had been in litigation, and the judge ruled that maintaining fish in "good condition" included preserving an assemblage of native, nongame species even though none of the component species was endangered.

Plains topminnows are present on one national forest and three national grasslands within Region 2, where the distribution range appears stable (**Table 2**). The major land-use on these Forest Service administered lands, livestock grazing, could be detrimental to water quality in several ways. Bank erosion coupled with extensive use of waterways by cattle could reduce water clarity to the point where the aquatic plants that are an important component of plains topminnow habitat would be lost (Platts 1991). Congregations of livestock can result in the accumulation of manure and subsequent degradation of water quality, especially in isolated pools during periods of intermittency. In addition, livestock trampling of stream banks can result in wide, shallow channels that are prone to drying up.

Plains topminnow evolved in stream systems subject to intermittency and other disturbances, such as floods and winterkill. Therefore, dispersal and recolonization after local extirpation are likely important mechanisms allowing regional persistence of the species. Thus, anthropogenic features that impede fish movements such as impoundments or highway culverts will be detrimental to the persistence of plains topminnow within a drainage. Impoundments also provide habitat for nonnative fishes that can be predators or competitors with plains topminnow such as largemouth bass and green sunfish.

Tools and practices

Inventory and monitoring of populations and habitat

Most inventory efforts to date have involved determining the presence or absence of plains topminnow at a range of sites across major drainages. Examples include surveys of the South Platte and Arkansas River drainages in Colorado (Nesler et al. 1997, 1999), the Missouri River drainage in Wyoming (Patton 1997), and the Platte River system in Nebraska (Lynch and Roh 1996). These inventories typically involve sampling fishes using seining, electrofishing, or trapping (Hays et al. 1996, Hubert 1996, Patton et al. 2000). Measures of catch-per-unit-effort provide a cost-effective index of fish abundance and are useful for trend monitoring if sites are sampled in successive time periods (Ney 1999). Estimates of actual population size can be obtained through mark-recapture or depletion-removal approaches, but these approaches require more effort and would reduce the number of sites that could be sampled.

Often, the results are compared with earlier inventories to determine which species have decreased and which species have increased their geographic range. For example, the distributions of native fishes in the South Platte River drainage collected in the 1992 survey were compared with distributions reported in earlier surveys starting in 1900 (Nesler et al. 1997). Likewise, Patton et al. (1998) compared species distributions in the 1990's with distributions from a fish survey done in the 1960's. Unfortunately, except for Patton et al. (1998), recent fish surveys rarely involved the same set of sites from earlier surveys, making it difficult to quantify changes in the occurrence of small fishes such as the plains topminnow. Although one can determine if a species is still present within a drainage, it is difficult to determine if the species is increasing or decreasing. This makes it difficult to identify species in the early stages of decline because we often cannot recognize declines until a species is lost from a drainage basin. Given that the entire assemblage of small, plains stream fishes in a reach can be sampled efficiently and simultaneously, standardized monitoring programs that revisit sites at regular intervals could be a cost-effective way to determine trends for a number of species within a national forest or grassland. When there is a large number of possible survey sites and one wishes to make inferences involving a spatially-extensive area, a probability-based sampling design such as that used in the U.S. Environmental Protection Agency's EMAP program could be employed (Olsen et al. 1999). Managers should be aware that individual populations can show considerable fluctuations in population size given that the species occurs in systems with naturally high hydrological variability. Fausch and Bestgen (1997) monitored populations of a related species, the plains killifish, at four sites over 12 years in the Cache la Poudre River near Fort Collins and noted that this species achieved a high abundance at two of the sites for several years but was nearly absent from the sites before and after that period.

We are aware of only one national grassland within Region 2 where a regular inventory program involving nongame fishes is on-going. The Pawnee National Grassland in northern Colorado began a systematic sampling program in 1998 that has continued through to the present.

There has been virtually no systematic inventorying or monitoring of habitats of plains streams except for occasional studies involving single streams and time periods seldom exceeding a decade (e.g., Bramblett and Fausch 1991). Although there have been some synoptic papers describing broad scale changes in plains streams during the past century (e.g., Cross and Moss 1987), there is little information available to make quantitative estimates of habitat change, especially for smaller streams. Standardized protocols for assessing habitat conditions of prairie streams need to be developed. Historically, most efforts to measure habitat quality in streams have involved coldwater streams and salmonid sportfishes. Recently, there has been increased attention to quantifying and monitoring warmwater streams and nongame fishes (Bain and Stevenson 1999). An example of a habitat assessment protocol that might be appropriate for prairie streams has been developed by the Wyoming Game and Fish Department (Quist et al. 2004). This protocol details techniques for measuring habitat features important at the reach scale (e.g., elevation, turbidity, intermittence) as well as features important at the channel-unit scale (depth, substrate characteristics, availability of cover). The protocol also attempts to assess anthropogenic disturbances to streams such as those leading to degraded water quality, disruptions of movement pathways for fish, or introduction of nonnative species. Such protocols could prove useful in detecting changes in habitat conditions before they cause extirpations of fish populations and in guiding rehabilitation efforts. Given that plains topminnows often occur in widely-separated habitats in drainages subject to intermittency, it would be useful to monitor the dynamics of these areas at a large spatial scale, such as through the use of aerial photography or satellite imagery. Such images could help to detect bodies of water that are most permanent, and thus likely to serve as refuges during drought periods and a source of colonists when stream flows return (Scheurer et al. 2003).

Population or habitat management practices

We found one example of conservation efforts being directed specifically toward the plains topminnow in Region 2. The Pawnee National Grassland in Colorado began attempts to create new populations of this species in 1994 (Ball personal communication 2002). Individuals from populations in Willow Creek were transplanted to sites on Pawnee Creek, Howard Creek, Wild Horse Creek, and Coal Creek. These transplants have resulted in some new populations of plains topminnow being established, but continued monitoring will be necessary to determine the long-term success of these translocation efforts.

The establishment of preserves for native plains fishes has lagged behind efforts to preserve native coldwater fish species in the region, particularly cutthroat trout (*Oncorhynchus clarki*) (Young 1995). However, management agencies are increasing their interest in the conservation of native nongame fish species (Nesler et al.1999, Weitzel 2002). In Wyoming, for example, the Wyoming Game and Fish Department has a Habitat Protection Program that reviews all environmental impact statements for potential effects on state sensitive species (Miller and Weitzel 2003). The goal of this program is no net loss of habitat for sensitive species such as the plains topminnow. The Wyoming Game and Fish Department also notes the potential for partnerships with federal management agencies to benefit native, non-game species. Such partnerships could be formed with the National Park Service at Fort Laramie and Devil's Tower National Monument. Also, private conservation organizations could play a role in preserving native stream fishes. For example, The Nature Conservancy has purchased the Fox Ranch on the Arikaree River near Wray, Colorado and is helping to preserve the site as an example of a free-flowing, plains stream (Web site: http://nature.org/wherewework/northamerica/states/colorado/preserves/). This preserve will afford conservation protection for an entire assemblage of native fishes. Continued efforts to improve upon physical habitat parameters and to secure in-stream flows will be critical conservation management activities for native plains fishes.

In areas where preserves may not be possible in the near future, management of livestock grazing can be done to minimize damage to permanent pools that serve as refuges for plains topminnow and other native prairie fishes during periods of intermittency. Such pools could be protected from livestock damage by localized fencing and provision of alternate water sources. To allow plains topminnow to recolonize habitats after local extirpation, managers should also strive to preserve movement pathways in a drainage. This may involve removing dams that impede fish passage or redesigning road culverts so they do not prevent upstream fish movement.

Information Needs

Major information needs for plains topminnow include basic life history data, the roles of predation and competition in regulating population size, and the mechanisms by which this species re-establishes populations after local extirpations. Gaps in our understanding of the life history of plains topminnow include no studies of population age structure from which annual mortality rates could be discerned. The population demography modeling (see Demography section) was done using data from plains killifish populations. Also, data on fecundity are sparse and do not allow age-specific egg production rates to be determined. Better demographic data would help to refine our knowledge about the life history parameters that are most influential for population growth.

Plains topminnows are usually collected in habitats containing few other fish species. This suggests that competition and/or predation by other fish species may play a role in limiting the distribution and abundance of plains topminnow. However, we found no studies that examined competitive interactions among plains topminnows and other fishes native to streams in the Great Plains. It has been suggested that competition with nonnative mosquitofish has caused the decline of plains topminnow populations in the Platte River system in Nebraska (Lynch 1988a, Lynch and Roh 1996). Although this explanation is plausible, studies elucidating the mechanism of competition have not been conducted. Plains topminnow exists in habitats having few native piscivorous fish species. However, humans have introduced piscivorous game fish such green sunfish, bullheads, and largemouth bass into drainages containing plains topminnow populations. Often these introductions follow construction of impoundments that alter the habitat to favor larger-bodied, piscivorous game fishes at the expense of small-bodied, native nongame fishes. Although introduced piscivores undoubtedly prey on plains topminnows, we do not know the extent to which such predation causes the extirpation of plains topminnow populations. If predation by introduced piscivores is a major cause of declines in plains topminnow populations, then cessation of stocking and removal of existing populations could be undertaken. This would be especially true in headwater tributaries where nonnative piscivores are likely concentrated in reaches having small impoundments.

Plains topminnow evolved in systems where stream intermittency is prevalent. This suggests that they have mechanisms to tolerate extreme abiotic conditions and to recolonize areas once streamflows are re-established. Although we have some insights into their ability to tolerate extreme temperature, salinity, and oxygen conditions (see Habitat section), we know little about their movement patterns and recolonization ability. This species is not known to make long-distance upstream migrations associated with spawning. Also, the species is small and has a body form not adapted for sustained swimming in high currents. How individuals are able to move through a drainage network is unknown, yet such movements would appear to be necessary for this species to survive in drought-prone drainages of the Great Plains. Studies whereby individual fish are marked and their movements are tracked throughout a drainage would further our understanding of the role of dispersal in maintaining populations over the long-term (Labbe and Fausch 2000). Understanding movement patterns is especially important given that human activities often decrease the connectivity of aquatic systems through impoundments, road culverts, and irrigation practices that dewater stream reaches.

Although the plains topminnow is not of conservation concern at the global level (see Management Status section), we know little about population trends on individual national grasslands and forests within the Rocky Mountain Region of the USFS. Monitoring plains topminnow populations could be done within the framework of monitoring the entire fish assemblage. There is also a need to develop standard aquatic habitat inventory protocols that can be used to track changes in plains topminnow habitat. These techniques will not only need to monitor local habitat conditions (e.g., water quality and macrophyte abundance), but also landscape features relating to habitat connectedness (e.g., the extent of movement barriers or the degree of intermittency between areas of suitable habitat).

DEFINITIONS

Connectivity — refers to the pathways that allow fish to move about a drainage and to recolonize areas after local extinctions have occurred. Dams and road culverts often interrupt the connectivity of a drainage.

Fecundity — the number of eggs produced by a female fish.

Intermittent tributary — a stream that flows into a larger stream and that ceases to flow during certain periods of the year. The stream may dry up completely or exist as a series of pools.

Macrophytes — vascular plants that grow in standing or flowing water.

Management Indicator Species — a species used in land management planning because its population changes indicate the effects of management activities.

Meristic character — an anatomical feature that can be counted, such as the number of spines on the dorsal fin or the number of scales along the lateral line of a fish. Meristic characters are frequently used to identify fish species using a taxonomic key.

Metapopulations — spatially isolated populations that function as independent populations but which can exchange occasional individuals. This exchange allows extirpated populations to become reestablished.

Microhabitats — the localized habitat conditions used by organisms.

Morphometric character — an anatomical feature that can be measured, such as the length of various body parts or ratios of body parts (e.g. diameter of the eye divided by the length of the head). Morphometric characters are used to identify fish species using a taxonomic key.

National Heritage Rank of the Nature Conservancy — a system of rating the conservation status of species based on the following categories: S1 = critically imperiled (< 5 occurrences, very small range); S2 = imperiled (6 to 20 occurrences, small range); S3 = vulnerable (21 to 100 occurrences, restricted range); S4 = apparently secure (> 100 occurrences, uncommon not rare), S5 = secure (widespread and abundant).

Piscivorous — "fish-eating".

Range of variability — the set of habitat conditions that a species must tolerate in order to survive.

Sensitive species — as defined by the USDA Forest Service, 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 or in habitat capability that would reduce the species' distribution.

Sexual dimorphism — the situation where males and females are different in body size, shape, coloration, or morphology.

Sink populations — populations where the death rate exceeds the birth rate. Sink populations require continual immigration from nearby populations if they are to avoid going extinct.

Source populations — populations where the birth rate exceeds the death rate. These populations are a source of emigrants to nearby areas, including sink populations.

Species of concern — a species that has declined in abundance or distribution to the point that management agencies are concerned that further loss of populations or habitat will jeopardize the persistence of the species within that region.

Species viability — the likelihood that a species will continue to persist.

Vital rates — demographic characteristics such as birth rate, fecundity and survival rate that determine the growth rate of a population.

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Appendix A

Matrix Population Analysis of Population Demographics for Plains Topminnow

The studies of Stribley and Stasiak (1982) and Kinney and Lynch (1991) provided the basis for formulating a life cycle graph for plains topminnow that comprised four age-classes and assigned first reproduction to the second age-class (**Figure 4** in species assessment). The egg production rates described by Kinney and Lynch (1991) provided the basis for calculating age-specific fertilities. We found no data on annual survival rates for adult plains topminnow and thus used values for a related species, the plains killifish, presented by Minckley and Klaassen (1969), Brown (1986), and Schemeidler and Brown (1990). Because no estimate for first-year survival was available, first-year survival (P_{21}) was assigned a value that yielded a population growth rate (λ) of 1.0. This "missing element" method (McDonald and Caswell 1993) is justified by the fact that, over the long term, population growth rate (λ) must be near 1 or the species will go extinct or grow unreasonably large. From the resulting life cycle graph (**Figure 4** in species assessment) we produced a matrix population analysis with a post-breeding census (McDonald and Caswell 1993, Caswell 2000). The model has two kinds of input terms: P_i describing survival rates, and m_i describing fertilities (**Table 4** in species assessment). **Figure A1** shows the symbolic terms (top) and corresponding numeric values (bottom) for the projection matrix corresponding to the life cycle graph. The model assumes female demographic dominance so that fertilities are given as female offspring per female; thus, the egg number used was half the total clutch, assuming a 1:1 sex ratio. The population growth rate (λ) is 1.001 based on the estimated vital rates used for the matrix. Although this suggests a stationary population, the value was used as an assumption for deriving a vital rate, and should not be interpreted as an indication of the general well-being of the population. Other parts of the analysis provide a better guide for assessment. It is important to note that, in contrast to some fisheries terminology, the convention here is ordinal numbering beginning with 1 (first, second, third and fourth age-classes). Thus, age-class 0 in fisheries terminology corresponds to age class 1 in the matrix model. Each age-class describes a one-year census interval period, such as the age-class that begins with an egg at the census and proceeds to the birthday of that egg as a yearling (as described by the survival arc P_{21} in **Figure 4** in species assessment).

Age-class	1	2	3	4
1	$P_{21}m$	P_am	P_am	
2	P_{21}			
3		P_a		
4			P_a	

Age-class	1	2	3	4
1	0.84	3.44	3.44	
2	0.042			
3		0.17		
4			0.17	

Figure A1. The top matrix shows symbolic values for the projection matrix of vital rates, **A** (with cells a_{ij}) corresponding to the plains topminnow life cycle graph of **Figure 4**. Meanings of the component terms and their numeric values are given in **Table 4**. The bottom matrix presents the numeric values used for the matrix analysis.

Sensitivity analysis

A useful indication of the state of the population comes from the sensitivity and elasticity analyses. **Sensitivity** is the effect on population growth rate (λ) of an **absolute** change in the vital rates (a_{ij}, the arcs in the life cycle graph [**Figure 4** in species assessment] and the cells in the matrix, **A** [**Figure A1**]). Sensitivity analysis provides several kinds of useful information. First, sensitivities show "how important" a given vital rate is to population growth rate (λ) or fitness. For example, one can use sensitivities to assess the relative importance of survival (P_i) and reproductive (F_i) transitions. Second, sensitivities can be used to evaluate the effects of inaccurate estimation of vital rates from field studies. Inaccuracy will usually be due to paucity of data, but could also result from use of inappropriate estimation techniques or other errors of analysis. In order to improve the accuracy of the models, researchers should concentrate additional effort on transitions with large sensitivities. Third, sensitivities can quantify the effects of environmental perturbations, wherever those can be linked to effects on stage-specific survival or fertility rates. Fourth, managers can concentrate on the most important transitions. For example, they can assess which stages or vital rates are most critical to increasing the population growth (λ) of endangered species or the "weak links" in the life cycle of a pest. **Figure A2** shows the "possible sensitivities only" matrix for this analysis (one can calculate sensitivities for non-existent transitions, but these are usually either meaningless or biologically impossible — for example, the sensitivity of λ to moving from age-class 3 to age-class 2).

In general, changes that affect one type of age-class or stage will also affect all similar age-classes or stages. For example, any factor that changes the annual survival rate of age-class 2 females is likely to cause similar changes in the survival rates of other "adult" reproductive females. Therefore, it is usually appropriate to assess the summed sensitivities for similar sets of transitions (vital rates). For this model, the result is that the summed sensitivity of population growth rate (λ) to changes in survival is of overriding importance. Plains topminnow shows large sensitivity (80 percent of total) to changes in survival, with first-year survival alone accounting for 77 percent of the total (**Figure A2**). The summed "reproductive" survival sensitivity is just 20 percent of the total. The major conclusion from the sensitivity analysis is that first-year survival is overwhelmingly important to population viability.

Elasticity analysis

Elasticities are useful in resolving a problem of scale that can affect conclusions drawn from the sensitivities. Interpreting sensitivities can be somewhat misleading because survival rates and reproductive rates are measured on different scales. For instance, a change of 0.5 in survival may be a large alteration (e.g., a change from a survival rate of 90 percent to 40 percent). On the other hand, a change of 0.5 in fertility may be a very small proportional alteration (e.g., a change from a clutch of 3,000 eggs to 2,999.5 eggs). Elasticities are the sensitivities of population growth rate (λ) to proportional changes in the vital rates (a_{ij}) and thus partly avoid the problem of differences in units of measurement. The elasticities have the useful property of summing to 1.0. The difference between sensitivity and elasticity conclusions results from the weighting of the elasticities by the value of the original arc coefficients (the a_{ij} cells of the projection matrix). Management conclusions will depend on whether changes in vital rates are likely to be absolute (guided by sensitivities) or proportional (guided by elasticities). By using elasticities, one can further assess key life history transitions and stages as well as the relative importance of reproduction (F_i) and survival (P_i) for a given species.

Elasticities for plains topminnow are shown in **Figure A3**. Population growth rate (λ) is most elastic to changes in first-year reproduction ($P_{21}m$, the self-loop on the first node in **Figure 4**) followed by first-year

Age-class	1	2	3	4
1	**0.841**	0.035	0.006	
2	**3.324**			
3		**0.119**		
4			0.000	

Figure A2. Possible sensitivities only matrix, $\mathbf{S_p}$ (blank cells correspond to zeros in the original matrix, **A**). The three transitions to which the λ of plains topminnow is most sensitive are highlighted: first-year survival (Cell s_{21} = 3.324), first-year reproduction (s_{11} = 0.841), and survival of age-class 2 (s_{32} = 0.119).

Stage	1	2	3	4
1	**0.702**	**0.119**	0.020	0
2	**0.139**			
3		**0.020**		
4			0.000	

Figure A3. Elasticity matrix, **E** (remainder of matrix consists of zeros). The population growth rate (λ) of plains topminnow is most elastic to changes in first-year reproduction (e_{11} = 0.702), followed by first-year survival (e_{21} = 0.139) and then reproduction by age-class 2 (e_{21} = 0.119). Note the considerably greater relative importance of fertility transitions in the elasticity analysis relative to the sensitivity analysis.

survival (P_{21}) and then second-year reproduction ($P_a m$). The sensitivities and elasticities for plains topminnow do not correspond in rank magnitude. The first and third most elastic transitions involve reproduction, in contrast to the first-year survival so heavily emphasized by the sensitivity analysis. The summed reproductive elasticities account for fully 84 percent of the total (compared to 16 percent for the summed survival elasticities). Thus, survival and reproduction in the first year, and to a lesser extent survival and reproduction in the second year, are the data elements that warrant careful monitoring in order to refine the matrix demographic analysis.

Other demographic parameters

The stable age distribution (**Table A1**) describes the proportion of each age-class in a population at demographic equilibrium. Under a deterministic model, any unchanging matrix will converge on a population structure that follows the stable age distribution, regardless of whether the population is declining, stationary or increasing. Under most conditions, populations not at equilibrium will converge to the stable age distribution within 20 to 100 census intervals. For plains topminnow at the time of the post-breeding annual census (just after the end of the breeding season), eggs represent 95 percent of the population, second-year individuals represent another 4 percent and older fish are extremely rare. Reproductive values (**Table A2**) can be thought of as describing the "value" of a stage as a seed for population growth relative to that of the first (newborn or, in this case, egg) stage. The reproductive value of the first stage is always 1.0. A female individual in age-class 2 is "worth" 3.95 eggs, and so on (Caswell 2000). The reproductive value is calculated as a weighted sum of the present and future reproductive output of a stage discounted by the probability of surviving (Williams 1966). The peak reproductive value (3.95) occurs at the second age-class, and these females are an important stage in the life cycle (though they represent only 4 percent of the census). The cohort generation time for this fish is 1.2 years (SD = 0.45 years).

Stochastic model

We conducted a stochastic matrix analysis for plains topminnow. We incorporated stochasticity in several ways, by varying different combinations of vital rates or by varying the amount of stochastic fluctuation (**Table A3**). Under Variant 1 we subjected first-year reproduction (F_{11}) to stochastic fluctuations. Under Variant 2 we varied the survival of all age classes, P_i. Each run consisted of 2,000 census intervals (years) beginning with a population size of 10,000 distributed according to the stable age distribution under the deterministic model. Beginning at the stable age distributions helps avoid the effects of transient, non-equilibrium dynamics. The overall simulation consisted of 100 runs (each with 2,000 cycles). We varied the amount of fluctuation by changing the standard deviation of the random normal distribution from which the stochastic vital rates were selected. The default value was a standard deviation of one quarter of the "mean" (with this "mean" set at the value of the original matrix entry [vital rate], a_{ij} under the deterministic analysis). Variant 3 affected the same transition as Variant 1 (F_{11}) but was subjected to half the variation (SD was 1/8 of the mean). Variant 4 further reduced variation at F_{11} to 1/16 of the mean. We calculated the stochastic growth rate, $log\lambda_S$, according to Caswell (2000), after discarding the first 1,000 cycles in order to avoid transient dynamics.

The stochastic model (**Table A3**) produced two major results. First, varying first-year reproduction had a greater effect on population growth rate (λ) than varying all the survival rates. For example, 98 of 100 runs led to extinctions with variable first-year reproduction under Variant 1 from the starting size of 10,000. In contrast, varying the survival rates of all age classes under Variant 2 did not lead to any extinctions. This difference in the effects of stochastic variation is

Table A1. Stable age distribution (right eigenvector). At the census, 95 percent of the individuals in the population should be eggs. The remaining 5 percent of individuals will be reproductive yearlings or older. Of the yearling or older fish, 83 percent will be yearlings.

Age Class	Description	Proportion
1	Eggs (to yearling)	0.952
2	Second-year females	0.040
3	Third-year females	0.007
4	Fourth-year females	0.004

Table A2. Reproductive values (left eigenvector). Reproductive values can be thought of as describing the "value" of an age class as a seed for population growth relative to that of the first (newborn or, in this case, egg) age class. The reproductive value of the first age class is always 1.0. The peak reproductive value (second-year females) is highlighted.

Age Class	Description	Reproductive values
1	Eggs/first-year females	1.00
2	Second-year females	**3.95**
3	Third-year females	3.38
4	Fourth-year females	0.00

Table A3. Summary of four variants of stochastic projections for plains topminnow.

	Variant 1	Variant 2	Variant 3	Variant 4
Input factors:				
Affected cells	F_{11}	P_i	F_{11}	F_{11}
S.D. of random normal distribution	1/4	1/4	1/8	1/16
Output values:				
Deterministic λ	1.006	1.006	1.006	1.006
# Extinctions/100 trials	98	0	1	0
Mean extinction time	812	N.a.	1,685	N.a.
# Declines/# survived pop	1/2	0/100	16/99	0/100
Mean ending population size	39,367	$1.2X10^9$	$2.9X10^9$	$3.2X10^9$
Standard deviation	55,665	$2.5X10^9$	$2.8X10^{10}$	$1.5X10^{10}$
Median ending population size	39,367	$4.2X10^8$	531,474	$1.4X10^8$
Log λ_s	-0.0144	0.0053	0.002	0.0049
λ_s	0.9857	1.0053	1.002	1.0049
% reduction in λ	2.01	0.07	0.39	0.11

predictable largely from the elasticities. Population growth rate (λ) was more elastic to changes in first-year reproduction, F_{11} (e_{11} = 0.702), than to changes in the survival rates (summed survival elasticities = 0.16). Second, the magnitude of stochastic fluctuation largely determines the negative effect on population dynamics. This negative effect occurs despite the fact that the average vital rates remain the same as under the deterministic model — the random selections are from a symmetrical distribution. This apparent paradox is due to the lognormal distribution of stochastic ending population sizes (Caswell 2000). The lognormal distribution has the property that the mean exceeds the median, which exceeds the mode. Any particular realization will therefore be most likely to end at a population size considerably lower than the initial population size. For plains topminnow under the F_{11} Variant 3 with reduced (1/8 vs. 1/4) variability, only 1 (vs. 98 under Variant 1) out of 100 trials of stochastic projection went to extinction. Variant 4 further demonstrates that the magnitude of fluctuation has a potentially large impact on the detrimental effects of stochasticity. Decreasing the magnitude of fluctuation (to SD = 1/16 of the mean) decreased the severity of the negative impacts — the number of extinctions went from 1 in Variant 3 to 0 in Variant 4. Note that Variant 4 is reasonably similar to the outcome of Variant 2 — that is, it takes fairly large magnitude fluctuations in survival (SD = 1/4) to have the same detrimental effects produced by even small fluctuations in first-year reproduction (SD = 1/16). These results indicate that populations of plains topminnow are vulnerable both to stochastic fluctuations in production of newborns (due, for example, to annual climatic change or to human disturbance) and, to a far lesser degree, to variations in survival. Pfister (1998) showed that for a wide range of empirical life histories, high sensitivity or elasticity was negatively correlated with high rates of temporal variation. That is, most species appear to have responded to strong selection by having low variability for sensitive transitions in their life cycles. A possible concern is that anthropogenic impacts may induce variation in previously invariant vital rates (such as annual adult survival), with consequent detrimental effects on population dynamics. For this fish, with stochasticity having the greatest impact on first-year reproduction, the life history may not allow the kind of adjustment of risk load that may be possible in other species. Variable spawning conditions are likely to be the rule rather than the exception.

Potential refinements of the models

Survival data for plains topminnow are needed. The population modeling described above used survival estimates for a related species, the plains killifish. Data from natural populations on the range of variability in the vital rates would allow more realistic functions to model stochastic fluctuations. For example, time series based on actual temporal or spatial variability, would allow construction of a series of "stochastic" matrices that mirrored actual variation. The sensitivity and elasticity analyses assume that changes in the vital rates are small (occurring near equilibrium). With a species such as the plains topminnow, fluctuations may actually be large and severe. Monitoring populations under a range of conditions would allow stochastic simulations that incorporated very different life cycle graphs/ matrices and would greatly improve our understanding of the population dynamics in the face of a fluctuating environment. An additional advantage of such a series would be the incorporation of observed correlations between variation in vital rates. Using observed correlations would incorporate forces that we did not consider (e.g., variation in predator or competitor load). Those forces may drive greater positive or negative correlation among life history traits. Other potential refinements include incorporating density-dependent effects. At present, the data appear insufficient to assess reasonable functions governing density dependence.

Summary of major conclusions from matrix projection models:

- ❖ First-year survival accounts for 84 percent of total "possible" sensitivity. Any absolute changes in this rate will have major impacts on population dynamics.

- ❖ First-year reproduction (F_{11}) accounts for 70 percent of the total elasticity, compared to 14 percent (next highest value) accounted for by first-year survival. Proportional changes in first-year reproduction will have a major impact on population dynamics.

- ❖ The contrast between the conclusions from the sensitivity and elasticity analyses suggests that survival and reproduction in the first year of life are both critical to the population dynamics of plains topminnow.

- ❖ Where the potential exists for survival through to the third year, reproductive values of females in that age-class will be high. Such populations may be important sources of recolonization for other sites or in periods when local conditions improve.

- ❖ Stochastic simulations echoed the elasticity analyses in emphasizing the importance of variation in first-year reproduction to population dynamics. In comparison to life histories of other vertebrates, plains topminnow appear to be vulnerable to local extinction. Management should occur at a scale that encompasses a broad range of habitat sites and ecological conditions.

- ❖ Management will need to take account of the potential for considerable variability in population trajectories and the need for multiple habitat sites as a buffer against the likelihood of reasonably frequent local population extinctions.

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APPENDIX B

Sources of information used to produce the distribution map (**Figure 3**) showing the occurrence of plains topminnow within HUB 4 drainages in the five states comprising Region 2 of the USDA Forest Service.

Colorado:

Nesler, T.P., R. VanBuren, J.A. Stafford, and M. Jones. 1997. Inventory and status of South Platte River native fishes in Colorado. Colorado Division of Wildlife, Fort Collins, CO.

Kansas:

Stream Assessment and Monitoring Program Database and 1970's Stream Database, State of Kansas, Department of Wildlife and Parks, Pratt, KS.

Cross, F.B. and J.T. Collins. 1995. Plains topminnow, *Fundulus sciadicus*. Page 176 *in* Fishes in Kansas. University of Kansas Natural History Museum. Public Education Series No. 14. University Press of Kansas, Lawrence, KS.

Nebraska:

Fisheries survey data supplied by the Nebraska Game and Parks Commission, Lincoln, NE.

South Dakota:

Natural Heritage Database Reports for South Dakota, provided by the Department of Game Fish and Parks, Pierre, SD.

Fisheries survey data collected by Eco~Centrics of Bassett, NE and David Fryda, M.S. Candidate, South Dakota State University on Buffalo Gap National Grassland. Copies of the fisheries survey data were provided by the Nebraska National Forest Supervisor's Office.

Wyoming:

Weitzel, D.L. 2002. Conservation and Status Assessments for the Finescale Dace (*Phoxinus neogaeus*), Pearl Dace (*Margariscus margarita*), and Plains Topminnow (*Fundulus sciadicus*): Rare native fish species of the Niobrara and Platte River basins, Wyoming. Fish Division Administrative Report. Wyoming Fish and Game Department, Cheyenne, WY.