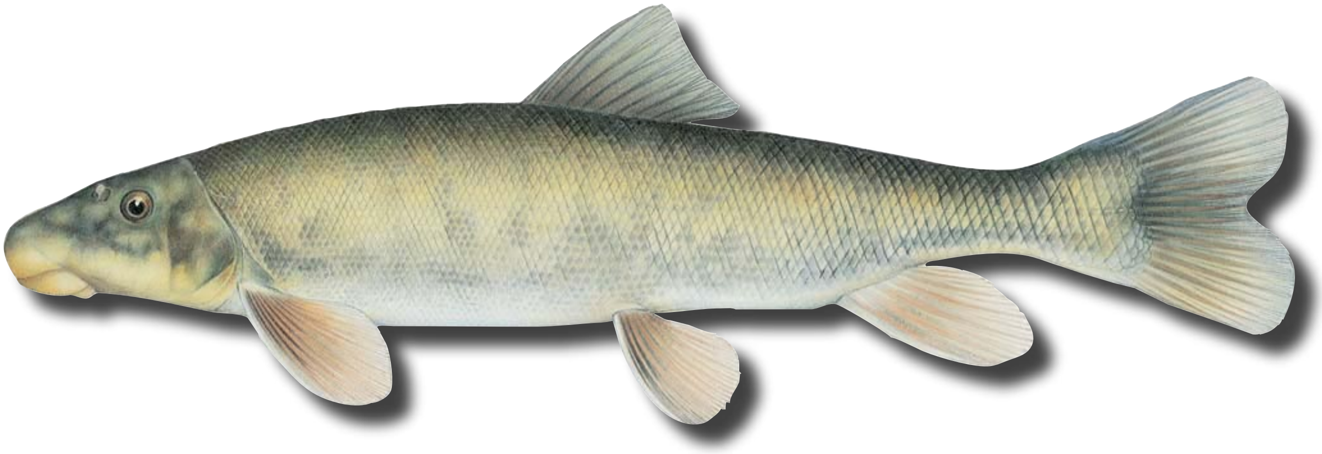
Mountain Sucker (*Catostomus platyrhynchus*): A Technical Conservation Assessment



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

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COVER ILLUSTRATION CREDIT

Mountain sucker (*Catostomus platyrhynchus*). Illustration by © Joseph Tomelleri.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF THE MOUNTAIN SUCKER

Status

The mountain sucker (*Catostomus platyrhynchus*) is found throughout much of western North America, ranging from southern Canada in the north to Utah in the south, and from eastern California in the west to western South Dakota in the east. It is widely distributed in some parts of its range and sparsely distributed in others. In USDA Forest Service, Rocky Mountain Region (Region 2), the mountain sucker occurs throughout Wyoming and in northwestern Colorado and western South Dakota. Information regarding population trends of mountain sucker throughout its range is lacking, but the species appears to be stable in some regions while declining in others. Several state and federal agencies consider the mountain sucker to be a sensitive species, or species of concern, based on its rarity in some areas, apparent population declines, its sensitivity to further habitat loss, and the lack of knowledge of population trends at local and regional scales.

Primary Threats

The main threats to the mountain sucker generally result from anthropogenic activities, with geographically isolated populations or those that previous anthropogenic activities have adversely affected being the most susceptible to extirpation. Habitat loss due to stream impoundment has been the cause of mountain sucker population declines in some drainages, while habitat degradation from increased sedimentation has also contributed to observed declines in others. Construction of passage barriers, such as dams and culverts, results in population and habitat fragmentation, leaving populations vulnerable to extirpation. Although less well understood, the introduction of non-native fishes also appears to threaten mountain sucker populations, primarily through increased predation, but also via increased competition. Hybridization may be a concern for some populations, but little is known about hybridization between mountain sucker and other sucker species found in Region 2. In the past, fisheries management projects that have used piscicides to control unwanted species have posed a threat to mountain sucker populations. However current practices, which include efforts to salvage native non-game species, have reduced that threat within Region 2.

Primary Conservation Elements, Management Implications and Considerations

There is insufficient information regarding mountain sucker populations in Region 2 to identify population trends or to assess the impacts of particular land and water management activities on the species. Suggested priorities for conservation and management of the mountain sucker include better documentation of its occurrence in Region 2 and the initiation of long-term monitoring programs for select populations. Coordination with state and other federal agencies would be beneficial in efforts to update mountain sucker distributions at local levels in Region 2 and in establishing monitoring programs. Knowledge of mountain sucker habitat associations and movement patterns, especially dispersal and seasonal movements, is necessary for assessing the impacts of land and water management activities that could result in habitat loss, degradation, or fragmentation. The matrix demographic model suggested that mountain sucker population persistence is vulnerable to variations in survival rates, particularly of young age-classes, age-0 up to the age of female recruitment into the breeding population at around age-3 or age-4. Consequently, a better understanding is needed of mountain sucker habitat requirements, particularly for young and young adults, to understand population persistence in the long term. Considering the limited information available on the mountain sucker, conservation and management efforts should be directed to inventorying populations and maintaining stream habitat quality and connectivity where populations are known to occur on or downstream of National Forest System lands in Region 2.

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INTRODUCTION

Goal

This assessment of the mountain sucker (*Catostomus platyrhynchus*) was prepared for the USDA Forest Service (USFS), Rocky Mountain Region (Region 2), Species Conservation Project. It addresses the status, biology, ecology, conservation, and management of the mountain sucker throughout its range, with an emphasis on Region 2. This assessment provides a synthesis of the published information on the mountain sucker and is intended to improve the understanding of the species based on current knowledge for use by the USFS in conserving the species and designing its management plans. The mountain sucker was targeted for assessment by the Species Conservation Project because of its status as a sensitive species in Region 2 of the USFS.

Scope, Uncertainty, and Limitations

The mountain sucker has rarely been the focus of research, and little is known about most populations, especially those in Region 2. This assessment summarizes all published information found regarding the species throughout its range in western North America. The information synthesized in the assessment is primarily drawn from peer reviewed literature, but theses, dissertations, and agency reports provide additional information. Agency personnel were contacted for information on current management practices and also provided data on mountain sucker occurrence within Region 2.

This assessment is limited by the lack of information on mountain sucker, particularly within Region 2. The primary research describing the biology and ecology of the species was conducted outside of Region 2. Consequently, interpretation and application of research findings regarding mountain sucker populations from other regions to Region 2 should be undertaken with caution, as some aspects of mountain sucker biology and ecology may vary with environmental conditions, community composition, and land and water management history. Inferences made from the information compiled and synthesized in the assessment are limited by the differences in research methodologies used among studies, in addition to the paucity of research on the species. To provide a better understanding of the information compiled in this assessment, pertinent research methods are included as part of the summarized information, as well as strength of evidence of results when available. Alternative explanations or inferences made from observational data are provided in the context of the complete body of knowledge of the species. When information regarding particular aspects of the species' biology or ecology was completely lacking, information on closely related species considered to have similar biological or ecological characteristics is provided.

This assessment describes what is known about the mountain sucker throughout its range. It is a guide to the range of biological and ecological parameters documented for the species and, as such, can be used to guide future investigations or management actions. This assessment also identifies critical gaps in the knowledge of mountain sucker biology and ecology that may impede effective management.

Web Publication and Peer Review

This assessment will be published on the USFS Region 2 World Wide Web site (www.fs.fed.us./r2/projects/scp/assessments/index.shtml). In keeping with the standards of scientific publication, assessments developed for the Species Conservation Project have been externally peer reviewed prior to their release on the Web. This assessment was reviewed through a process administered by the American Fisheries Society, which chose two recognized experts (on this or related taxa) to provide critical input on the manuscript.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Federal Endangered Species Act

The mountain sucker is not listed as a threatened or endangered species under the U.S. Endangered Species Act (U.S. Fish & Wildlife Service; http://endangered.fws.gov), nor is it a candidate for listing or been proposed for listing.

Natural Heritage Ranks

The Natural Heritage Network has designated the Global Status of mountain sucker as Secure (G5). In the United States, the National Status is also Secure (N5), and in Canada, its National Status is Apparently Secure (N4). In the United States, mountain sucker populations are found in 11 states in which their state status designations range from Critically Imperiled in one state to Secure in five states (**Table 1**). In Canada, the mountain sucker occurs in three provinces and is considered

Table 1. Natural Heritage Network state and provincial status ranks for mountain sucker.

State or Province	Conservation Status
California	Imperiled, S2
Colorado	Imperiled, S2
Idaho	Secure, S5
Montana	Secure, S5
Nebraska	Critically Imperiled, S1
Nevada	Not Ranked
Oregon	Apparently Secure, S4
South Dakota	Vulnerable, S3
Utah	Apparently Secure, S4
Washington	Imperiled, S2
Wyoming	Secure, S5
Alberta	Apparently Secure, S4
British Columbia	Vulnerable, S3
Saskatchewan	Vulnerable, S3

Vulnerable in British Columbia and Saskatchewan (S3) and Apparently Secure in Alberta (S4).

Of the states included within USFS Region 2, the mountain sucker has a state conservation status of Secure (S5) in Wyoming, Vulnerable (S3) in South Dakota, Imperiled (S2) in Colorado, and Critically Imperiled (S1) in Nebraska. This species does not occur in Kansas.

USDA Forest Service

In Region 2 of the USFS, the mountain sucker is designated as a sensitive species. In the National Forest System, a sensitive species is a plant or animal whose population viability has been identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance and/or in habitat quality that would reduce its distribution (FSM 2670.5 (19)).

The mountain sucker is also designated as a Management Indicator Species by the Black Hills National Forest. MIS are plant and animal species, groups of species, or special habitats that have been selected for emphasis in planning and that are monitored during forest plan implementation to assess the effects of management activities on their populations and the populations of other species with similar habitat needs that the MIS species may represent (USDA Forest Service 1991).

Bureau of Land Management

The Colorado State Office of the BLM includes the mountain sucker on the State Director's Sensitive Species List, which was last updated in 2000; it is not included on the sensitive species lists of other state offices.

State agencies

The Colorado Division of Wildlife has designated the mountain sucker as a species of special concern (Natural Diversity Information Source: http://ndis.nrel.colostate.edu), and it is likely to remain on the state's special concern list due in part to the recent increase in energy exploration and development impacts occurring in western Colorado (T. Nesler personal communication 2006). The Wyoming Game and Fish Department considers the mountain sucker a non-game fish and assigns it a Native Species Status designation of NSS3, meaning that populations in Wyoming are considered to be widespread and stable, but that habitat availability is declining (Weitzel 2002). State agencies in South Dakota and Nebraska have not assigned the mountain sucker any special status. Status designations of mountain sucker by state agencies, including states outside of Region 2, are provided in **Table 2**.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

With the exception of monitoring plans for the mountain sucker and its habitat in the Black Hills

Table 2. Mountain sucker status designations by stage agencies in states of occurrence.

State	Status	Source
California	Species of Special Concern	Fish Species of Special Concern in California, California Department of Fish and Game, 1995: http://www.dfg.ca.gov/
Colorado	State Special Concern	Colorado Division of Wildlife, Natural Diversity Information Source: http://ndis.nrel.colostate.edu/wildlifespx.asp?SpCode=010635
Idaho	Not ranked	Idaho Fish and Game, Idaho Conservation Data Center: http://fishandgame.idaho.gov/cdc/
Montana	Not ranked	Montana Fish Wildlife and Parks Department, Montana's Species of Concern List 2004. http://fwp.mt.gov/wildthings/concern/fish.html
Nevada	Not ranked	State of Nevada Department of Natural Resources & Conservation, Natural Heritage Program List: http://heritage.nv.gov/lists/fishes.html
Oregon	Not ranked	Oregon Department of Fish and Wildlife, 2005 Oregon Native Fish Status Report Public Review Draft: http://www.dfw.state.or.us/fish/ONFSR/report.asp and Oregon Department of Fish and Wildlife 1997 Sensitive Species List: http://www.dfw.state.or.us/wildlife
South Dakota	Not ranked	South Dakota Department of Game, Fish and Parks, Threatened, endangered and candidate species of South Dakota, January 2006: http://www.sdgfp.info/Wildlife/Diversity/TES.htm
Utah	Senstive Species	State of Utah Department of Natural Resources Division of Wildlife Resources, Utah Sensitive Species List May 2006: http://dwrcdc.nr.utah.gov/ucdc/ViewReports/SSL051206.pdf
Washington	Species of Concern	Washington Department of Fish and Wildlife, Species of Concern in Washington State: http://wdfw.wa.gov/wlm/diversty/soc/soc.htm (current through 6/7/2006)
Wyoming	NSS3 - wide spread and stable, but habitat declining	Wyoming Game and Fish, Comprehensive Wildlife Conservation Strategy: http://gf.state.wy.us/wildlife/CompConvStrategy/Species/Fish/index.asp

National Forest, we found no existing state or federal agency management plans or conservation strategies specifically targeting this species within USFS Region 2. The mountain sucker is a non-game fish and not actively exploited or managed, but it can be harvested as a baitfish in some states. State regulations on mountain sucker harvest vary among the four states of Region 2 where the species occurs and are summarized below.

In South Dakota, the mountain sucker is considered a baitfish, and the possession limit is 12 dozen of any combination of designated baitfish species. Legal anglers may collect the limit for personal use, but they must obtain a commercial dealers license to take bait for sale or other commercial purposes (South Dakota Department of Game, Fish, and Parks 2005 Fishing Handbook: http://www.sdgfp.info/Publications/FishingHandbook.pdf).

In Nebraska, the mountain sucker is designated as a non-game fish. Anglers collecting bait for personal use are required to return non-baitfish species to the waters from which they were collected (Nebraska Game and Parks Commission 2005 Fishing Guide: http:// www.ngpc.state.ne.us).

In Colorado, the mountain sucker is a non-game fish of state special concern (Colorado Division of Wildlife; http://wildlife.state.co.us), and it is illegal to harvest or possess them (Colorado Division off Wildlife, Fishing Regulations and Property Directory 2006; http://wildlife.state.co.us/Brochures).

In Wyoming, the mountain sucker is a non-game fish, but they may be taken for use as bait with legal fishing methods (Wyoming Game and Fish Commission, Fishing Regulations 2004-2005; http://gf.state.wy.us/downloads/pdf/fish/fishregs.pdf). The Wyoming Game and Fish Commission mitigation category is high for mountain sucker, meaning that projects should be conducted so that there is no net loss of habitat function within the biological community, impacts are avoided, or similar habitat is enhanced or an equal amount of similar habitat is created (Weitzel 2002).

Biology and Ecology

Description and systematics

Identification

The mountain sucker has a slender, cylindrical body; rounded fins; and a short, conical head (Simpson and Wallace 1982, Page and Burr 1991, Baxter and Stone 1995). Like most suckers, the mouth is sub-terminal, and their lips provide key identifying characteristics. The mountain sucker, and other members of the subgenus *Pantosteus*, possess a cartilaginous plate or ridge on the lower lip, presumably for scraping algae and invertebrates from rocky stream substrates (Baxter and Stone 1995, Moyle 2002). Adult and juvenile mountain sucker can be identified by the deep lateral indentations that separate the upper and lower lips and the shallow notch in the middle of the lower lip (Simpson and Wallace 1982, Snyder 1983, Page and Burr 1991, Baxter and Stone 1995). The papillae on the lower lip are concentrated around the center of the lip, in three to four rows (Page and Burr 1991), and have been described as forming a half rosette pattern (Baxter and Stone 1995). The upper lip has few to no papillae (Simpson and Wallace 1982, Snyder 1983, Page and Burr 1991, Baxter and Stone 1995).

The mountain sucker is a dusky color dorsally (gray, olive, or greenish) that fades along the sides to a light-colored belly (white or yellow) (Simpson and Wallace 1982, Page and Burr 1991, Baxter and Stone 1995). The sides have a dark, greenish stripe that extends from the snout to the caudal fin (Simpson and Wallace 1982), and the sides and back may have a series of darker blotches and speckling (Simpson and Wallace 1982, Page and Burr 1991, Baxter and Stone 1995). The mountain sucker also has a dusky or black peritoneum and pelvic axillary process (Page and Burr 1991).

Both male and female mountain sucker display secondary sexual characteristics that allow them to be easily distinguished during the breeding season (Hauser 1969). Both sexes have breeding tubercles, but they are more numerous and larger in males (Simpson and Wallace 1982). Males are covered with minute tubercles on the entire body and all fins except the dorsal fin (Hauser 1969). Males also have prominent tubercles on the caudal fin and their enlarged anal fin. Females have few tubercles on the caudal fin and their small anal fin, and the minute tubercles on their bodies are restricted to the dorsal and lateral parts of the head and body (Hauser 1969). Next to the dark, greenish lateral stripe on their sides, breeding males have a bright red-orange band that begins behind the eye and extends to the base of the caudal fin (Hauser 1969, Page and Burr 1991, Baxter and Stone 1995). Breeding females may also exhibit spawning colors; Hauser (1969) described breeding females as having a reddish-orange lateral band similar to the males, but not as vivid and shorter, extending from the opercular opening to near the anal fin.

The mountain sucker is moderately long-lived; the maximum age reported is 9 years for females, which are thought to be longer lived than males (Hauser 1969). Mountain sucker are small for catostomids; the maximum length attained is usually reported as about 25 cm (9.75 inches; Page and Burr 1991, Baxter and Stone 1995); however, there is one report of a mountain sucker reaching 30.5 cm (12 inches; Tomelleri and Eberle 1990). More commonly, adult specimens are smaller with normal adult size ranging from 15 to 20 cm (6 to 8 inches; Tomelleri and Eberle 1990). In Wyoming, where the mountain sucker is most widely distributed in Region 2, the largest specimens are often around 15 cm (6 inches) in length, with 20 cm (8 inches) thought to be maximum length attained in the state (Baxter and Stone 1995). Snyder (1983) summarized morphometric measurements and meristic traits for adult mountain sucker throughout its range.

Snyder (1983) also developed an identification key for larval catostomids present in the Truckee River system (mountain sucker, Tahoe sucker (*Catostomus tahoensis*), and cui-ui *Chasmistes cujus*)) and found that most mountain sucker larvae could be identified with “reasonable confidence” on the basis of mid-ventral pigmentation for larvae less than 21 mm (0.8 inch) total length (TL), and peritoneal pigmentation, gut-loop formation, and mouth characters for metalarvae greater than 21 mm (0.8 inch) TL or juveniles less than 50 mm (2 inches) TL. Recently, a guide titled “Catostomid fish larvae and early juveniles of the upper Colorado River basin”, which includes illustrations and photographs and is accompanied by a computer-interactive key, has been published; it is the best source for identification of larval suckers (Snyder et al. 2004).

Taxonomy

Suckers, Family Catostomidae, are an ecologically important component of the North American fish fauna, with roughly 100 species occurring from the Arctic to the tropics (Sigler and Sigler 1996). In the United States, 60 species of suckers represent 11 genera (Lee et al. 1980).

The mountain sucker (*Catostomus platyrhynchus* Cope) is also known as the northern mountain sucker or plains sucker (Campbell 1992). The genus name *Catostomus* refers to the inferior mouth, or mouth below, and *platyrhynchus* to their flat snout (Sigler and Sigler 1996). The mountain sucker was first definitively described in 1874 by Cope as *Minomus platyrhynchus* from a specimen collected in 1872 by Yarrow and Henshaw near Provo, Utah (Smith 1966). *Minomus delphinus* and *M. bardus* were described previously in 1872 and were likely mountain sucker; but because the collection localities were uncertain, the descriptions inadequate, and the specimens lost by 1878, the lectotype is the Provo, Utah specimen named *M. platyrhynchus* (Smith 1966). The mountain sucker was soon renamed *Pantosteus platyrhynchus* by Cope and Yarrow in 1875 (Smith 1966, Snyder 1983).

In an 1893 publication, Evermann described mountain sucker specimens from the eastern side of the Rocky Mountains as *Pantosteus jordani* (Smith 1966, Baxter and Stone 1995), and in 1903, Rutter described a form found in the Lahontan basin as *P. lahontan* (Smith 1966, Snyder 1983). In 1958, Miller concluded that *P. jordani* was synonymous with *P. platyrhynchus* (Baxter and Stone 1995).

After an extensive review of the characters of the *Pantosteus* species, and consideration of their geographical distributions in the context of the geologic history of the region, Smith (1966) concluded that the three species *P. platyrhynchus*, *P. lahontan*, and *P. jordani* were a single species and consolidated the taxa under the senior synonym *platyrhynchus* (Campbell 1992, Moyle 2002). Smith (1966) further proposed that the *Pantosteus* spp. (which also included *P. plebeius*, *P. santaanae*, *P. clarki*, *P. discobulus*, and *P. columbianus*) were not distinct enough from *Catostomus* spp., especially considering the documented hybridization between *Catostomus* and *Pantosteus* species, to merit generic distinction (Smith 1966, Moyle 2002). *Pantosteus* spp. were reclassified as *Catostomus*, and *Pantosteus* was demoted to the level of subgenus (Smith 1966).

Later taxonomic investigations of the genus *Catostomus* examined variations in phenotypes of biochemical characteristics among species and the subgenus *Pantosteus* (Koehn 1969, Koehn 1970), or employed phenetic and cladistic methods to examine variation of biochemical and morphological characteristics within the genus (Smith and Koehn 1971). The review of the taxonomy and revisions of Smith (1966) have generally been accepted (Campbell 1992). The most recent research and interpretation by Smith and Koehn (1971) and Smith (1992) have contributed additional information, but not altered the revisions of Smith (1966) (Isaak 2003). However, considering the long isolation of mountain sucker populations in the major basins of western North America, Moyle (2002) suggested that a reanalysis of the taxonomy, based on current molecular and statistical techniques, might result in the re-emergence of several distinct taxa.

Phylogeny and geographical patterns of regional populations

The phylogeny of the mountain sucker precedes recent geographic patterns and, consequently, regional populations have been isolated for many thousands of years, several since before the last ice age (Smith 1966, Campbell 1992). The early evolution of the subgenus *Pantosteus* is thought to have occurred in the Pliocene somewhere in the highlands of the eastern Great Basin, Colorado Plateau, and in headwaters of the ancestral Snake and Missouri Rivers (Campbell 1992).

The long period of isolation of regional mountain sucker populations resulted in morphological variability among populations and led to the description of three species, complicating the taxonomy of the mountain sucker (Campbell 1992). Smith (1966) proposed the current taxonomic classification based on a comparison of the morphological characteristics of populations and his understanding of geologic history.

Based on the current understanding of the species phylogeny and taxonomy, populations of mountain sucker from the Great Basin and Upper Missouri regions are the most distinct, which suggests a long isolation (Campbell 1992). Among several sub-basin populations occurring in the Great Basin, little differentiation is apparent, which is thought to suggest slow evolution (Smith 1966, Campbell 1992).

Populations of mountain sucker from the Missouri River drainage are more similar to those of the Green, Snake, Sevier, and Columbia River basins (Smith 1966, Campbell 1992). This suggests that mountain sucker may have inhabited the area of western Wyoming for a long period, with the eastern and northern spread into the Bighorn Mountains of Wyoming and Black Hills of South Dakota occurring sometime in the late Pliocene early Pleistocene (Smith 1966, Campbell 1992). Populations of mountain sucker on the lower Snake River are more similar to those of the Missouri River system than populations above the falls, which share more similarities with Great Basin populations (Campbell 1992).

Mountain sucker from the upper Missouri, Milk, and Saskatchewan basins are thought to be "undifferentiated post-glacial derivatives which survived glaciation in a Missouri refugium" and are most likely still expanding in distribution with geologic processes (Campbell 1992). Populations in the Fraser River system are thought to be post-glacial derivatives of the Columbia River populations (Campbell 1992).

Distribution and abundance

Range

The mountain sucker is the most widely distributed member of the subgenus *Pantosteus* (Campbell 1992). It occurs throughout large portions of the western United States and Canada and is most common in the center of its range in the Intermountain region of the United States. The range of the mountain sucker extends from eastern California in the west to western South Dakota in the east and from southern Alberta in the north to southern Utah in the south. This species occurs in the Saskatchewan and Fraser River systems in the north, through the Columbia, Snake, upper Missouri, upper Sacramento, Lahontan, and Bonneville basins to the southern-most populations in tributaries of the Colorado River in southern Utah (**Figure 1**; Page and Burr 1991).

Among the five states included in Region 2, the distribution of mountain sucker is most widespread in Wyoming (**Figure 2**), where it is considered common to all drainages west of the Continental Divide (including the Bear, Green, Snake, Madison, Yellowstone, Wind-Bighorn, and Little Snake river basins), as well as the state's northern and northeastern drainages east of the Divide (including the Tongue, Powder, Cheyenne and Belle Fourche River basins) (Baxter and Stone 1995). The mountain sucker is absent from the Niobrara and South Platte drainages in southeastern Wyoming. Although historical records indicate that this species once occurred in tributaries of the North Platte River in Wyoming (Smith 1966), Baxter and Stone (1995) considered mountain sucker rare and most likely extirpated from the North Platte River drainage.

In Colorado, mountain sucker populations are found in the northwestern part of the state, in the Green River drainage, and Snyder (1981) also reported them in the headwaters of the Colorado, Yampa, White, and Green rivers. The mountain sucker is widely distributed throughout the Black Hills of South Dakota, which comprises the eastern most extension of the species' range; they are considered rare or non-existent in the rest of South Dakota (Isaak 2003).

Mountain sucker occurrence in Nebraska has been considered extremely rare (Tomelleri and Eberle 1990). Historic collections of mountain sucker in Nebraska were from areas near the South Dakota border and are considered to have represented the extreme limit of its historic range (Schainost and Koneya 1999). In 1896, Eveman and Cox reported collecting mountain sucker from a tributary of the White River in Nebraska (Schainost and Koneya 1999). Another historic report of mountain sucker collected from the Niobrara River in Nebraska was suggested to be a labeling error when the accession papers at the National Museum were copied (Smith 1966). Mountain sucker has not been collected in Nebraska since 1939 when found by Raymond Johnson in a tributary of Hat Creek, part of the Cheyenne River drainage (Schainost and Koneya 1999). Because it has not been collected in Nebraska since 1939 and because many sections of the streams in which it was historically found now become seasonally dry, mountain sucker is considered extirpated in the state (Schainost and Koneya 1999, S. Schainost personal communication 2006). Mountain sucker do not occur in Kansas.

Within USFS Region 2 lands, mountain sucker are known to occur on the Bighorn, Black Hills, Medicine Bow, and Routt national forests (W. Young personal communication 2006, S. Hirtzel personal communication 2006, G. Allison personal communication 2006, K. Foster personal communication 2006). Its occurrence in the Medicine Bow and Routt national forests is restricted to streams on the western side of the Continental Divide (G.T. Allison personal communication 2006, K. Foster personal communication 2006). Mountain sucker also are thought to occur on the Arapaho-Roosevelt and White River national forests (D. Renner personal communication 2006, C. Hirsch personal communication 2006) and are considered likely to occur on the Shoshone National Forest (USDA-Forest Service R2 Sensitive Species Evaluation Form).

There are few reports of mountain sucker introductions to stream systems, and the practice does not appear to have been widespread, despite early suggestions of the value of mountain sucker as forage for trout in mountain streams (Simon 1938). In Utah, the mountain sucker was introduced (as a baitfish) to the Strawberry River drainage by 1950 and to the Duchesne and Price River basins, all part of the Colorado River system (Sigler and Miller 1963). Sigler and Miller

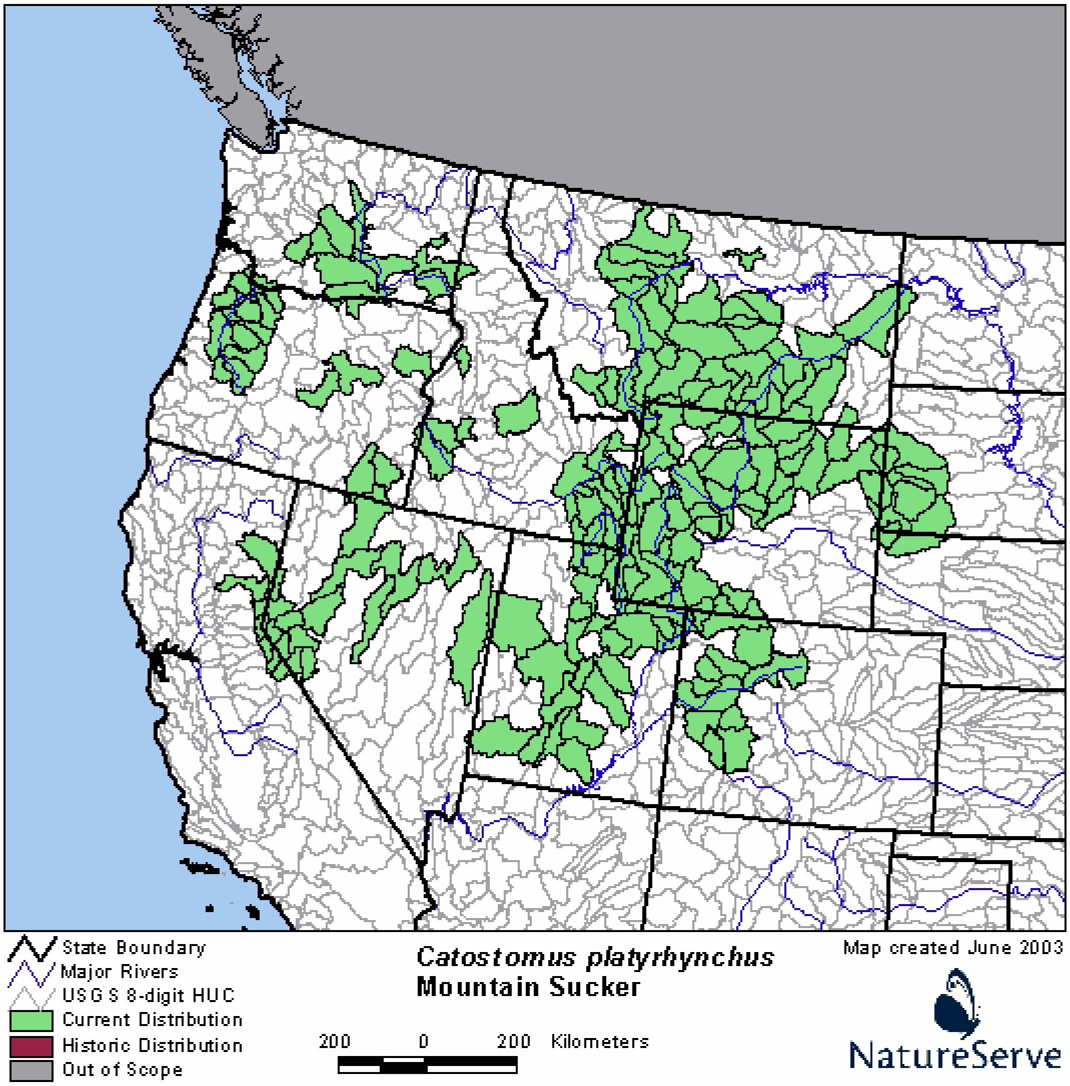

Figure 1. Mountain sucker distribution in the United States obtained from NatureServe Explorer: An online encyclopedia of life [web application]. Version 5.0. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer (Accessed: December 19, 2005).

(1963) also referenced attempts to propagate mountain sucker as a baitfish in Marysvale in southern Utah, and noted that the species was used as bait in impoundments along the lower Colorado River. More recently, the mountain sucker was considered common in the Duchesne River drainage, but it was considered rare elsewhere in the mainstem Colorado River drainage (Sigler and Sigler 1996).

A record of a mountain sucker collected from the South Platte River drainage in Colorado was published in 1952 (Smith 1966). However, Smith (1966) examined the specimen and re-identified the fish as *Catostomus plebeius* (Rio Grande sucker). He speculated that its occurrence in the South Platte River location was the result of an introduction. In California, the mountain sucker was found in the North Fork of the Feather River, a part of the Sacramento River drainage, presumably introduced via a transbasin irrigation diversion from the Little Truckee River (Moyle 2002). In Nevada, several mountain sucker specimens were recorded by multiple fisheries workers from the north end of Spring Valley (White Pine County) in the late 1940s through the early 1960s; however, those populations may have been introduced, as Cope and Yarrow had reported the valley as "fishless" in 1875 (Smith 1966).

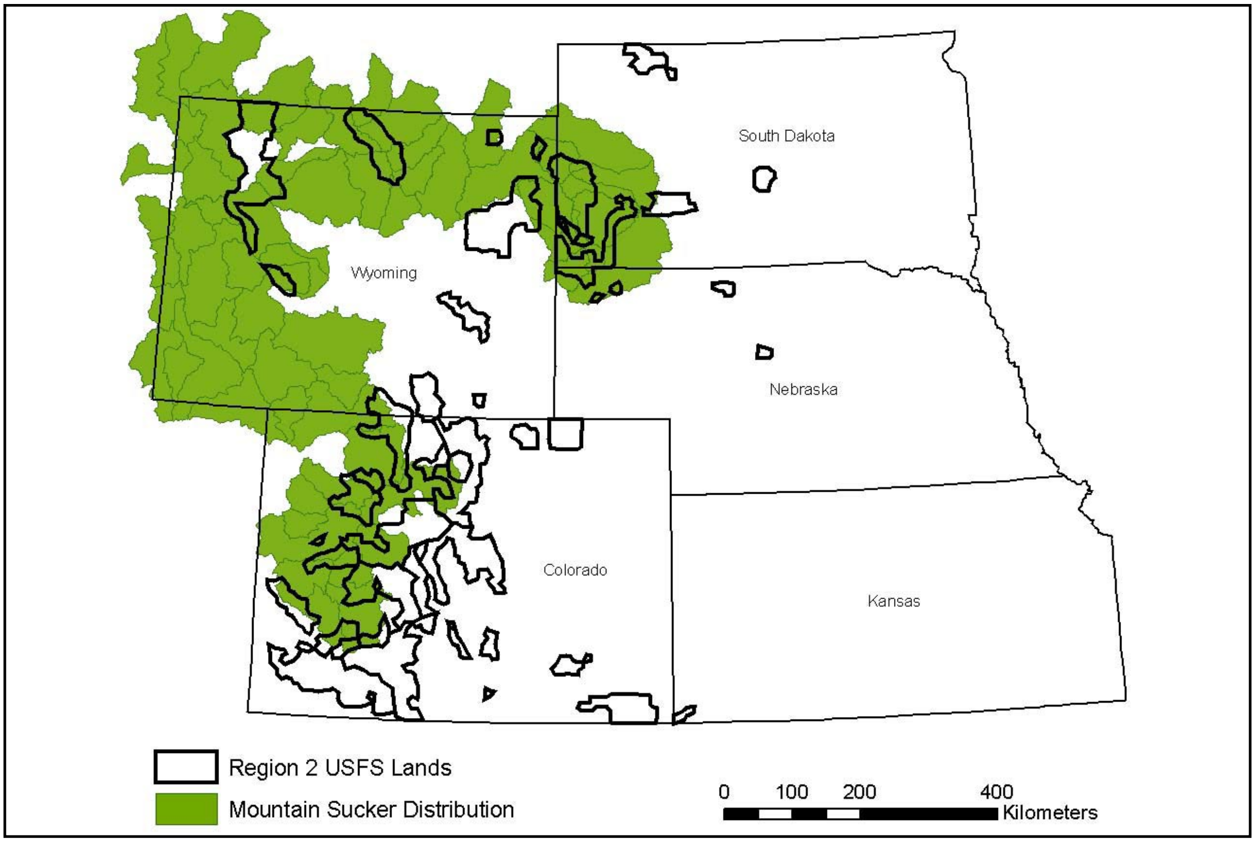

Figure 2. Distribution of mountain sucker by 8-digit hydrologic unit, relative to USDA Forest Service Region 2 lands.

Abundance

The ability to evaluate patterns in abundance over time and among localities is a critical part of fisheries management (Ney 1999). Abundance statistics are used to compare populations in different locations or, when collected over time for a single population, provide valuable information on population trends, outcomes of management actions, and impacts of environmental changes (Ney 1999). Unfortunately, there are few published estimates of abundance for the mountain sucker. Those that were found were from disparate parts of the species' range and in locations with different environments, all of which complicates comparisons. Based on the limited information available, mountain sucker populations appear to vary in abundance across their range. Differences in abundance among populations are most likely related to variations in habitat, as well as being influenced by differences in community ecology and management impacts, among other factors. Furthermore, mountain sucker distribution within streams appears to be patchy, with large variations in relative abundance among sampling sites. Following is a summary of mountain sucker abundance information compiled from the literature.

In the Black Hills region, South Dakota Game Fish and Parks personnel have routinely surveyed streams where mountain sucker occur and have derived density estimates using a closed-population, removal-estimator methodology (Isaak et al. 2003). Estimated mountain sucker densities (number of fish per area) for 59 stream sites sampled between 1993 and 1999 ranged from 7 to 13,399 fish per hectare, with a mean of 1,262 fish per ha and a median of 265 fish per ha. Mountain sucker abundance estimates (number of fish per mile) obtained from Stewart and Thilenius (1964) for several streams in the Black Hills National Forest were compiled in the Black Hills National Forest FY2004 Monitoring and Evaluation Report (http://www.fs.fed.us/r2/blackhills/projects/planning/index.shtml), and ranged from 20 to 3,390 fish per mile. In the more recent surveys of some of the same streams, the number of mountain sucker estimated in sampled stream sections (usually 100 m reaches) ranged from zero to 257 fish for sites where mountain sucker were expected to occur (Table 3).

Isaak et al. (2003) could not find other published abundance statistics for mountain sucker except for density estimates provided by Moyle and Vondracek (1985) for an eastern California stream, Martis Creek.

Table 3. Population estimates for mountain sucker at designated survey sites (1980's - present). Reproduced from the Black Hills National Forest FY2004 Monitoring and Evaluation Report (http://www.fs.fed.us/r2/blackhills/projects/planning/index.shtml). Estimates are for the number of mountain sucker in a sampled stream section, usually a 100-m reach. Only sites where mountain sucker occurred and were considered a target species were included.

Sampling Site	Date	Estimated Number of Fish
Bear Butte Creek Site 14	September 1984	7
	September 1997	87
	November 1997	257
	September 1998	0
	September 1999	3
	September 2000	168
	October 2001	78
	September 2002	17
	September 2003	4
	September 2004	21
Bear Butte Creek Site 15	September 1984	14
	September 1992	134
	July 1997	80
	November 1997	12
	September 1999	0
	September 2000	123
Boxelder Creek Site 1	July 1984	22
	July 1993	19
Boxelder Creek Site 2	July 1993	5
Elk Creek Site 4	June 1985	253
	July 1997	213
Elk Creek Site 5	September 1984	89
	August 1997	250
French Creek Site 5	May 1992	31
	September 1993	1
Spring Creek Site 3	July 1984	21
	July 1993	28
Spring Creek Site 7	July 1984	0
	September 1993	25

The reported density in Martis Creek ranged from zero fish per 100 m^2 to a maximum of 28 fish per 100 m^2 during five years of sampling at four sampling stations 30 to 40 m (98 to 131 ft.) in length. The Martis Creek research was conducted on a 2.9 km (1.8 mile) segment between a reservoir and the creek's confluence with the Truckee River. The maximum density of mountain sucker of 28 fish per 100 m^2 was anomalous in the Martis Creek study (Moyle and Vondracek 1985). Of the 20 estimates of density (four sites over five years), mountain sucker numbers were less than three fish for 19 of the estimates (Moyle and Vondracek 1985). Aside from the single estimate of 28 fish per 100 m^2, 55 percent of the estimated mountain sucker densities were zero fish, 15 percent were less than one fish, 10 percent were one fish, 5 percent were two fish, and 10 percent were three fish (Moyle and Vondracek 1985). At one sampling station, no mountain sucker were collected over five years, and for the other three sampling stations there was at least one year in which no mountain sucker were collected (Moyle and Vondracek 1985).

The maximum densities of mountain sucker reported in the California stream sites were a third or less of those estimated for the Black Hills stream sites, with a mean density of 428 fish per ha and a median of 50 fish per ha (Isaak et al. 2003). Isaak et al. (2003) noted that the segment of Martis Creek sampled was downstream of a dam and had a "highly altered" fish community; it was very different from the Black Hills streams, so little could be inferred from a comparison of the populations.

In the Bitter Creek drainage of southwestern Wyoming, the mountain sucker was one of two indigenous species of fish found to predominate (Carter and Hubert 1995). Estimates by Carter (1993) of the abundance of mountain sucker from sampling sites on Bitter Creek and its tributaries ranged from 37 fish per mile (23 fish/km) to 7,059 fish per mile (4,396 fish per km), with a mean of 1,664 fish per mile (1,034 fish per km) (**Table 4**).

No abundance estimates for mountain sucker populations in Colorado or Nebraska were identified in the literature. The Colorado Division of Wildlife provided records of collection of mountains sucker in the Green River drainage in Colorado, but we were not able obtain abundance information for this report due to data limitations. Mountain sucker collection locations in Colorado were compiled and are included in **Table 5**. Following are some incidental and qualitative reports found in the literature that provide some indication of the abundance of mountain sucker throughout their range.

In 1981, Snyder classified mountain sucker occurrence as occasionally common or generally less common (<1 percent of all fish collected regularly) in streams of the Yampa, Green, White and Colorado River drainages in Colorado. In the intermediate to large streams of the Yampa and upper mainstem of the Colorado River drainages, mountain sucker were collected rarely or infrequently (Snyder 1981). Goettl and Edde (1978) described the mountain sucker as abundant in Piceance Creek, Colorado (Campbell 1992).

In Washington State, where the mountain sucker occurs in the Columbia River System, 48 individuals were collected from the Yakima River, below three dams located between river mile 47 and river mile 128 during the period from November 1998 to July 1999. However, during the previous year's sampling, using similar effort, no mountain sucker were collected. Similar fluctuations in mountain sucker relative

Table 4. Abundance of mountain sucker found in Bitter Creek and tributaries, Wyoming. Reproduced from Carter (1993).

Stream	Site	Fish per mile	Fish per km
Bitter Creek	1	1072	666
Bitter Creek	2	122	76
Bitter Creek	3	1276	793
Bitter Creek	4	0	0
Bitter Creek	5	340	211
Bitter Creek	6	0	0
Little Bitter Creek	1	0	0
Little Bitter Creek	2	0	0
Little Bitter Creek	3	2923	1816
Little Bitter Creek	4	482	300
Little Bitter Creek	5	37	23
Salt Wells Creek	1	0	0
Salt Wells Creek	2	0	0
Bean Spring Creek	1	0	0
Gap Creek	1	7059	4386
Gap Creek	2	0	0

Table 5. Mountain sucker occurrence in Colorado, ordered by Hydrologic Unit Code. Lakes and reservoirs where mountain sucker were collected are italicized. This information was provided by the Colorado Division of Wildlife.

HUC 10	Stream	HUC 10	Stream
1018000100	Snyder Creek	1405000100	South Fork Williams Fork Yampa River
1401000100	Colorado River	1405000100	*Steamboat Lake*
1401000106	*Fraser Kids Pond*	1405000100	Williams Fork Yampa River
1401000500	*Bonham Reservoir*	1405000100	Willow Creek
1404010600	Beaver Creek	1405000101	Day Creek
1404010900	Vermillion Creek	1405000109	*Stagecoach Reservoir*
1405000100	Armstrong Creek	1405000200	Milk Creek
1405000100	Beaver Creek	1405000300	Fourmile Creek
1405000100	Bunker Creek	1405000300	Little Snake River
1405000100	Coulton Creek	1405000300	Middle Fork Little Snake River
1405000100	Deep Creek	1405000300	North Fork Little Snake River
1405000100	Deer Creek	1405000300	Slater Creek
1405000100	East & Williams Fork Yampa River	1405000300	South Fork Little Snake River
1405000100	Elk River	1405000300	Willow Creek
1405000100	Elkhead Creek	1405000500	Big Beaver Creek
1405000100	Fish Creek	1405000500	Coal Creek
1405000100	Fortification Creek	1405000500	Flag Creek
1405000100	Hinman Creek	1405000500	North Fork White River
1405000100	Indian Run	1405000500	Strawberry Creek
1405000100	Miller Creek	1405000500	White River
1405000100	Morapos Creek	1405000600	Dry Fork Piceance Creek
1405000100	North Fork Deer Creek	1405000600	Piceance Creek
1405000100	*Pearl Lake*	1405000600	Yellow Creek
1405000100	Red Creek	1405000602	Fawn Creek
1405000100	Smith Creek	1405000700	Missouri Creek
1405000100	South Fork Elk River		

abundance were reported for the Grand Ronde River in which 18 fish were captured in 1997, none in 1998, and 61 in 1999 (Wydoski and Whitney 2003). In the Truckee River in California, Snyder (1983) noted that the mountain sucker was "especially common" in the upstream segments. In the East Fork of the Carson River, abundance of sucker species, which included mountain sucker, was estimated to range from 1,000 to 44, 000 per km of stream in 1988 (J. Deinstadt unpublished data (1996) as referenced by Moyle (2002)). Sigler and Sigler (1996) noted the abundant populations of mountain sucker in the Blacksmith Fork River in Utah, but they were perplexed by the absence of the species from a similar and nearby stream, the Logan River. Sigler and Miller (1963) noted that the mountain sucker was abundant enough to be used as food for captive furbearing animals in some states, but they were not more specific. Wydoski and Wydoski (2002) reported that mountain sucker populations were "thriving" in Birch Creek, Lost Creek, and Woodruff reservoirs in northeastern Utah.

The mountain sucker is not thought to be distributed widely or abundantly in Canada (Campbell 1992). Collection records from the University of Alberta Museum of Zoology, the Canadian Museum of Nature, and the Royal Ontario Museum indicate that from one to 96 fish were collected from various sites in Alberta during field surveys; usually, however, less than 20 fish were collected from a site (Campbell 1992). Reportedly, the mountain sucker is common in the Milk River drainage of Alberta, and although sparsely distributed in British Columbia, it is abundant where found (Campbell 1992).

Population trends

At the regional scale, several researchers have commented on perceived declines in mountain sucker populations. However, there have been few mountain sucker populations monitored sufficiently for an evaluation of actual population trends.

The only reported population trend analysis for the mountain sucker was performed using density data from several streams in the Black Hills region. Isaak et al. (2003) evaluated the available data to discern population trends at four sites on three streams that had been sampled at least three times during the period from 1992 to 1998 in standardized surveys. Of these, two sites were downstream of the Black Hills National Forest boundary (one of which was adjacent to the forest in a state park), and two sites were located on private inholdings on the forest. The population trend analysis was performed using linear regression, with density (abundance per ha) as the response variable and time (sampling year) as the predictor variable. This method indicates a trend if the slope of the regression line is not zero (Ney 1999). The direction and rate of change of the slope and the strength of the relationship describe the population trend (Ney 1999). Isaak et al. (2003) found no indication of trends in mountain sucker density at the four sites. Although the slopes at two of the sites were negative and two were positive, none differed significantly from zero ($\alpha = 0.05$, p values ranged from 0.12 to 0.55). Isaak et al. (2003) pointed out that data suitable for the analysis was limited and that the statistical power to detect trends was weak. Since the data used in the analysis only spanned a six-year period, it is also probable that short-term variability obscured longer-term population trends (Ney 1999).

Based on a comparison of the historic reports of mountain sucker distribution with more recent reports, Isaak et al. (2003) concluded that there has been minimal change in mountain sucker distribution in the Black Hills region in the past century. A possible exception is in the upper Cheyenne River where mountain sucker had not been collected in more recent surveys; however, it was unclear whether the apparent absence indicated a range contraction or resulted from less frequent sampling of those locations (Isaak et al. 2003). Although mountain sucker distribution in the region appears stable, occurrence at several locations in the Black Hills National Forest has varied over time, and “localized population reductions or absence at selected sites may have occurred” (Black Hills National Forest FY2004 Monitoring and Evaluation Report).

In the 1990’s, Patton (1997) resampled 42 stream sites in the Missouri River drainages of Wyoming that had been sampled during the 1960s. The majority of Wyoming drainages are part of the Missouri River system and account for 72 percent of the land area of the state. Because of data limitations, however, abundance estimates could not be used to assess species trends, so presence-absence data were used instead. Patton et al. (1998) subtracted the number of sites from which the species was collected in the 1990s from the number of sites from which it had been collected in the 1960s. Species trends were evaluated in this manner at four different spatial scales (sites, streams, sub-drainages and drainages) using raw data and data adjusted for differences in gear efficiency between the survey periods (Patton 1997, Patton et al. 1998). A species was considered to have declined if it had declined in at least two of the four spatial scales and there was no indication of increase at any of the spatial scales (Patton 1997, Patton et al. 1998). The mountain sucker was considered to have declined in 12 of 18 sites, 11 of 15 streams, eight of 10 sub-drainages, and five of five drainages (Patton 1997). The decline was attributed to effects of land management and irrigation practices that increased turbidity and siltation of small, cool, clear, gravel streams that mountain sucker inhabited (Patton et al. 1998).

Using a method similar to Patton (1997), Wheeler (1997) evaluated changes in distributions of native non-salmonid fish in the drainages of southwestern Wyoming including the Green, Snake, Little Snake, and Bear River drainages. Wheeler (1997) found the distribution of mountain sucker had not decreased when results from 1990’s surveys (that consisted of both electrofishing and seining) were compared to seining surveys in 1965. However, when only the seining survey data from the 1990s were compared to 1965 seining survey data (controlling for gear differences), mountain sucker distribution appeared to have decreased. Mountain sucker populations were thought to have declined, but because of the increased effort and efficiency of the seining, plus electrofishing surveys performed in the 1990s, the distribution of the mountain sucker was not found to have changed (Wheeler 1997). Elsewhere in Wyoming, there is a single report of a mountain sucker population expansion in which the relative abundance (number of fish per kilometer) of mountain sucker increased from 0 to 206 fish per km, after a restoration project (R. Wiley personal communication as referenced by Wydoski and Wydoski (2002)).

The mountain sucker population in Sagehen Creek, California has declined since research first began there in the 1950s, when the combined proportion of mountain and Tahoe suckers was 18 percent of the fish assemblage (Erman 1986). The combined proportion of the two sucker species expanded to 61 to 79 percent of the fish assemblage in the 1970s for a few years after a reservoir was constructed on the stream; but by 1983, the proportion of the two sucker species in the assemblage had dropped to about 4 percent (Erman 1986). Erman (1973) noted that during the 1950s Tahoe sucker were "a minor part of the sucker population" in Sagehen Creek. Erman (1973) also reported that Tahoe sucker were infrequently collected in the 1970s, suggesting that historically mountain sucker comprised a greater proportion of the sucker population. However, by the 1980s the relative proportions of the two sucker species appeared to have reversed. Decker (1989) reported that mountain sucker comprised just 12.5 percent of the sucker population (both species combined), and the sucker population (both species combined) comprised only 4 percent of the fish assemblage by the 1980s. Of the two sucker species found in Sagehen Creek, mountain sucker abundance was thought to have declined the most. The apparent decline of mountain sucker in Sagehen Creek was attributed to the inundation of the lower section of the stream, which had contained the habitats where mountain sucker had been most abundant prior to impoundment. Decker (1989) estimated that mountain sucker were restricted to only 12 percent of its historical stream habitat due to the inundation of the lower sections Sagehen Creek by the reservoir. Notably, Tahoe sucker are larger-bodied and thought to be better adapted to lentic environments than mountain sucker (Decker 1989, Moyle 2002).

Decker (1989) reported similar decreases of mountain sucker populations in three other impounded streams in the western Lahontan basin. Historically, the mountain sucker was considered more abundant in two of the streams and about equally abundant as Tahoe sucker at a third site (Decker 1989). By 1983, there were significant differences in relative proportions of the two species compared to earlier surveys (chi square $p < 0.05$), with Tahoe sucker comprising 100 of the sample at two locations and 95 percent at the other (Decker 1989). All three streams had been affected by reservoir construction, and two of the streams had also been treated with piscicide (Decker 1989). In general, the mountain sucker populations in eastern California are thought to be declining as a result of stream modifications, particularly dam construction (Moyle 2002).

In contrast to the impounded eastern California streams, the relative proportions of mountain and Tahoe suckers were not significantly different ($p > 0.05$) from earlier surveys in three relatively unimpacted streams in Nevada. In one stream, equal proportions of mountain sucker and Tahoe sucker were found in both 1942 and 1983, but the number of hybrids of the two species had increased from 1 to 10 percent (Decker 1989). At another site, mountain sucker comprised 78 percent of the sucker population in 1942 and 70 percent in 1983 (Decker 1989). Both of these sites had been exposed to human and livestock disturbance, and the first site discussed had an upstream diversion structure (Decker 1989). The third site was unchanged from previous descriptions, with mountain sucker comprising 87 and 83 percent of the sucker population in 1938 and 1983 respectively.

There are some impoundments that appear to have minimal effects on mountain sucker populations. Wydoski and Wydoski (2002) described mountain sucker populations in three northeastern Utah reservoirs as "thriving and resilient". They attributed the difference in abundance between the reservoir-affected Utah sites and those in eastern California to the availability of "high quality water and habitat" in the "relatively pristine" tributary streams of the Utah reservoirs.

Within streams, mountain sucker abundance at sites appears to vary temporally, which affects the ability to interpret population trends among years. Variation in mountain sucker abundance estimates can be high between surveys. For instance, at a site on Bear Butte Creek in the Black Hills National Forest, mountain sucker abundance estimates were made annually, in late summer to early fall, over an eight year period. The abundance estimates for this site ranged from zero to 257 mountain sucker over the eight-year period (**Table 3**; Black Hills National Forest FY2004 Monitoring and Evaluation Report). The temporal variability in mountain sucker abundance estimates also is seen at shorter time scales. Estimated mountain sucker abundance was 87 fish in September and 257 fish in November when Bear Butte Creek site was sampled twice in 1997 (Black Hills National Forest FY2004 Monitoring and Evaluation Report).

Some of the variation in abundance estimates of mountain sucker is probably related to movements. There are two examples of mountain sucker movements resulting in short-term variability in abundance. Wydoski and Wydoski (2002) observed a spawning run of a reservoir population of mountain sucker into a tributary stream, finding hundreds of mountain sucker in the tributary stream during the spawning period and few after spawning ended. Variability in relative abundance of mountain sucker related to movements was also observed in Sagehen Creek, California where snorkeling surveys were conducted every two weeks during summer in a 1.2 km (0.75 mile) section of stream immediately above a reservoir (Decker 1989, Decker and Erman 1992). Prior to the observed peak abundance of 37 mountain sucker on August 2, few to no mountain sucker were observed in the 1.2 km segment (Decker 1989). The peak abundance was maintained through August 16 when 34 mountain sucker were observed in the 1.2 km segment (Decker 1989). However, by September 22 mountain sucker were again absent from the stream segment (Decker 1989). Mountain sucker were thought to inhabit the reservoir downstream before and after spawning (Decker and Erman 1992).

Population trends of the mountain sucker are difficult to discern based on the limited information, the inconsistency in sampling methods, and a lack of focus on the species in the past. Evaluation of population trends is further confounded by a lack of knowledge regarding the movement patterns of the species, in addition to fluctuations in abundance related to natural variability in recruitment rates and environmental conditions, and those stemming from anthropogenic impacts. In general, mountain sucker populations that have been affected by factors such as habitat degradation or loss appear to be in decline, whereas populations in relatively unmodified areas appear to be more stable.

Habitat

Mountain sucker primarily occur in lotic waters, from small montane streams to large rivers (Simpson and Wallace 1982, Page and Burr 1991, Baxter and Stone 1995). They are most commonly found in smaller headwater streams but have been collected from several rivers throughout their range including the Cheyenne, Powder, Yellowstone, and the Columbia and its tributaries, such as the Snake, Yakima, and Willamette rivers (Bond 1953, Smith 1966, Weitzel 2002, Isaak 2003, Wydoski and Whitney 2003).

Mountain sucker have also been found in lentic habitats including lakes and reservoirs. They are reported to occur in some alpine lakes in Wyoming (Baxter and Stone 1995) and in Lower Green River Lake (Smith 1966). In Colorado, the mountain sucker has been collected from several lakes, including Steamboat Lake (**Table 5**). In Utah and California, researchers have documented mountain sucker populations utilizing impoundments on headwater streams (Decker and Erman 1992, Wydoski and Wydoski 2002). In Idaho, mountain sucker have been collected from Stanley Lake and Bear Lake (Smith 1966).

Mountain sucker populations occur at elevations ranging from 1,189 to 2,804 m (3,900 to 9,200 ft.) in the Great Basin region (Smith 1966, Sigler and Sigler 1996) and from near sea level to almost 2,134 m (7,000 ft.) in northern drainages (Smith 1966). In Wyoming, this species is found at elevations up to 3,048 m (10,000 ft.) in the Wind River Mountains (Baxter and Stone 1995).

Streams

There is more information regarding adult mountain sucker habitat associations in smaller mountain streams, where they have more often been the focus of research, than their habitat associations in large rivers or lentic environments. Most observations of mountain sucker stream habitat associations have been made during the summer.

In streams, mountain sucker are most common in low gradient segments that consist of a mix of riffles, pools, and runs. In Region 2, mountain sucker are typically found in low gradient stream reaches in meadows (K. Foster personal communication 2006). In Montana, Hauser (1969) collected mountain sucker from two low gradient streams (less than 1 percent), which he described as 6 to 10 m (20 to 33 ft.) wide with pools as deep as 1.5 m (5 ft.) interspersed with riffles. Mountain sucker are found in the lower segment of Sagehen Creek, California, which is described as a meandering low gradient channel (1 percent gradient) with runs, pools, and riffles and a mean width of 5 m (16 ft.) (Decker and Erman 1992). Prior to the impoundment of lower Sagehen Creek, Gard and Flittner (1974) found mountain and Tahoe suckers in abundance in stream reaches that had moderate to high pool to riffle ratios (1: 1.6 to 49:1) and channel gradients of around 1 percent. Mountain sucker were found in sections of Martis Creek, California that consisted of a regular alternation of riffles, pools, runs, and glides and had low channel gradients (1.5 to 2.3 percent) and mean channel widths that ranged from 3.2 to 6.6 m (10.5 to 21.7 ft.) (Moyle and Vondracek 1985).

During non-breeding periods, mountain sucker are usually found in deeper parts of streams with lower current velocities (Hauser 1969, Decker 1989). Hauser (1969) reported that during non-spawning periods, mountain sucker were usually found in deep pools in Montana streams. During bi-weekly surveys in the summer in Sagehen Creek, California, Decker

(1989) found mountain sucker in pools (33 percent of observations), pool-run edge habitats (49 percent of observations), or runs (18 percent of observations) and did not observe any in riffle habitats.

Microhabitats used by mountain sucker in Sagehen Creek had mean depths of 0.61 m (2 ft.) with mean current velocities of 0.2 m per s (0.7 ft. per s) (Decker 1989). In Utah streams, Sigler and Sigler (1996) characterized the habitat of mountain sucker adults and juveniles as areas of "moderate to swift currents in water from 0.3 to 0.9 m deep (1 to 3 ft.)."

Mountain sucker are associated with cover such as exposed tree root masses, undercut banks, logs, and boulders (Hauser 1969, Decker 1989, Wydoski and Wydoski 2002). Decker (1989) found that the presence of cover was the primary microhabitat factor for this species. Of 434 microhabitat observations made for Tahoe and mountain sucker together (there were only 39 mountain sucker observed, but most frequently they were found in groups of Tahoe sucker), only 8.2 percent of the sites lacked some form of cover (Decker 1989).

The conditions of the water that mountain sucker inhabit range from clear to easily roiled or turbid (Smith 1966). Mountain sucker are also associated with a wide range of substrates from clay, mud, and sand, through gravel and cobble, up to boulders (Smith 1966, Hauser 1969, Decker 1989). In Sagehen Creek, mountain sucker tended to be associated more with cobble/rubble-sized substrates (Decker 1989), while in several Montana streams, Hauser (1969) found mountain sucker associated with substrates that were "largely silt and coarse gravel in areas with abundant filamentous algae but few aquatic plants." Decker (1989) found mountain sucker at sites with mean algal cover of 73 percent (n = 31, SD = 14 percent).

Daytime summer temperatures of mountain sucker habitat are reported to range from about 10 to 28 °C (50 to 82 °F) and are usually between 15 and 23 °C (59 and 73 °F), while in the winter, temperatures may be just above freezing (Smith 1966). Isaak et al. (2003) noted that mountain sucker distribution was restricted to the lower elevation, warmer section of Sagehen Creek, as compared to the upstream areas "suitable only for trout" as reported by Gard and Flittner (1974). However, the occurrence of mountain sucker in the lower sections of Sagehen Creek may relate more to the lower channel gradients and higher pool to riffle ratios (Gard and Flittner 1974). Yet, water temperature may influence mountain sucker habitat preferences, as in one instance where they were reported to be more abundant downstream of a warm spring than above it (Pierce (1966) as referenced by Hauser (1969)).

Rivers

Only one report of mountain sucker use of larger rivers was found in the literature. Smith (1966) relayed R.M. Bailey's collection of mountain sucker at depths up to 2.4 m (8 ft.) in the Yellowstone River, in a section where the channel was 122 to 183 m (400 to 600 ft.) wide.

Impoundments

Several researchers have reported the occurrence of adult and larval mountain sucker in lakes and reservoirs (Smith 1966, Snyder 1983, Decker and Erman 1992, Baxter and Stone 1995, Wydoski and Wydoski 2002). Decker and Erman (1992) suggested that fish, such as the mountain sucker, which are native to the Intermountain region, are able to exploit both lotic and lentic conditions since the region has experienced a range of hydrologic extremes in the past 15,000 years. However, little is known about the habitat associations of mountain sucker in lentic environments. Where mountain sucker occur in impoundments, it appears that the impoundments are the primary habitat for most of the year and that tributary streams are used for spawning (Decker and Erman 1992, Wydoski and Wydoski 2002).

Wydoski and Wydoski (2002) reported that a reservoir population of mountain sucker used a tributary stream only during the spawning period. Hundreds of mountain sucker were observed in a short segment of a stream above a reservoir, but after the spawning period ended, only 15 to 25 were seen in the same section (Wydoski and Wydoski 2002). The reservoir was sampled from March through September 1977, and both adult and larval mountain sucker were collected (Wydoski and Wydoski 2002). No ripe adults were collected in the reservoir during the breeding season, but spent females would return to the reservoir after spawning while males remained concentrated in the tributary until the spawning period ended (Wydoski and Wydoski 2002). During late summer, adult mountain sucker were captured in vertical gill nets in the deeper and cooler waters of the reservoir (i.e., at depths of 5 to 10 m (16 to 33 ft.) in waters 15 to 17 °C (59 to 63 °F)) (Wydoski and Wydoski 2002).

Spawning habitat

During the spawning period, mountain sucker are found in abundance in the riffle habitats in which they spawn. Hauser (1969) noted that during the breeding season, mountain sucker were 'most abundant' in riffles located downstream of pools. Wydoski and Wydoski (2002) measured the water depth and current velocity of mountain sucker spawning locations in gravel riffles. Stream current velocities ranged between 0.0 and 0.79 m per s (0 to 2.6 ft. per s), but most mountain sucker reportedly preferred to spawn in currents of 0.12 to 0.15 m per s (0.4 to 0.5 ft. per s) in water about 18 cm (7 inches) deep (Wydoski and Wydoski 2002). The majority of mountain sucker (75 percent; n = 252) were found in areas with water depths from 11 to 30 cm (4 to 12 inches) and current velocities of 0.06 to 0.20 m per s (0.2 to 0.7 ft. per s). Wydoski and Wydoski (2002) also noted that mountain sucker not engaged in spawning occupied glide habitat associated with cover along the stream shorelines.

Seasonal habitat use

Aside from the breeding season when mountain sucker congregate on riffles to spawn, possible seasonal variations in mountain sucker habitat use are largely unknown. Hauser (1969) reported that during late winter and early spring, larger mountain sucker (>130 mm (5 inches) TL) were found adjacent to pools at depths of 1 to 1.5 m (3 to 5 ft.) where the water velocity was 0.5 m per s (1.6 ft. per s).

Young-of-year habitat

Young-of-year mountain sucker utilize shallower and lower velocity habitats. Hauser (1969) found mountain sucker larvae (20 to 35 mm (0.8 to 1.4 inches) TL) usually behind obstructions in water 15 to 40 cm (6 to 16 inches) deep with "moderate" currents. As larvae grew, they were found at the margins of runs and moved into deeper water when disturbed. The majority of young-of-year (35 to 130 mm (1.4 to 5 inches) TL) collected by Hauser (1969) were captured from a small, shallow (15 to 50 cm (6 to 20 inches) deep) intermittent side channel that had abundant aquatic vegetation. At other sampling sites, mountain sucker young-of-year were typically found associated with deep pools (Hauser 1969).

Mountain sucker young-of-year were not observed in Lost Creek, Utah but were seen "in abundance" along the shoreline of the reservoir in late June and July, utilizing the shallow warm waters (18.0 to 19.5 °C (64 to 67 °F)) throughout the summer (Wydoski and Wydoski 2002). Snyder (1983) reported an abundance of mountain sucker larvae and small juveniles (10 to 45 mm TL) in the Truckee River, but also collected a few mountain sucker larvae ranging from 13 to 34 mm TL from Pyramid Lake near the Marble Bluff Fishway, the fishway itself, and the Truckee river delta leading to the lake. Mountain sucker young-of-year apparently drift or move into shallow, low current habitats (including downstream lakes and impoundments) from the spawning riffles in which eggs are deposited.

Activity and movement patterns

Little is known about the activity and movement patterns of mountain sucker. To date there has been only one study that has reported on their diel behavior and feeding activity. There have been two reports of short distance spawning 'migrations' by reservoir populations, but no observations of movements by stream populations. Movements related to seasonal shifts in habitat use, life stage transitions, and dispersal or immigration/emigration have not been investigated or documented for the mountain sucker.

Social pattern for spacing

Several researchers have observed mountain sucker congregating in shoals (Hauser 1969, Decker 1989, Baxter and Stone 1995). Decker (1989) frequently observed mountain sucker in mixed-species shoals with Tahoe sucker (93 percent of 88 observations); mountain sucker were rarely observed alone (only 5 percent of observations). Hauser (1969) reported that while mountain sucker often formed small shoals, they remained separate from the other catostomid species (white sucker (*Catostomus commersoni*) and longnose sucker (*C. catostomus*) present in the stream). Although spawning behavior has not been described for the mountain sucker, based on inferences regarding their spawning behavior (see Reproductive biology section), it is unlikely that males become territorial during spawning.

Daily activity patterns and behavior

Decker (1989) described the behavior and feeding activity of mountain sucker, in the presence of Tahoe sucker, based on observations from an underwater stream observation tank and from snorkeling surveys. Both species were reported to be most active at night, when feeding intensity appeared to be the greatest and the groups less structured (Decker 1989). The higher level of nighttime activity was followed by a period of less activity beginning after dawn, lasting about six hours. In early afternoon, activity of both species fluctuated at low levels.

In an observation tank, mountain and Tahoe suckers were gregarious, often resting side-by-side, even touching, under the cover provided in the tank (Decker 1989). No agonistic interactions between the two species were observed (Decker 1989). During snorkeling surveys, mountain sucker were observed resting on the stream bottom, near cover, for the majority of daylight hours, often along side juvenile Tahoe sucker (Decker 1989).

Mountain sucker feeding activity may vary seasonally. Decker (1989) reported that mountain sucker were rarely seen feeding until early July, and Hauser (1969) noted that they appeared to ingest less food during early spring than late spring and summer (based on an examination of stomach contents).

Movement patterns

Movement patterns of the mountain sucker have not been investigated, and the only movements that have been documented are spawning migrations by reservoir populations, mentioned previously. In California, mountain sucker migrated between 100 and 1000 m (328 and 3,280 ft.) upstream from the reservoir into Sagehen Creek, presumably to spawn; most moved roughly 300 to 600 m (984 to 1,968 ft.) (Decker and Erman 1992). In Utah, mountain sucker also moved short distances from a reservoir into Lost Creek to spawn. Distances from the spawning grounds in Lost Creek to the reservoir were not reported but were less than 800 m (2,625 ft.), as a beaver dam was thought to impede further upstream movements (Wydoski and Wydoski 2002). In both reports of spawning migrations of reservoir populations, mountain sucker returned to the reservoirs after the breeding period (Decker and Erman 1992, Wydoski and Wydoski 2002).

It is not fully known what types of natural and man-made features in streams might impede mountain sucker movements. Clearly, in-stream structures such as dams impede fish movements, but the effects of various culvert types on mountain sucker movements are unknown. Beaver dams may be barriers to mountain sucker movements, at least during summer low flow periods. Beaver dams were thought to preclude upstream movements by spawning mountain sucker in Lost Creek, Utah (Wydoski and Wydoski 2002), and in Sagehen Creek, California mountain sucker reportedly do not occur in significant numbers upstream of a 2 km long complex of beaver dams and ponds (Decker and Erman 1992). However, in Sagehen Creek the locations of the beaver ponds are coincident with a change in stream gradient and dominant substrates (Gard and Flittner 1974, Decker and Erman 1992). Gard and Flittner (1974) did not describe the beaver dams and ponds during their work in the 1950s, so it is unknown if they were present at that time. However, they did suggest that the increasing stream gradient and changes in dominant substrates in upstream reaches were less suitable for the catostomids in the fish assemblage and explained the restriction of suckers to the three most downstream sampling stations (Gard and Flittner 1974). Decker (1989) argued that the change in gradient and the beaver complex were both unlikely causes of the absence of mountain sucker upstream because neither impeded the movements of Tahoe sucker, which had expanded their distribution several kilometers upstream by the 1980s. Instead, Decker (1989) suggested that mountain sucker were found only in downstream habitats because there was sufficient spawning habitat available there for the small population, and migratory movements beyond the beaver complex were not required. It should be noted that the Tahoe sucker is larger than the mountain sucker, and the ability of the mountain sucker to traverse instream barriers has not been studied.

Whether stream populations of mountain sucker make any movements related to spawning or seasonal changes in habitat requirements (e.g., winter refugia) is unknown. No information on seasonal changes in fish distribution and abundance in Sagehen Creek was collected before the impoundment was created, so it is unknown if mountain sucker exhibited the same pattern of spawning migrations before most of their stream habitat was inundated by the reservoir. Isaak et al. (2003) questioned whether stream resident populations, which have access to suitable spawning habitat, unlike reservoir fish, would make spawning migrations. In unmodified streams, distances moved for spawning may be quite short, varying with the availability of suitable riffle habitats and their proximity to the pool-run habitats that mountain sucker prefer during non-breeding periods.

Decker (1989) noted that the arrival of most mountain sucker in Sagehen Creek coincided with increased algal abundance on stream substrates. However, considering that little is known about mountain sucker movement patterns and because summer is both the breeding season and the primary feeding season, it is difficult to infer to what degree movements from the reservoir into the stream were influenced by the spawning period or increases in forage availability.

Dispersal movements

The potential range of distances moved by dispersing mountain sucker cannot be inferred from the sparse information. Larval mountain sucker apparently drift or move into low velocity habitats, but the extent of their drift downstream is unknown. It is also unknown whether or how frequently different populations of mountain sucker may interact. Isaak et al. (2003) noted that in the Black Hills region, where mountain sucker occur in headwater streams, fish would necessarily have to travel through mainstem river channels and in some cases traverse dams for populations to interact. The exchange of fish among headwater populations is not impossible since mountain sucker have been collected from several large rivers throughout its range; however, exchanges between populations may be quite rare and vary with proximity, local geography, and barriers.

Food and feeding habits

The mountain sucker is thought to be a primarily benthic feeder, browsing on stream bottoms for algae, small invertebrates, and organic matter (Moyle 2002). They have comb-like pharyngeal teeth that break up food items and long-coiled intestines that have a greater surface area that allows them to absorb more nutrients from a diet that includes a high proportion of indigestible material (Moyle 2002). The cartilaginous edges, or plates, on the lower lips of mountain sucker are used for scraping algae and invertebrates from stream substrates (Baxter and Stone 1995, Moyle 2002).

Algae, which are relatively rich in both energy and protein, are considered a primary component of the mountain sucker diet (Bowen 1996). The main constraint on growth of fish species that feed primarily on algae is energy assimilation, but the long digestive tract of the mountain sucker (Simpson 1941) increases digestion efficiency and is an expected adaptation for algae-feeding fish (Bowen 1996). Fishes with diets predominately composed of detritus or plant foods often are omnivorous, complementing their diets with animal prey (Bowen 1996). The mountain sucker has occasionally been characterized as an herbivore (Simpson 1941, Sigler and Miller 1963); however, classification as an omnivore that feeds predominately on algae is more appropriate given the relatively high frequencies of occurrence of invertebrates found in their digestive tracts (Simpson 1941, Hauser 1969).

Ideally, fish diet analyses consider variations in diel activities of fish and prey, seasonal cycles of prey abundance, life stage variations in diet, and differential rates of digestion of various food items (Bowen 1996). There have been two studies of mountain sucker diet, but data are insufficient for a complete understanding of the food habits of the species. While considering results of the diet analyses of mountain sucker presented below, it is worthwhile to remember that digestive tract contents may not accurately reflect diet in fish. Some rapidly digested prey may not be identifiable and are consequently overlooked (Bowen 1996). Alternatively, slowly digested prey may accumulate in greater amounts and be over-represented in the diet (Bowen 1996). In addition, researchers have (understandably) tended to ignore organic detritus as a possible food item because it is difficult to separate from inorganic detritus and to assess its nutritional value. However, organic detritus can be an important component of fish diets (Bowen 1996).

Simpson (1941) examined the digestive tract contents of 14 mountain sucker from the Bear River (12 fish) and Sweetwater River (two fish) in Wyoming during summer; two fish had empty tracts. The remaining 12 specimens examined ranged in size from 47 to 65 mm (1.9 to 2.6 inches) TL, with a mean of 57 mm (2.2 inches) TL. These lengths are consistent with an age-1 mountain sucker and perhaps larger young-of-year mountain sucker (see Age and growth section). Of the 12 specimens, 21 percent of the volume of all digestive tract contents combined was “animal matter” (invertebrate larvae, pupae and cases), 13 percent of the total volume was “plant matter” (blue-green algae, green algae, and diatoms), and the remainder was mud, sand, and organic detritus (Simpson 1941). The percent occurrence (number of fish containing a type of food, out of the total number of fish examined) was 66 percent for animal matter and 100 percent for plant matter (Simpson 1941). Percentage of occurrence (or frequency of occurrence) data indicate the extent to which fish in the sample have similar feeding habits, or function as a single feeding unit (Bowen 1996). The high frequency of occurrence for algae indicates that all mountain sucker young select algae as part of their diet.

The “animal matter” reported by Simpson (1941) included Trichoptera larvae, Diptera larvae and cases, Chironomidae larvae, Dixidae larvae, and an uncertain identification of Dixidae pupae. He did not specify the inclusion of Trichoptera cases in the food item analysis. Percent occurrences of invertebrate classes, in the order listed previously, were 25, 8.3, 25, 41.6, 8.3 percent. The greatest number of Dixidae larvae found in one stomach was 24, and 14 Chironomidae larvae were found in another specimen. Lower occurrence frequencies among invertebrate types may indicate that mountain sucker feed opportunistically on invertebrates (Bowen 1996) and that young mountain sucker are omnivorous, but primarily algae feeders.

Hauser (1969) also studied the diet of the mountain sucker. Specimens ranged in size from young-of-year just 20 mm TL to adult fish up to 212 mm TL (0.8 to 8.3 inches TL). In total, 79 mountain sucker were collected from February to September 1967, most from the East Gallatin River and some from the Madison River in Montana. Fish were grouped into three size classes: 20 to 30 mm (0.8 to 1.2 inches) TL (n = 6), 31 to 69 mm (1.2 to 2.7 inches) TL (n = 20), and 70 to 212 mm (2.7 to 8.3 inches) TL (n = 53). Quantities of food items identified were described as sparse, common, or abundant, and frequencies were calculated by combining the contents of the alimentary tracts of each size group. Food item classes included diatoms, other algae, higher plants, Diptera, other animals, and unidentified matter. A high proportion of contents were unidentified and described as sand and debris (Hauser 1969). Diatoms were most abundant, followed by other algae, which was found in nearly all tracts; but both occurred less frequently in fish smaller than 31 mm (1.2 inches) TL (Hauser 1969). *Closterium* algae were reported as more important in smaller fish and filamentous algae as more important in larger fish (Hauser 1969). Diatoms were "relatively more numerous in larger fish" (Hauser 1969). Fragments of higher plants were present in the contents of all size groups but were always sparse (Hauser 1969). Diptera larvae were the most abundant animal food identified, but pupae were abundant in one collection (Hauser 1969). The "other animals" included Turbellaria found in four tracts, Ephemeroptera found in four tracts, Rotifera found in one tract, Plecoptera found in one tract, and Coleoptera also found in one tract (Hauser 1969).

Using the same three categories as Simpson (1941) (i.e., "plant matter" [including mainly diatoms, algae and additionally higher plants in Hauser's study], "animal matter" [including Diptera and other invertebrates], and "unidentified matter"), the diets of the different size classes reported by Hauser (1969) were very similar to and consistent with Simpson's findings. The frequency of occurrence of the food categories for the 20 to 30 mm TL size class was 100 percent plant matter: mainly diatoms (100 percent), followed by other algae (50 percent), 100 percent for animal matter (primarily Diptera, 100 percent], other animals (50 percent), and 100 percent for unidentified matter. For the 31 to 59 mm TL size class, comparable to Simpson's sample, the frequency of occurrences were: 100 percent plant matter (100 percent for diatoms, 95 percent for other algae), 65 percent for animal matter (50 percent Diptera, 15 percent other), and 100 percent unidentified matter. For the juvenile and adult size class (70 to 212 mm TL) frequency of occurrence was: 100 percent plant matter (100 percent for both diatoms and other algae), 79 percent for animal matter (primarily Diptera, 68 percent), and 100 percent unidentified matter. Of invertebrates consumed, Diptera were the most important, and the relatively low occurrence frequency of other invertebrates in mountain sucker diets suggests that they are opportunistic in their consumption of invertebrates.

Another consideration is that percent composition by weight can aid in identification of foods important to fish nutrition, because unlike percent occurrence, weight quantifies food types in comparable units and, with few exceptions, food value is roughly proportional to weights (Bowen 1996). If the same is true for percent composition by volume, which was estimated by Simpson (1941), then the higher proportion of animal matter (21 percent) to plant matter (13 percent) suggests that animal matter is important to mountain sucker nutrition. Also notably, organic detritus comprised 25.6 percent of the total volume of stomach contents (Simpson 1941); given the morphological adaptation of the mountain sucker intestine, organic detritus may also contribute to the diet of mountain sucker.

Based on results of only frequency of occurrence of food item classes, and considering length of the intestines and the plasmolized condition of the algae in the stomachs, Simpson (1941) suggested that the mountain sucker should be classified as herbivorous rather than omnivorous. However, other findings of Simpson (1941) in combination with the findings of Hauser (1969) demonstrate that mountain sucker young and adults consume high proportions of animal matter. Therefore, the classification of mountain sucker as an omnivore that feeds predominately on algae is more appropriate (Lee et al. 1980).

Reproductive biology

The life history strategy of the mountain sucker is similar to that of most suckers in that they have high fecundities and are moderately long lived; these adaptations allow populations to persist through periods of unfavorable environmental conditions (Moyle

2002). The limited information available regarding the reproductive biology of the mountain sucker is summarized below and augmented with information on the spawning behaviors of another closely related species. Related information on certain aspects of the reproductive biology of the mountain sucker, specifically age of maturity and fecundity-size relationships, is presented in the Population demography section.

Spawning behavior

While several researchers may have observed the spawning behavior of mountain sucker, it has not been described in the literature (Snyder 1983, Wydoski and Wydoski 2002). Other researchers have reported seeing mountain sucker with breeding colors and tubercles, but they did not observe spawning (Hauser 1969, Decker 1989, Baxter and Stone 1995). Moyle (2002) speculated that mountain sucker might spawn at night.

Despite the lack of a description of mountain sucker spawning behavior, this species is considered to be an open substrate spawner (Snyder et al. 2004), and its reproductive strategy can be inferred from the available information and the described spawning behavior of a closely related species with which mountain sucker hybridize. Following is a description of the spawning behavior of the Tahoe sucker, as quoted by Moyle (2002) from Snyder (1918). Since the mountain sucker is known to hybridize with the Tahoe sucker (Smith 1966, Decker 1989), their breeding behaviors are likely to be similar.

> “Males appear first on the spawning beds and are always represented there in large numbers, each female being attended by from two to eight or more. Twenty-five males were seen attending one female in a pool. Occasionally another female would enter the pool from below, when she would be met and inspected by a school of males and then allowed to pass without further notice. Several of these passing females proved on examination not to be ripe. On account of the presence of so many males nothing definite can be observed of the spawning act, more than that the eggs are extruded and shaken down in the gravel by the female while the males struggle over and under her, churning the water to foam by their activities.”

Open substrate spawners typically spawn in large groups, males usually outnumber the females on the spawning grounds, and there is little to no courtship behavior, with multiple males spawning with a single female (Moyle and Cech 2000). Eggs of open substrate spawners are scattered during the spawning act and are not actively hidden or guarded (Moyle and Cech 2000). Typically, eggs are adhesive and stick to substrate, or they swell with water and become lodged in cracks among rocky substrates (Moyle and Cech 2000).

The conclusion that the mountain sucker is an open substrate spawner is consistent with observations of the sex ratio on the spawning ground and the characteristics of mountain sucker eggs. Wydoski and Wydoski (2002) reported the ratio of male to female mountain sucker sampled during a spawning run as 3.5 to 1 (i.e., 77 percent of the mountain sucker collected were males). Snyder et al. (2004) described mountain sucker eggs as initially adhesive and demersal.

Spawning season

The timing of spawning of mountain sucker is correlated with water temperature and, accordingly, varies with latitude and elevation across its range. Throughout its range, spawning season occurs sometime during late spring or summer, between May and mid-August, at water temperatures between 11 and 19 °C (52 and 66 °F) (Snyder 1983).

In Lost Creek, Utah, spawning occurred from late May to late June, peaking in early June when stream temperatures ranged from 9 to 11 °C (48 and 52 °F) and the surface temperature of the reservoir ranged from 12.5 to 18 °C (55 to 64 °F) (Wydoski and Wydoski 2002). The greatest abundance of spawning fish was observed on two dates in mid-June when stream water temperature was between 10 and 11 °C (50 and 52 °F) (Wydoski and Wydoski 2002). Mountain sucker were reported to spawn near Salt Lake City, Utah in late May, and in Jackson Hole, Wyoming on June 25 (Baxter and Stone 1995). In Flathead Creek and the East Gallatin River, Montana, based on the collection of spent females, spawning was estimated to occur during the last two weeks of June and first two weeks of July when stream temperatures ranged from 17 to 19 °C (63 to 66 °F) and 11 to 19 °C (52 to 66 °F) in the two streams respectively. The estimated spawning period was consistent with maximum calculated ripeness and the peak development of spawning coloration and breeding tubercles (Hauser 1969).

In Sagehen Creek, California, mountain sucker abundance peaked in early August when stream temperatures ranged between about 8 and 12 °C (46 and 54 °F) and discharge was about 1 meter per second (Decker 1989, Decker and Erman 1992). Snyder (1983) estimated that the mountain sucker spawning season occurred from late May through mid to late July for Truckee River populations based on the development stage of mountain sucker larvae collected in Pyramid Lake, Nevada. (Snyder 1983).

Incubation

The incubation period of mountain sucker embryos is thought to be short, around 8 to 14 days, which is consistent with reports for other sucker species (Campbell 1992). Incubation periods probably vary somewhat across the range of the mountain sucker in relation to water temperatures, with longer incubation periods at cooler water temperatures. Snyder (1983) reported a 7-day incubation period at water temperatures of 15 °C (59 °F). Mountain sucker eggs incubated at 18 °C (64 °F) were also reported to hatch in 7 to 8 days (Snyder et al. 2004). Interestingly, in Sagehen Creek, California, water temperatures continued to rise for about 5 days (to a summer maximum of about 12 °C (54 °F) after the reported peak abundance of mountain sucker in the stream (Decker and Erman 1992).

Egg characteristics

Mature eggs of the mountain sucker are yellowish and "somewhat translucent" (Hauser 1969). Water-hardened mountain sucker eggs range from 2.5 to 3.0 mm in diameter but tend to be on the smaller side of the range (Snyder 1983). Preserved eggs from Montana stream populations ranged from 1.47 to 2.22 mm, and mean egg size of individual females was reported to increase directly with fish length (Hauser 1969). At Lost Creek reservoir, Utah, preserved mountain sucker eggs ranged from 1.61 to 1.93 mm, egg size varied widely at all fish lengths, and no relationship between fish age and mean egg size was observed (Wydoski and Wydoski 2002). However, females in the Montana stream populations reached age-9, whereas the oldest females collected from the Lost Creek reservoir population were age-5. Atretic or regressing eggs were found in mountain sucker ovaries and were described as large, opaque, and irregularly shaped (Hauser 1969). Immature eggs were white and opaque, ranging in size from 0.84 to 1.05 mm in diameter.

Notably, Hauser (1975) reported collecting a hermaphroditic mountain sucker from the East Gallatin River, Montana. The specimen was male with normal appearing gonads, but ova were present in normal appearing testes (Hauser 1975). All three classes of eggs (i.e., immature, mature, atretic) were present, but the eggs were smaller than those of true female mountain sucker (Hauser 1975).

Fertility and survivorship

Despite their high fecundity, spawning success of mountain sucker in terms of fertility and number of young surviving is probably very low. It is an open substrate spawner and, consequently, large proportions of eggs may not be fertilized. Offspring receive no protection or parental care during incubation, and mortality is likely very high during the free embryo or larval periods. In general, survivorship rates for fish are inversely related to fecundity, (i.e., fishes with high fecundity tend to have low fertility, with particularly high mortality rates in free-embryo and larval stages) (Moyle and Cech 2000).

Among years, there is likely much variation in survival rates of young-of-year mountain sucker as Moyle (2002) described for Tahoe sucker:

> "…large numbers of young-of-the-year typically appear during years when there are sustained high flows during spawning. This presumably is the result of flooded vegetation, which provides habitat for larval and postlarval fish. This habitat has abundant food (small invertebrates), warm temperatures and shelter from both predators and high stream velocities."

Age and growth

Two studies have provided age and growth information for mountain sucker populations, namely Hauser's (1969) research on populations in several Montana streams, and Wydoski and Wydoski's (2002) description of the Lost Creek reservoir population in Utah. In brief, mountain sucker grow fastest during their first year of life, after which growth rates decline steadily for several years before stabilizing for older age classes. Females tend to be longer lived and slightly larger than males. Females and males mature at younger ages than other larger and longer-lived species of suckers, with females typically maturing between ages 3 and 5, and most males at age 2 or 3. Faster growing individuals are likely to mature earlier.

Differences in growth rates and maximum lengths attained were evident between the reservoir population described by Wydoski and Wydoski (2002) and stream populations studied by Hauser (1969). Both males and females from the reservoir population matured at younger ages than did mountain sucker in Montana streams. However, at the time of the research, the reservoir was relatively new (i.e., 6 years old), and consequently the observations of higher growth and earlier maturity may be explained by the favorable environment of the reservoir, which resulted in an expanding population (Moyle and Cech 2000).

The following summary of age and growth information is from Hauser (1969) unless otherwise noted. Age and growth rates in mountain sucker populations in Flathead Creek and the East Gallatin River, Montana were estimated using scale annuli (sub-sample of 22 were compared to ages estimated from otoliths). Time of first annulus formation was determined to be late spring to early summer from 60 juvenile mountain sucker collected from the Madison River. An annulus was present on 5 percent of fish taken on May 24, and by June 16, 95 percent of the specimens had an annulus. Mean size of fish without an annulus was 48.3 mm (1.9 inches) TL (range = 38 to 61 mm (1.5 to 2.4 inches) TL). Mean calculated length at first annulus formation was 48.6 mm (1.9 inches) TL (range = 38 to 60 mm (1.5 to 2.36 inches) TL). Based on a handful of age-1 fish collected from the East Gallatin River (n = 2) and Flathead Creek (n = 4), Hauser (1969) commented that first-year growth rates appeared better in those streams than in the Madison River, with fish 52 to 65 mm (2.0 to 2.6 inches) TL at first annulus formation.

Ages and calculated lengths at ages were then determined for 185 mountain sucker collected from Flathead Creek and 273 from the East Gallatin River. Lee's phenomenon (when back-calculated lengths at age are smaller for older fish than for younger fish) was observed at each annulus, and the effect was more pronounced on scales of older fish. For that reason, Hauser suggested that growth history of mountain sucker from those populations was best represented by using calculated lengths at the last annulus for each age group rather than by grand averages for each age class. The table from Hauser (1969) showing the mean lengths at the last annulus for each age class for each population of mountain sucker is reproduced in **Table 6**.

From mean annual growth increments calculated for each age class, it was observed that mountain sucker growth rate was greatest during the first year of life, then decreased until age 3, after which it remained roughly constant. Female mountain sucker were longer lived than males and tended to be slightly longer. The oldest males collected were age 7 (n = 11). In contrast, of 101 females collected that were age 7 (n = 60) or older, 33 females were age 8, and eight were age 9. Differences between male and female mean length at age were statistically significant only for age 6 and age 7 fish from Flathead Creek (α = 0.05).

The following information on age and growth was provided by Wydoski and Wydoski (2002) for the reservoir population of mountain sucker in Lost Creek, Utah. Age and calculated lengths at ages were estimated for 313 fish from scale annuli (**Table 7**) and total lengths measured. The grand average of mean back-calculated lengths at each annulus for the Lost Creek population was compared to the grand average of mean back-calculated lengths at each annulus reported for Flathead Creek and East Gallatin River populations. Based on comparison of grand averages, mountain sucker attained notably greater lengths at each age in Lost Creek than in the Montana streams.

A comparison of Lost Creek's grand average length at each annulus compared to calculated lengths at the annulus for each age group of the Montana samples (as recommended by Hauser) suggests that there is less difference in growth rates (particularly for age-1 and age-2) between the Utah and Montana populations than that perceived when comparing the grand averages (**Table 8**). However, even with the comparison using calculations recommended by Hauser (1969), it is apparent that growth rates in Lost Creek exceeded those of Montana streams and that fish attained larger sizes in Lost Creek.

Wydoski and Wydoski (2002) also found that growth was greatest during the first year of life, after which growth rate declined steadily through age-4 and then seemed to stabilize for the Lost Creek reservoir population. The oldest mountain sucker collected from Lost Creek was an age-6 male, and the oldest female collected was age-5. Notably, the reservoir was constructed only six years prior to the research, and the oldest fish likely entered the new reservoir as a young-of-year.

Wydoski and Wydoski (2002) also developed regression equations to convert standard lengths and fork lengths used by other investigators to total lengths using the Lost Creek mountain sucker population. The equation for standard length (SL) to TL conversion is SL = 0.87 (TL – 2.49) (N = 227, r = 0.995). The equation for fork length (FL) to TL conversion is FL = 0.96 (TL – 1.37) (N = 227, r = 0.996).

Table 6. Average calculated total lengths (mm) and average calculated annual growth increments of mountain sucker from Flathead Creek (1966) and the East Gallatin River (1967), Montana, reproduced from Hauser (1969).

				Calculated total length at each annulus									
Location	**Age**	**Number**	**Mean capture length**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Annual growth increment**
Flathead Creek	1	4	93.0	61.5									61.5
	2	10	116.8	52.2	96.5								35.0
	3	21	131.0	38.1	79.5	118.5							22.0
	4	19	151.0	30.0	63.3	103.4	137.7						19.2
	5	33	168.2	25.9	58.0	95.6	134.1	158.6					20.9
	6	35	183.0	24.3	51.6	90.5	132.7	159.3	176.1				17.5
	7	36	204.4	21.8	46.6	81.2	124.2	157.4	179.9	196.6			20.5
	8	23	215.2	20.3	42.9	74.2	111.7	145.9	174.5	194.7	208.4		11.8
	9	4	226.5	21.0	50.3	86.0	125.3	154.8	174.8	199.0	214.3	222.5	14.1
	Total	185	Grand average:	28.0	57.6	92.1	128.2	156.2	177.1	196.0	209.3	222.5	
East Gallatin River	1	2	82.5	60.5									60.5
	2	24	125.3	51.3	98.7								38.2
	3	24	136.6	39.9	80.7	115.3							16.6
	4	52	149.1	30.8	65.1	105.0	133.2						17.9
	5	63	160.4	27.1	57.4	94.6	127.4	149.3					16.1
	6	59	173.4	26.7	55.1	89.3	123.2	149.7	164.6				15.3
	7	35	194.3	26.7	54.7	90.2	124.5	153.2	174.1	187.5			22.9
	8	10	209.2	27.3	52.9	90.7	122.0	152.6	175.8	192.1	202.9		15.4
	9	4	225.8	26.8	48.3	74.0	105.8	139.8	168.3	191.0	210.3	220.8	17.9
	Total	273	Grand average:	31.2	63.4	96.5	126.6	150.2	168.8	188.8	205.0	220.8	

Table 7. Mean back-calculated total length (mm) of mountain sucker at the end of each growing season from Lost Creek, Utah, 1977. Reproduced from Wydoski and Wydoski (2002).

				Calculated total length at each annulus						
Location	**Age**	**Number**		**1**	**2**	**3**	**4**	**5**	**6**	**Annual growth increment**
Lost Creek Reservoir	1	46		63						64
	2	134		64	112					44
	3	136		63	107	138				31
	4	77		64	108	142	160			21
	5	30		64	102	136	159	174		15
	6	10		64	95	134	162	181	193	18
	Total	433	Grand average:	64	108	139	160	175	193	

Table 8. Comparison of the Lost Creek Reservoir, Utah mountain sucker population lengths at age to those of the Flathead Creek and the East Gallatin River populations in Montana. For the Lost Creek Reservoir population the mean (grand average) of calculated lengths at each annulus are provided from Wydoski and Wydoski (2002). For the Montana populations the calculated lengths at the last annulus for each age group are provided from Hauser (1969) because the grand averages displayed Lee's phenomenon.

		Grand average of calculated length at each annulus								
Location	**Total number of fish**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Lost Creek Reservoir	433	64	108	139	160	175	193	—	—	—
		Calculated lengths at the last annulus for each age group								
Flathead Creek	185	62	97	119	138	159	176	196.6	208.4	222.5
East Gallatin River	273	61	99	115	133	149	165	187.5	202.9	220.8

Weight-length relationships

The relationship between fish length and weight can be used as a measure of the variation of the weight of a fish from the expected weight based on its length, providing an indication of an individual's "well-being" or "fatness" (Anderson and Neumann 1996). Log transformation of weight and length data allows estimation of the relationship with linear regression and is reported in the form: $\log_{10}(\text{Weight}) = a + b * \log_{10}(\text{Length})$ (Anderson and Neumann 1996). In general, a value of b >3.0 indicates that fish rotundness increases with length, whereas b values <3.0 mean fish become less rotund as length increases (Anderson and Neumann 1996).

Hauser (1969) calculated the following weight-length relationship for 155 female mountain sucker ranging in size from 96 to 231 mm (3.8 to 9.1 inches TL) from the East Gallatin River. Using 10 mm (0.4 inch) interval length groups, the relationship was $\log_{10}(\text{Weight}) = -5.71963 + 3.31250 * \log_{10}(\text{Length})$. Hauser (1969) also reported that differences between empirical and calculated weights were usually small. Wydoski and Wydoski (2002) calculated a weight-length relationship for a sample of 465 mountain sucker (both sexes combined) as $\log_{10}(\text{Weight}) = 4.902 + 2.972 * \log_{10}(\text{Length})$.

Population demography

Information regarding several aspects of mountain sucker populations has been discussed in preceding sections (i.e., Distribution and abundance, Breeding biology, and Age and growth). The following sections concentrate on the vital statistics of mountain sucker populations (i.e., age at maturity, fecundity, sex ratio) and a matrix demographic model.

Age of maturity

In Montana streams, Hauser (1969) reported that some mountain sucker females were sexually mature by age-3 and all females were mature by age-5. Most females between 130 and 145 mm (5.1 and 5.7 inches) TL and all females longer than 145 mm (5.7 inches) TL had mature eggs in their ovaries or exhibited evidence of spawning (Hauser 1969). The smallest female with mature eggs was 127 mm (5.0 inches) TL (Hauser 1969). Males matured at younger ages and smaller sizes than females. Some males were mature by age 2, and all were mature at age 4 (Hauser 1969). Most males between 115 and 120 mm (4.5 and 4.7 inches) TL and all males longer than 130 mm (5.1 inches) TL were mature. The smallest male with well-developed testes was 107 mm (4.2 inches) TL, and the smallest male with milt was 122 mm (4.8 inches) TL. The individuals that grew faster in their age group were probably the ones to mature at younger ages (Hauser 1969).

In Utah, both males and females from the Lost Creek reservoir population matured at earlier ages than those in the Montana stream populations. More than a quarter of age-2 females examined were mature (28 percent), 91 percent of age-3 females were mature, and all females age-4 were mature (Wydoski and Wydoski 2002). The smallest mature female was age-2, 143 mm (5.6 inches) TL and 36 g (1.26 oz.). Males were also observed to mature sooner in the Lost Creek reservoir population, where 90 percent of all age-2 males were mature and all age-3 males were mature. The smallest mature male examined was actually age-3, 115 mm (4.5 inches) TL and only 12 g (0.4 oz.).

Higher growth rates in the Lost Creek reservoir were probably related to earlier maturity and larger sizes at first maturity than those reported for Montana streams (Wydoski and Wydoski 2002). The effect of maturity at earlier ages was observed in the Lost Creek spawning run from which 92 percent of males collected were age-2 or age-3 and 84 percent of the females collected were age-3 and age-4 (Wydoski and Wydoski 2002).

Smith (1966) reported that mature mountain sucker females usually ranged in length from 90 to 120 mm (3.5 to 4.7 inches) SL (106 to 141 mm [4 to 5.5 inches] TL). Smith estimated one large mature female 175 mm (6.9 inches) SL (204 mm [8 inches] TL), collected from the Bear River drainage, Utah, to be age-4 or age-5. Smith (1966) reported that mature males usually ranged in length from 80 to 110 mm (3.1 to 4.3 inches) SL (about 95 to 129 mm [3.7 to 5 inches] TL), but reported mature males as small as 64 mm (2.5 inches) SL (about 76 mm [3 inches] TL) collected from Bitter Creek, Wyoming and Shoal Creek, Utah. The largest mature male reported by Smith (1966) was 127 mm (5.0 inches) SL (149 mm [6 inches] TL), collected from the Sevier River drainage, Utah. Standard lengths reported in mm by Smith (1966) were converted to total lengths in mm using the relationship provided by Wydoski and Wydoski (2002)). Except where explicitly noted above, Smith (1966) did not indicate the collection locations of mountain suckers used to develop the range of lengths at maturity that he provided.

Size and fecundity relationships

Fecundity, the number of eggs in the ovaries of a female fish, is the most commonly used measure of reproductive potential in fisheries since it is relatively easy to measure (Moyle and Cech 2000). Fecundity tends to increase with fish size, larger fish producing more eggs than smaller fish, both in absolute numbers of eggs produced and relative to body size, indicating that energetic investment in egg production is greater in larger members of the species (Moyle and Cech 2000). The exponential relationship between size and fecundity in females is especially true for species such as the mountain sucker that spawn just once a year and produce large numbers of eggs (Moyle and Cech 2000). In contrast, reproductive potential of male fish usually increases linearly with size throughout their life.

Hauser (1969) determined fecundity by counting all mature eggs in three mountain sucker females; fish lengths were not reported. The total number of eggs counted for the three females were 2,100, 2,670, and 3,474 eggs (Hauser 1969). Hauser (1969) estimated the fecundity of another 18 mountain sucker by counting mature eggs present in 10 percent of the volume of the ovaries. The estimated number of eggs for the 18 fish ranged from 990 (for a female 131 mm [5.2 inches] TL) to 3,710 (for a female 184 mm [7.2 inches] TL). The relationship between female total length and estimated fecundity was plotted, and lines were fit for females from each stream population; equations for estimated length-fecundity relationships were not provided (Hauser 1969).

Wydoski and Wydoski (2002) estimated fecundity using the gravimetric method for five females, 131 to 181 mm (5.2 to 7.1 inches) TL, from the Lost Creek reservoir population. The error rate determined from the five fish (mean percentage error = 2.9 percent, range = 4.1 to 4.8 percent) was used to correct fecundity estimates of another 20 females ranging in length from 131 to 182 mm (5.2 to 7.1 inches) TL. The mean total length of the 20 females was 162 mm (6.4 inches) (SE = 3.47 mm (0.14 inch)) and weights ranged from 26 to 75 g (0.9 to 2.6 oz.) with a mean of 51.4 g (1.8 oz.) (SE = 3.18 g (0.11 oz.)). Estimated fecundity of the 20 females ranged from 1,239 to 2,863 eggs, with a mean of 2,087 (SE = 123.6).

Wydoski and Wydoski (2002) found that mountain sucker fecundity was strongly correlated with both fish size and weight. Fish of the same size but different ages had similar fecundity. Fecundity increased with total length for age-3 to age-5 females (no older females were sampled from the population) (Wydoski and Wydoski 2002). Regression equations were calculated to estimate fecundity from total length and weight using "standard statistical analysis" based on Simpson et al. (1960) (Wydoski and Wydoski 2002). The length-fecundity regression equation determined (using TL in mm) was Fecundity = 31.24 * TL – 2,893 (r = 0.932, n = 20) . The relationship between fecundity and weight was also strong. Fecundity increased from 1,327 eggs in a 26 g (0.9 oz.) fish to 2,900 eggs in a 75 g (2.6 oz.) fish. The weight-fecundity relationship (using weight in grams) was Fecundity = 492 - 31.2 * Weight (r = 0.88, n = 20).

Sex ratio

The only report of the proportion of males to females in a mountain sucker population is for the Lost Creek reservoir population in Utah. A sample of 166 mountain sucker collected from Lost Creek during the spawning run was 77 percent males (Wydoski and Wydoski 2002), giving a sex ratio of males to females of 3.5:1. Because males remain on spawning grounds longer than females (which are thought to leave when spent), sex ratios estimated from the spawning run may over-represent the proportion of males in the population.

Hauser (1969) reported using 155 females in his determination of the weight-length relationship of mountain sucker for the East Gallatin River. The total number of mountain sucker that he reported collecting from the East Gallatin River for age and growth analysis was 273. If it can be assumed that the females used in the weight-length relationship represented all females in the sample of 273 fish, and that fish in the sample were collected throughout the reported sampling period from February to September, then the estimated ratio of males to females of 0.76:1 may be more representative of the population during non-spawning periods.

Morality rates

No estimates of mortality rates for mountain sucker were identified in the literature. Because they are not a game fish, sources of mortality are largely from natural causes (i.e., predation, disease, natural disturbances) in most populations, except where mountain sucker are harvested as baitfish. Mortality rates are most likely greatest among young-of-year, after which mortality rates would be expected to decrease with fish size and may stabilize among older age groups.

Life cycle graph and matrix model development

Matrix demographic models facilitate the assessment of critical transitions in the life history of animals. A key first step is to create a *life cycle graph*, from which to compute a *projection matrix* amenable to quantitative analysis using computer software (Caswell 2001) (the analysis was performed using the software Mathematica^{TM} with a program written by David McDonald). The life history data for mountain sucker provided by Wydoski and Wydoski (2002) and Hauser (1969) provided the basis for a stage-classified life cycle graph that had 10 stages (**Figure 3**). The first nine stages are age-specific (age-classes) while the tenth stage includes all fish in their tenth year or later. From the life cycle graph, we conducted a matrix population analysis assuming a birth-pulse population with a one-year census interval and a post-breeding census (McDonald and Caswell 1993, Caswell 2001). Beyond this introductory paragraph, rather than using an age-indexing system beginning at 0, as is the norm

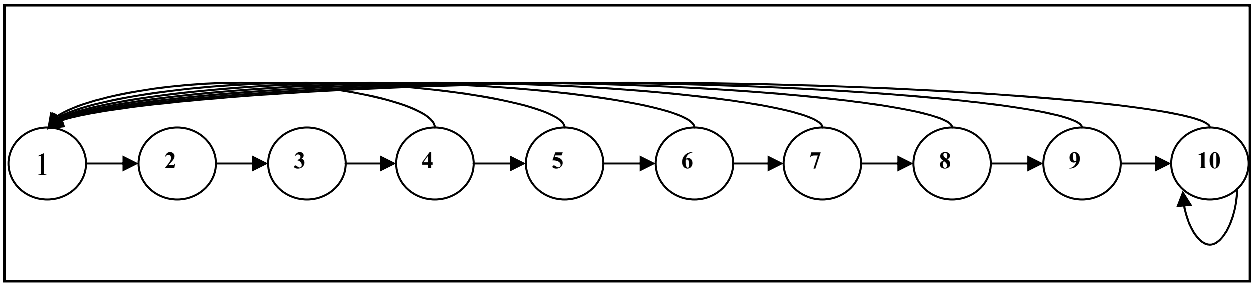

Figure 3. Life cycle graph for mountain sucker, consisting of circles (*nodes*), describing stages in the life cycle and *arcs*, describing the *vital rates* (transitions between stages). The horizontal arcs are survival rates (e.g., first-year survival, P_{21}= 0.008). The remaining arcs, pointing back to Node 1, describe fertility (e.g., P_{54}* m_4). Each of the arcs corresponds to a cell in the matrix of **Figure 4** and the vital rates (used as inputs for projection matrix entries in **Figure 4**) are provided in **Table 10**. The self-loop on Node 10 denotes constant low survival for fish in their tenth year and older.

in the fisheries literature, we use stage-based indexing beginning at 1 (first-year, second-year etc.). Note that the breeding pulse comes at the end of each one-year census interval. Individuals are, therefore, larger when breeding than when they were censused in that stage (almost a year earlier). For example, Stage-5 fish are estimated to be approximately 136.4 mm (5.4 inches) in length at the time of the census, but they will have grown to an estimated 149.6 mm (5.9 inches) by the time they breed, just prior to the next census (**Table 9**). In order to estimate the vital rates (**Table 10**) we used the following criteria:

- Egg production by size was estimated from the equation provided by Wydoski and Wydoski (2002): *Eggs* = 31.24 * *TotalLength* -2,893

- The estimated size ranges of the stages were based on the weighted means of size ranges presented by Hauser (1969) from the East Gallatin River in Montana (**Table 6**).

- Survival rates were not available for mountain sucker and were based on ratios of size/age-

Table 9. Relationship between conventional fisheries age categories, life cycle stage, weighted mean size of stage and size range for stage, for mountain sucker (after Hauser, 1969).

Age	Stage	Size (weighted mean)	Size range (mm)
0	1		n.a.
1	2	n.a.	n.a.
2	3	n.a.	100-105
3	4	123	110-125
4	5	136.4	130-140
5	6	149.6	145-155
6	7	166	160-175
7	8	189.1	180-195
8	9	205.4	200-210
9	10	216.7	215-220

Table 10. Vital rates for mountain sucker, used as inputs for projection matrix entries of **Figure 3** and **Figure 4**.

Vital rate (fertility or survival)	Numerical value	Description
m_4	118.7	# of female eggs produced by a 4th-year female
m_5	684.5	# of female eggs produced by a 5th-year female
m_6	890.8	# of female eggs produced by a 6th-year female
m_7	1,147	# of female eggs produced by a 7th-year female
m_8	1,508	# of female eggs produced by an 8th-year female
m_9	1,761	# of female eggs produced by a 9th-year female
m_{10}	1,938	# of female eggs prod by 10th-year & older females
P_{21}	0.008	First-year survival
P_{32}	0.4	Second-year survival
P_{43}	0.4	Third-year survival
P_{54}	0.588	"Adult" survival
P_{65}	0.588	"Adult" survival
P_{76}	0.588	"Adult" survival
P_{87}	0.588	"Adult" survival
P_{98}	0.588	"Adult" survival
$P_{10,9}$	0.588	"Adult" survival
$P_{10,10}$	0.222	Survival in tenth year and beyond

class counts, smoothed over the "adult" stages (= Stage 4).

- We assumed that survival for the second and third stages (P_{32} and P_{43}) was two-thirds of that for the "adult" reproductive stages.
- We assumed that only 25 percent of Stage-4 individuals breed.

Because the model assumes female demographic dominance, the egg number used was half the published value, assuming a 1:1 sex ratio. We assumed reproduction beginning at the end of Stage 4 (equivalent to age-3 female fish). Hauser (1969) reported that "some" females were mature by age 3 (Stage 4) and all were mature by age 5 (Stage 6). Wydoski and Wydoski (2002) reported that 28 percent of age 2 (Stage 3) females were mature in a reservoir population. However, the reservoir population studied by Wydoski and Wydoski (2002) exhibited greater growth rates and matured earlier than the stream populations studied by Hauser (1969). Because most mountain sucker populations are stream dwelling, we considered female breeding beginning with Stage 4 (age 3) to be more representative and assumed that only 25 percent of Stage-4 (age-3) females were mature. We also made a final and major assumption that the long-term value of the population growth rate (λ) must be near 1.0. This final assumption allowed us to solve for the major unknown, survival from the egg stage through the first year, using the characteristic equation (McDonald and Caswell 1993).

The model has two kinds of input terms: P_{ij}, describing survival rates, and m_i, describing fertilities (Table 10). Figure 4a shows the symbolic terms in the projection matrix corresponding to the life cycle graph, and Figure 4b gives the corresponding numeric values. Note also that the fertility terms (F_i) in the top row of the matrix include a term for offspring production (m_i) as well as a term for the survival of the mother (P_i) from the census (just **after** the breeding season) to the next birth pulse almost a year later. While λ was 1.009 based on the estimated vital rates used for the matrix, this should not be taken to indicate a stationary population, because the value was used as a target toward which to adjust estimated fertility rates and was subject to the many assumptions used to derive all the transitions. The value of λ should, therefore, not be interpreted as an indication of the general well-being or stability of the population. Other parts of the analysis provide a better guide for any such assessment.

Sensitivity analysis: A useful indication of the state of the population comes from the sensitivity and elasticity analyses. Sensitivity is the effect on λ of an absolute change in the vital rates (a_{ij}, the arcs in the life cycle graph (Figure 3) and the cells in the matrix, **A** (Figure 4)). Sensitivity analysis provides several kinds of useful information (see Caswell 2001, pp. 206-225). First, sensitivities show how important a given vital rate is to λ, which Caswell (2001, pp. 280-298) has shown to be a useful integrative measure of overall fitness. One can, therefore, use sensitivities to assess the relative importance of the survival (P_i) and fertility (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 a paucity of data, but it could also result from the 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 accurate estimation of transitions with large sensitivities. Third, sensitivities can quantify the effects of environmental perturbations, wherever those can be linked to effects on age-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 λ of endangered species or the "weak links" in the life cycle of a pest.

Figure 5 shows the "possible sensitivities only" matrix for this analysis. While one can calculate sensitivities for non-existent transitions, these are usually either meaningless or biologically impossible (e.g., the sensitivity of λ to moving backward in age, from Stage 3 to Stage 2). *In this analysis, the sensitivity of λ to changes in first-year survival (20.4; 93.4 percent of total) is overwhelmingly the most important key to population dynamics.*

Elasticity analysis: Elasticities are the sensitivities of λ to proportional changes in the vital rates (aij). 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 vital rates (the aij arc coefficients on the graph or 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. It is important to note that a)

$$\begin{array}{c|cccccccccc}
\text{Stage} & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 \\
\hline
1 & & & & P_{54}*m_4 & P_{65}*m_5 & P_{76}*m_6 & P_{87}*m_7 & P_{98}*m_3 & P_{10.9}*m_9 & P_{10.10}*m_{10} \\
2 & P_{21} & & & & & & & & & \\
3 & & P_{32} & & & & & & & & \\
4 & & & P_{43} & & & & & & & \\
5 & & & & P_{54} & & & & & & \\
6 & & & & & P_{65} & & & & & \\
7 & & & & & & P_{76} & & & & \\
8 & & & & & & & P_{87} & & & \\
9 & & & & & & & & P_{98} & & \\
10 & & & & & & & & & P_{10,9} & P_{10,10}
\end{array}$$

Figure 4a. Symbolic values for the cells of the projection matrix. Each cell corresponds to one of the arcs in the life cycle graph. The top row is fertility, with compound terms describing survival of the mother (P_{ij}) and egg production (m_i). Empty cells have zero values and lack a corresponding arc in **Figure 3**. Note that the matrix differs from a strictly age-classified (Leslie) matrix because of the entry in the bottom right, corresponding to the self-loop on the tenth node in the life cycle graph.

b)

$$\begin{array}{c|cccccccccc}
\text{Stage} & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 \\
\hline
1 & & & & 69.8 & 402.5 & 523.8 & 674.3 & 886.7 & 1,035.7 & 430.6 \\
2 & 0.008 & & & & & & & & & \\
3 & & 0.4 & & & & & & & & \\
4 & & & 0.4 & & & & & & & \\
5 & & & & 0.588 & & & & & & \\
6 & & & & & 0.588 & & & & & \\
7 & & & & & & 0.588 & & & & \\
8 & & & & & & & 0.588 & & & \\
9 & & & & & & & & 0.588 & & \\
10 & & & & & & & & & 0.588 & 0.222
\end{array}$$

Figure 4b. Numeric values for the projection matrix.

Figure 4. The input matrix of vital rates, **A** (with cells a_{ij}) corresponding to the mountain sucker life cycle graph (**Figure 3**). a) Symbolic values. b) Numeric values.

Stage	1	2	3	4	5	6	7	8	9	10
1				0	0	0	0	0	0	0
2	20.4									
3		0.41								
4			0.41							
5				0.25						
6					0.17					
7						0.11				
8							0.07			
9								0.03		
10									0	0

Figure 5. Sensitivities matrix, $\mathbf{S}_p$ (remainder of matrix is zeros). Only values that correspond to non-zero arcs in the life cycle graph are shown. The transition to which λ of mountain sucker is overwhelmingly sensitive is first-year survival.

elasticity as well as sensitivity analysis assumes that the magnitude of changes (perturbations) to the vital rates is small. Large changes require a reformulated matrix and reanalysis.

Elasticities for the mountain sucker are shown in **Figure 6**. *The population growth rate was most elastic to changes in survival over the first three years (16.2 percent each), followed by survival at older ages. Overall, survival transitions accounted for approximately 85.6 percent of the total elasticity of λ to changes in the vital rates*. Survival rates, particularly at early ages, are the demographic parameters that warrant most careful monitoring in order to refine the matrix demographic analysis.

Other demographic parameters: The stable stage distribution (SSD; **Table 11**) describes the proportion of each stage in a population at demographic equilibrium. Under a deterministic model, any unchanging matrix

Stage	1	2	3	4	5	6	7	8	9	10
1				0.01	0.05	0.04	0.03	0.02	0	0
2	0.16									
3		0.16								
4			0.16							
5				0.15						
6					0.10					
7						0.07				
8							0.04			
9								0.02		
10									0	0

Figure 6. Elasticity matrix, **E** (remainder of matrix is zeros). The λ of mountain sucker is most elastic to changes in survival over the first three years (Cells e_{21}, e_{32}, e_{43}), followed by survival at later ages. As with the sensitivities, changes in the fertility transitions have relatively little effect on λ.

Table 11. Stable Stage Distribution (SSD, right eigenvector). Because first-year fish (eggs) numerically dominate the population at the time of the census, the proportion of fish excluding eggs are shown in parentheses for Stages 2 to 5.

Stage	Description	Proportion (excluding 1st-year)
1	First-year females	0.986
2	Second-year females	0.008 (0.566)
3	Third-year females	0.003 (0.224)
4	Fourth-year females	0.001 (0.089)
5	Fifth-year females	0.001 (0.052)
6	Sixth-year females	0.000 (0.030)
7	Seventh-year females	0.000 (0.018)
8	Eight-year females	0.000 (0.010)
9	Ninth-year females	0.000 (0.006)
10	Tenth-year and older females	0.000 (0.004)

will converge on a population structure that follows the SSD, regardless of whether the population is declining, stationary, or increasing. Under most conditions, populations not at equilibrium will converge to the SSD within 20 to 100 census intervals. *For mountain sucker at the time of the post-breeding annual census (mid to late summer), eggs should represent 98.6 percent of the population. Second-year fish (hatched the previous breeding season) should constitute 56.6 percent of the non-egg population*. Reproductive values (**Table 12**) 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 (Caswell 2001). 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 reproductive value of the first stage is, by definition, always 1.0. For example, a fourth-year female (age of first breeding) is "worth" approximately 802 eggs. The cohort generation time for mountain sucker is 6.4 years (SD = 1.6 years).

Stochastic model: We conducted a stochastic matrix analysis for the mountain sucker, incorporating stochasticity in three variants, by varying different combinations of vital rates or by varying the amount of stochastic fluctuation (**Table 13**). Under Variant 1, we altered the vital rates (m_i and P_i) of all the reproductive stages (Stages 4 through 10). Under Variant 2, we varied the survival of the first three stages (P_{21}, P_{32}, P_{43}). For each variant we ran 100 replicate runs. Each run consisted of 2,000 census intervals (years) beginning with a population size of 10,000 distributed according to the SSD under the deterministic model. Beginning at the SSD helps to avoid the effects of transient, non-equilibrium dynamics.

Table 12. SReproductive values for females. Reproductive values can be thought of as describing the "value" of a stage as a seed for population growth, relative to that of the first (egg) stage, which is always defined to have the value 1.

Stage	Description	Reproductive value
1	First-year females	1
2	Second-year females	126
3	Third-year females	318
4	Fourth-year females	802
5	Fifth-year females	1,258
6	Sixth-year females	1,474
7	Seventh-year females	1,638
8	Eight-year females	1,663
9	Ninth-year females	1,346
10	Tenth-year and older females	547

Table 13. Summary of three variants of stochastic projections for mountain sucker. Each variant consisted of 100 runs, each of which ran for 2,000 annual census intervals. Stochastic vital rates were selected from a beta distribution with mean at the deterministic value and SD of ¼ or ⅛ of that deterministic mean.

	Variant 1	Variant 2	Variant 3
Input factors:			
Affected cells	1Vital rates for all Stages ≥ 4	P_{21}, P_{32}, P_{43}	P_{21}, P_{32}, P_{43}
S.D. of random normal distribution	1/4	1/4	1/8
Output values:			
Deterministic λ	1.009	1.009	1.009
# Extinctions / 100 trials	62	42	0
Mean extinction time	752	1,100	—
# Declines / # surviving populations	12/38	28/58	0/100
Mean ending population size	682,246	347,446	5,750,708
Standard deviation	1,445,838	1,268,904	1,717,729
Median ending population size	71,074	14,831	5,634,726
Log λ_s	-0.0062	-0.0036	0.0031
λ_s	0.994	0.996	1.003
Percent reduction in λ	1.5	1.2	0.6

We varied the amount of environmental fluctuation by varying the standard deviation of the beta distribution from which the stochastic vital rates were selected. The beta distribution has the useful property of existing in the interval zero to one, thereby avoiding problems of impossible parameter values (e.g., <0 or >1 for survival) or altered mean and variance (as when using a truncated normal distribution). For vital rates not in the interval zero to one (e.g., egg numbers), one can use a "stretched" beta distribution (Morris and Doak 2002). 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 transitions as Variant 2 (P_{21}, P_{32}, P_{43}) but was subjected to lower variability (SD was 1/8 rather than 1/4 of the mean). We calculated the stochastic growth rate, $log\lambda_S$, according to Equation. 14.61 of Caswell (2001), after discarding the first 1,000 cycles in order to further avoid transient dynamics. A population was considered "pseudoextinct" (Morris and Doak 2002) if it dipped below 10 individuals.

*The stochastic model (**Table 13**) produced two major results. First, altering the early survival rates had almost as much effect on λ as did altering the entire set of vital rates of the reproductive stages.* For example, under the varied "adult" vital rates of Variant 1, the median ending size was 71,074 with 62 pseudoextinctions and 12 populations declining from their initial size. In contrast, the same degree of variation acting on survival under Variant 2 resulted in 42 replicate populations going pseudoextinct, 28 populations declining in size, and a median ending size of 14,831. *Second, large-effect stochasticity has a negative effect on population dynamics, at least when it impacts transitions to which λ is highly sensitive*. The negative effect of stochasticity occurs despite the fact that the average vital rates remain the same as under the deterministic model. This apparent paradox is due to the lognormal distribution of stochastic ending population sizes (Caswell 2001). 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 mountain sucker under the adult vital rate Variant 3 with a low degree of stochasticity (SD = 1/8 of the mean), none of 100 trials went to pseudoextinction or declined in size. Median size for the surviving populations was greater than five million (the simulations had a ceiling that reduced huge sizes). Variant 3 shows that the magnitude of fluctuation has a potentially large impact on the detrimental effects of stochasticity. Decreasing the magnitude of fluctuation mitigated the negative impacts (i.e., the number of pseudoextinctions went from 42 to 0).

These differences in the effects of stochastic variation are predictable from the sensitivities and elasticities. Population growth rate was almost as elastic to changes in survival over the first three years (P_{21}, P_{32}, P_{43}, totaling 48.6 percent) as it was to changes in the entire set of "adult" vital rates (51.4 percent). *These results suggest that populations of mountain sucker are relatively tolerant of stochastic fluctuations in offspring production (due, for example, to annual climatic change or to human disturbance) but vulnerable to variations in the survival, particularly up to the point of recruitment to the breeding population*. 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 survival), with consequent detrimental effects on population dynamics*. Further, in the case of high sensitivity of λ to changes in first year survival, selection may be relatively ineffective in reducing variability that surely results from a host of biotic and abiotic factors.

Potential refinements of the models: Clearly, better data on survival and fertility rates for the species, range-wide and from Region 2, would increase the relevance and accuracy of the analysis. The present analysis should be considered, at best, only an approximate guide to the forces acting on the demography of mountain sucker in Region 2. Data from natural populations on the range of variability in the vital rates would allow improved modeling of the impact of 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. One advantage of such a series would be the incorporation of observed correlations between variations in vital rates. Using observed correlations would incorporate forces that we did not consider. 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:

- The major purpose of the matrix model is to assess critical stages in the life history (e.g., juvenile vs. adult survival, fertility vs. survival) rather than to make (often unwarranted) predictions about population growth rates, population viability, or time to extinction. Because the data are scanty, the model also provides preliminary guidance on which vital rates should be the focus of any future monitoring efforts.

- First-year survival accounts for 98.6 percent of total "possible" sensitivity. Any absolute changes in this vital rate will have major impacts on mountain sucker population dynamics.

- Survival through the first three years accounts for 48.6 percent of the total elasticity. Proportional changes in survival will have major impacts on mountain sucker population dynamics.

- The shift in emphasis between the sensitivity analysis (first-year survival) and the elasticity analysis (survival through the third year) indicates that it may be useful to understand whether variation is generally absolute vs. proportional. Regardless, survival through the first three years of life is clearly a critical feature of the population dynamics of the mountain sucker.

Ecological influences on survival and reproduction

The life history strategy of the mountain sucker is one adapted for population persistence in unpredictable environments. Mountain sucker combine high fecundity with a moderately long life span, enabling populations to persist in environments with unpredictable fluctuations in conditions (Moyle and Cech 2000). The longer life span of the species allows mature fish to spawn multiple years, in a sense averaging out the annual variations in environmental conditions and larval survival rates. The high fecundity of the mountain sucker means that even a few adults are able to produce a large number of offspring in good conditions (Moyle and Cech 2000).

The reproductive strategy of the mountain sucker involves no parental care of eggs, embryos, or larvae and, as a result, the mortality rates among the early life stages are probably extremely high. There is not enough information available to estimate the mortality rates of mountain sucker at different life stages. Potential causes of mortality at every life stage include predation, competition, parasitism, and adverse environmental events including floods, drought, and other disturbances.

The mountain sucker is well adapted to the abiotic conditions and the environmental fluctuations of the streams it inhabits. However, it is a comparatively small species, and juveniles and small adults are susceptible to predation. The introduction of trout not native to Region 2 may adversely affect mountain sucker populations in some locations (Isaak 2003). Mountain sucker have morphological adaptations for ingesting and digesting algae, and it is unlikely that competition for food resources as abundant as algae significantly influences mountain sucker populations. The specialization of mountain sucker may help them to avoid direct competition with other sucker species with which they are found (e.g., white sucker and longnose sucker (Everhart and Seaman 1971).

Limiting factors

Mountain sucker populations may be limited by their affinity for upland stream systems. Although some populations inhabit large rivers, such as those found in the Columbia Basin, records of mountain sucker occurrence in lowland rivers are rare in other parts of its range (Smith 1966). Factors limiting expansion of mountain sucker populations likely include geographic barriers, differences in water conditions and habitat associated with transitions between upland and lowland environments, physical barriers to movements, and the availability of suitable habitats (Smith 1966).

Habitat loss and alterations resulting from introduced species, land management, and stream modifications have negatively affected mountain sucker populations (Campbell 1992, Patton 1997). A key cause of mountain sucker habitat loss is stream impoundment, which results in a decline of mountain sucker populations and may create a population sink (Decker 1989, Decker and Erman 1992, Moyle 2002). Larval survivorship is naturally low for the mountain sucker, and drift into reservoir habitats where larvae may find limited food and cover and encounter increased predation may exacerbate larval mortality. In Lost Creek, Utah, where only 0.8 km (0.5 mile) of stream habitat between the reservoir and an upstream beaver complex was accessible to spawning mountain sucker, Wydoski and Wydoski (2002) reported observing larval mountain sucker in near shore areas of the impoundment throughout summer. The sensitivity analysis for the mountain sucker (see Life cycle graph and model development section) indicated that variations in the early life history survival rates significantly affect mountain sucker population growth rates. Results suggested that while the mountain sucker is relatively tolerant of annual fluctuations in fertility (related to natural stochastic variations), any major changes to the absolute survival of young-of-year in a population would have major effects on population dynamics. Reservoirs may also become population sinks for adult mountain sucker. In Flaming Gorge Reservoir in Wyoming, the mountain sucker initially "flourished," but a decade later it had disappeared as the predator population became established (Wengert 1985 as referenced by Wydoski and Wydoski (2002)). An additional impact of habitat loss from stream impoundment may be an increase in hybridization. Reproductive isolation between sympatric *Catostomus* species may be weakened by a decrease in spawning habitat availability coupled with a reduction in abundance of mountain sucker relative to other *Catostomus* species better adapted to reservoir habitats (Decker 1989, Decker and Erman 1992).

Habitat degradation resulting from land management practices that increase turbidity and sedimentation in streams and decrease habitat diversity can also negatively affect mountain sucker populations. In Wyoming, declines in occurrence of mountain sucker and other cold-water fishes that prefer clear streams and gravel substrates for spawning were attributed to increases in turbidity and sedimentation from various land management and irrigation practices (Patton et al. 1998).

Increased predation and competition from introduced species may also limit mountain sucker populations, but these impacts have not been investigated. Predation from non-native salmonids is considered a potentially a limiting factor for some populations (Isaak et al. 2003).

Spatial characteristics of populations and genetic concerns

Spatial characteristics of populations: The spatial characteristics of mountain sucker populations have not received much investigation. Mountain sucker populations are predominately found in upland streams and tend to be separated geographically from neighboring populations by their comparatively rare occurrence in lowland river systems (Smith 1966, Isaak 2003). Metapopulation dynamics and spatial characteristics such as sources and sinks have not been studied for the species, and sensitivity of mountain sucker to habitat fragmentation and population isolation is unknown.

The roles of dispersal movements and emigration/immigration have not been investigated. Mountain sucker larvae have been collected from shallow, low current habitats in streams and along shorelines of reservoirs and lakes, suggesting that larvae drift or move into nursery habitats from riffle spawning habitats. Adults of reservoir populations migrate relatively short distances up streams to spawn, but it is unknown if stream populations make similar spawning migrations. Expanding populations of Tahoe sucker have been documented to disperse as much as several kilometers upstream in one stream (Decker and Erman 1992) and downstream into sub-optimal habitat in another stream (Moyle and Vondracek 1985). Expanding populations of mountain sucker likely disperse similar distances, depending on habitat availability and pressure from intra-specific competition.

Natural and man-made barriers such as waterfalls and dams clearly will restrict fish movements and, therefore, limit gene flow among populations. Nothing, however, is known regarding the movement patterns and natural rates of interaction among mountain sucker populations. As a result, the impacts of habitat fragmentation and population isolation on the species are unknown. Isaak et al. (2003) noted that mountain sucker populations in the Black Hills were probably isolated, because fish would have to navigate the mainstem of the Missouri River and its dams to reach neighboring headwater streams. Habitat fragmentation caused by passage barriers, such as dams or culverts associated with stream crossings, may also isolate populations within streams. There is one report of the elimination of a mountain sucker population with piscicide upstream of a dam (Moyle and Vondracek 1985). Although the downstream population persisted, potential recolonization of upstream habitats was precluded by the dam.

Genetic and hybridization concerns: The genetic characteristics of mountain sucker populations have not been studied, but such information could yield insights into spatial characteristics of populations and a better understanding of mountain sucker phylogeny and the variation among and within populations.

Smith (1966) investigated variations in morphometric and meristic characteristics of regional populations of mountain sucker and found that variation among regional groups was not significantly greater than variation within groups, but differentiation in traits between some regional populations were evident. Smith (1966) found that fish from the same river system displayed differences in characteristics, such as the shape and width of the caudal peduncle, which were related to variations in current flow and rate (Campbell 1992). Other researchers have found that competition among sympatric species of catostomids in western North America results in geographic variation in growth, feeding efficiency, size, and other characters (Dunham et al. (1979) as referenced by Campbell 1992). The high fecundity of the mountain sucker may allow populations to adjust genetically to environmental change more quickly because selection pressures influence larval mortality, and consequently survivors are more likely to have higher fitness for prevailing environmental conditions (Moyle and Cech 2000).

Genetic studies would also be valuable in assessing the potential for hybridization between mountain sucker and other catostomids, which is a potential concern for mountain sucker populations. Hybrids of the mountain sucker and several other *Catostomus* species (i.e., Utah sucker (*C. ardens*), longnose sucker, white sucker, bluehead sucker (*C. discobolus*), Tahoe sucker, and bridgelip sucker [*C. columbianus*]) have been reported (Smith 1966, Campbell 1992). With the exception of the Tahoe sucker, reports of crosses with other *Catostomus* species have been rare (Smith 1966, Campbell 1992). Because the mountain sucker has been the focus of limited study, the few reports of hybridization may reflect the lack of investigation the species has received or it may indicate that reproductive isolation from other sucker species is generally maintained where mountain sucker are found with other catostomids. The survival rates and fecundity of mountain sucker hybrids and whether they back-cross with parent species have not been reported to our knowledge.

Hybridization appears to be most threatening to mountain sucker populations in eastern California where the most reports of mountain sucker hybridization with another catostomid, the Tahoe sucker, have been documented and introgressive hybridization may be occurring (Smith 1966, Decker 1989). In Sagehen Creek, California, peak abundance of mountain and Tahoe suckers occurred during the same period, suggesting overlap of spawning periods between the species (Decker and Erman 1992). Fish that appeared to be juvenile Tahoe sucker (or were possibly hybrids) were observed to be abundant at stream sites with mountain sucker in breeding condition in mid-August (Decker 1989). The mountain sucker population in Sagehen Creek was estimated to have declined from about 1,630 individuals to only 40 individuals in a three-decade period after an impoundment inundated the majority of the mountain sucker habitat in the stream (Decker 1989). Similar declines in the proportion of mountain sucker relative to Tahoe sucker have been observed in other impounded streams in eastern California, and in one of those streams, the number of mountain-Tahoe hybrids was reported to increase from 1 to 10 percent in a 40-year period between surveys (Decker 1989). Tahoe sucker are thought to be better adapted to lentic environments than mountain sucker (Moyle 2002), and the increase in hybridization between the two species may be caused by a loss of reproductive isolation related to habitat alteration coupled with a decline in mountain sucker abundance.

The degree of hybridization potential between mountain sucker and other *Catostomus* species occurring in Region 2 is not known. Mountain sucker have been reported to hybridize with several species found in Region 2, including the Utah sucker, longnose sucker, white sucker, and bluehead sucker (Smith 1966). Overlap of some of these species (particularly the Utah sucker) with the mountain sucker is limited within Region 2 due to the species' geographical distribution patterns. However, Smith did report mountain sucker hybridization with Utah sucker from the Green River, Wyoming (Smith 1966). Greater distributional overlap occurs between the mountain sucker and white and longnose suckers in Region 2 (Lee et al. 1980). There are reports of mountain sucker crosses with longnose sucker in the headwaters of the Sweet Water River in Wyoming and with white sucker in the Black Hills region (Smith 1966). Because the mountain sucker has historically coexisted with the white sucker in several drainages east of the Continental Divide where both species are considered native, the introduction of the white sucker to drainages west of the Divide may be less of a threat to mountain sucker than to other *Catostomus* species endemic west of the Divide.

Community ecology

As an inhabitant of cold-water streams, the mountain sucker is usually found in fish assemblages that include native and/or introduced salmonids, cyprinids, catostomids, and cottids (sculpins) (Moyle and Vondracek 1985). Hauser (1966) described a typical cold-water fish assemblage in Montana, of which the mountain sucker was a part, that included mountain whitefish (*Prosopium williamsoni*), cutthroat trout (*Oncorhynchus clarki*), rainbow trout (*O. gairdneri*), brown trout (*Salmo trutta*), brook trout (*Salvelinus fontinalis*), lake chub (*Hybopsis plumbea*), longnose dace (*Rhinichthys cataractae*), longnose sucker, white sucker, and mottled sculpin (*Cottus bairdi*). In eastern California, the mountain sucker was part of an assemblage that also contained rainbow trout, brook trout, brown trout, mountain whitefish, Lahontan redside (*Richardsonius egregius*), Lahontan speckled dace (*Rhinichthys osculus*), Tahoe sucker, and Paiute sculpin (*C. beldingi*) (Decker and Erman 1992).

The mountain sucker is found in a variety of aquatic habitats across its large range in western North America, and variations in community composition are likely numerous. For instance, in a high-desert stream system in Wyoming, the mountain sucker was part of an assemblage including only two other indigenous species, flannelmouth sucker (*Catostomus latipinnis*) and Lahontan speckled dace, and several introduced species, including white sucker, fathead minnow (*Pimephales promelas*), Utah chub (*Gila atraria*), and Bonneville redside shiner (*Richardsonius balteatus hydrophlox*). In the Powder River of Wyoming, the mountain sucker is found with shorthead redhorse (*Moxostoma macrolepidotum*), white sucker, longnose dace, sand shiner (*Notropis stamineus*), sturgeon chub (*Macrohybopsis gelida*), flathead chub (*Platygobio gracilis*), goldeye (*Hiodon alosoides*), fathead minnow, plains minnow (*Hybognathus placitus*), plains killifish (*Fundulus zebrinus*), stonecat (*Noturus flavus*), and channel catfish (*Ictalurus punctatus*) (Weitzel 2002).

Predators

Wydoski and Wydoski (2002) characterized the mountain sucker as an important link in the food chain between primary producers such as algae and secondary consumers such as trout. While early life stages of suckers are particularly susceptible to predation (Moyle 2002), the small size of adult mountain sucker compared to other sucker species contributes to their continued vulnerability to predation as young adults; they have been found in stomachs of cutthroat trout, brook trout, rainbow trout, and brown trout (Campbell 1992, Wydoski and Wydoski 2002). Because of the broad distribution of the mountain sucker in mountainous areas of western North America, the species likely has a long history of coexistence with cutthroat trout and rainbow trout in many areas; however, brown trout, rainbow trout, and brook trout are all non-native to Region 2. Mountain sucker populations occurring in the Black Hills of South Dakota and several of the Missouri River sub-basins east of the Continental Divide in Wyoming did not evolve with any trout species. In these areas, several species of trout (i.e., cutthroat, rainbow, brook, and brown) have been widely introduced to provide recreational fisheries (Baxter and Stone 1995).

All trout species, native and non-native, found in Region 2 may predate on the small young-of-year and juvenile mountain sucker. Trout that reach larger sizes typically switch from a predominately insectivorous diet to one primarily composed of small fishes (Baxter and Stone 1995, Behnke 2002). Brown trout in particular are known to be effective piscivores (Garmen and Nielsen 1982) and consequently may have an impact on mountain sucker. Areas managed for production of larger trout may result in increased predation on mountain sucker. In Sagehen Creek, stream reaches with high numbers of brown trout contained few mountain sucker, and researchers suggested that mountain sucker were being consumed by brown trout in those reaches or avoiding the reaches (Decker and Erman 1992). Similar inverse relationships between mountain sucker and brown trout abundance are seen in some streams in the Black Hills National Forest (Black Hills National Forest FY 2004 Monitoring and Evaluation Report).

Piscivorous mammals and birds also predate on mountain sucker (Scott and Crossman 1973 as referenced by Campbell 1992), and human harvest of mountain sucker for use as baitfish may be a factor in some locations. Egg predation also likely occurs since mountain sucker do not bury or guard their eggs. Erman (1986) reported observations of Lahontan redside feeding on eggs among breeding Tahoe sucker.

Competitors

Competitive interactions between mountain sucker and other species with which it is commonly found have not been studied. In many headwater systems where mountain sucker occur, their primarily algal diet is unlikely to bring them into direct competition with many other fish. In larger streams and rivers at lower elevations, with greater fish diversity, mountain sucker competition with other fishes is more likely. Where mountain sucker are found with other species of sucker that have similar food habits, particularly bluehead sucker, competition may affect populations (Baxter and Stone 1995, Isaak et al. 2003). Isaak et al. (2003) recounted evidence of competition between mountain and bluehead suckers, reported by Dunham et al. (1979), who found large differences in gill raker number in sympatric populations of the two species compared with allopatric populations of mountain sucker. Competition among the two species was thought to be the reason for divergent gill raker morphologies of sympatric populations (Isaak et al. 2003).

The native ranges of the white and longnose suckers have historically overlapped with mountain sucker in some parts of its range (Lee et al. 1980, Page and Burr 1991). However, the extent of current and historic coexistence between the species is unknown and may be, or have been (prior to anthropogenic modifications of streams and fish communities), minimal due to variations in habitat preferences. Simpson (1941) investigated the food habitats of both mountain sucker and stream-dwelling white sucker in Wyoming and found that mountain sucker consumed predominately algae, whereas algae was a very minimal (only 0.05 percent) component of the diet of white sucker. The specializations of mountain sucker, including the long intestine and "scraping" plate on their lip, may allow them to avoid direct competition with white and longnose suckers where they occur together (Everhart and Seaman 1971). However, white sucker are able to thrive in a variety of habitats and have been noted to have a wide range of food preferences. Where the white sucker has been introduced to drainages west of the Continental Divide, it may be a competitor in some locations.

There have been few studies reporting mountain sucker competitive interactions with other fish species for food or habitat resources. In Sagehen Creek, mountain sucker were frequently observed in mixed-species shoals that included Tahoe sucker and Lahontan speckled dace (Isaak et al. 2003). Decker (1989) reported no agonistic encounters between mountain and Tahoe suckers; however, Hauser (1969) noted that shoals of mountain sucker remained separated from aggregations of white and longnose suckers. Investigation into mountain sucker competition with other species with similar niches is needed.

Parasites and disease

Fish pathogens exist in all freshwater systems and, generally, healthy fish can withstand occasional exposure and even harbor pathogens (Strange 1996). Under particular conditions, fish can become diseased and growth, reproduction, and survival can be affected (Strange 1996). The interaction of several factors, such as degraded water quality (e.g., sedimentation, low dissolved oxygen, pollutants), high fish density, poor fish condition, and other environmental factors that promote pathogens, contribute to infections in fish populations (Strange 1996). Fish kills in wild fish are usually caused by adverse environmental conditions (Strange 1996).

Few pathogens have been reported for mountain sucker. Hoffman (1967) reported the parasitic trematode, *Posthodiplostomum minimum*, and several researchers have reported the metacercaria of the eye fluke *Diplostomum spathaceum* to be widespread in mountain sucker populations in Utah (Campbell 1992). Campbell (1992) noted, “the relative scarcity of known parasites to the species probably reflects the degree of investigation rather than a low incidence of infestation.”

Envirogram of ecological relationships

Envirograms are dendrograms that depict ecological relationships that influence the survival and reproductive success of a species (Andrewartha and Birch 1984). They consist of a centrum and a web, which together represent all major ecological relationships important to a species (Andrewartha and Birch 1984). The centrum consists of factors that directly affect the species and has four components: resources, malentities, predators, and mates (Andrewartha and Birch 1984). The web represents environmental factors affecting the species indirectly via their influence on centrum components (Andrewartha and Birch 1984). An envirogram for mountain sucker is presented in **Figure 7**.

The primary resource of mountain sucker is food, mainly algae, but also aquatic invertebrates. Mountain sucker food availability is linked to algal production, which is in turn influenced by factors such as geology, land-use, and weather and human modifications that influence water fertility and flow regimes. Malentities affecting mountain sucker populations are natural disturbances, human disturbances, and competitors. Natural disturbances are primarily influenced by climate, weather, geology, and land-use. Human disturbances include the myriad of land and water management activities that can result in habitat degradation or loss, such as land-uses that increase stream sedimentation or impoundments that alter flow regimes and habitat. Competitors include native and introduced fishes that share similar niches with mountain sucker. The potential impact of competitors is influenced by species introductions and the availability of suitable habitat, which is in turn influenced by abiotic conditions and human modifications. The degree of predation on mountain sucker by native piscivores is influenced by the availability of suitable habitat for the predator and availability of alternate prey. Piscivorous fishes, particularly salmonids, are predators of mountain sucker. The impact of piscivorous fish predation on mountain sucker is linked to both predator introduction and the availability of suitable habitat. The last component of the envirogram centrum, mates, consists of factors that influence the reproductive success of mountain sucker. The two primary factors are the availability of suitable spawning habitat and egg hatching success. Geology, climate, weather, land-use, and human modifications of stream habitat all affect spawning habitat availability. Because of the relatively short incubation periods required by the summer spawning mountain sucker, egg-hatching success is mainly determined by water temperature and factors that influence stream water temperature, such as riparian cover and weather.

CONSERVATION OF MOUNTAIN SUCKER IN REGION 2

Extrinsic Threats

Potential threats

Potential threats to the long-term persistence of mountain sucker in Region 2 include land and water management activities that result in habitat degradation, loss, or fragmentation, and fisheries management activities such as species introductions and control programs. Periodic natural disturbances, such as floods, droughts, and fires, are not thought to threaten the persistence of mountain sucker unless human activities have isolated populations or have otherwise made populations more susceptible to extirpation. As found in the matrix demographic model, the mountain sucker is relatively tolerant of annual fluctuations in fertility, but population growth rates are particularly sensitive to changes in absolute survivorship of young-of-year and changes in the proportional survivorship rates of juveniles up to their recruitment into the breeding population (age 3 to 4 for females). As a result, anthropogenic impacts that reduce young-of-year survivorship directly or lower survival rates among the immature age classes can adversely affect populations.

Water management

Dams and their impoundments have numerous effects on fish, impacts that are well known. As discussed in greater detail in previous sections, impoundments can decrease mountain sucker habitat, create barriers to movement and thus fragment populations, and alter community structure, all of which can threaten survival of mountain sucker populations.

A review of the literature indicates that the most detrimental impact of reservoirs on mountain sucker is direct loss of habitat through inundation of low gradient stream reaches (with high pool to riffle ratios) (Decker and Erman 1992, Moyle 2002). However, other indirect effects of stream modification were also shown to be detrimental to mountain sucker persistence in Sagehen Creek, California. Loss of habitat forced the

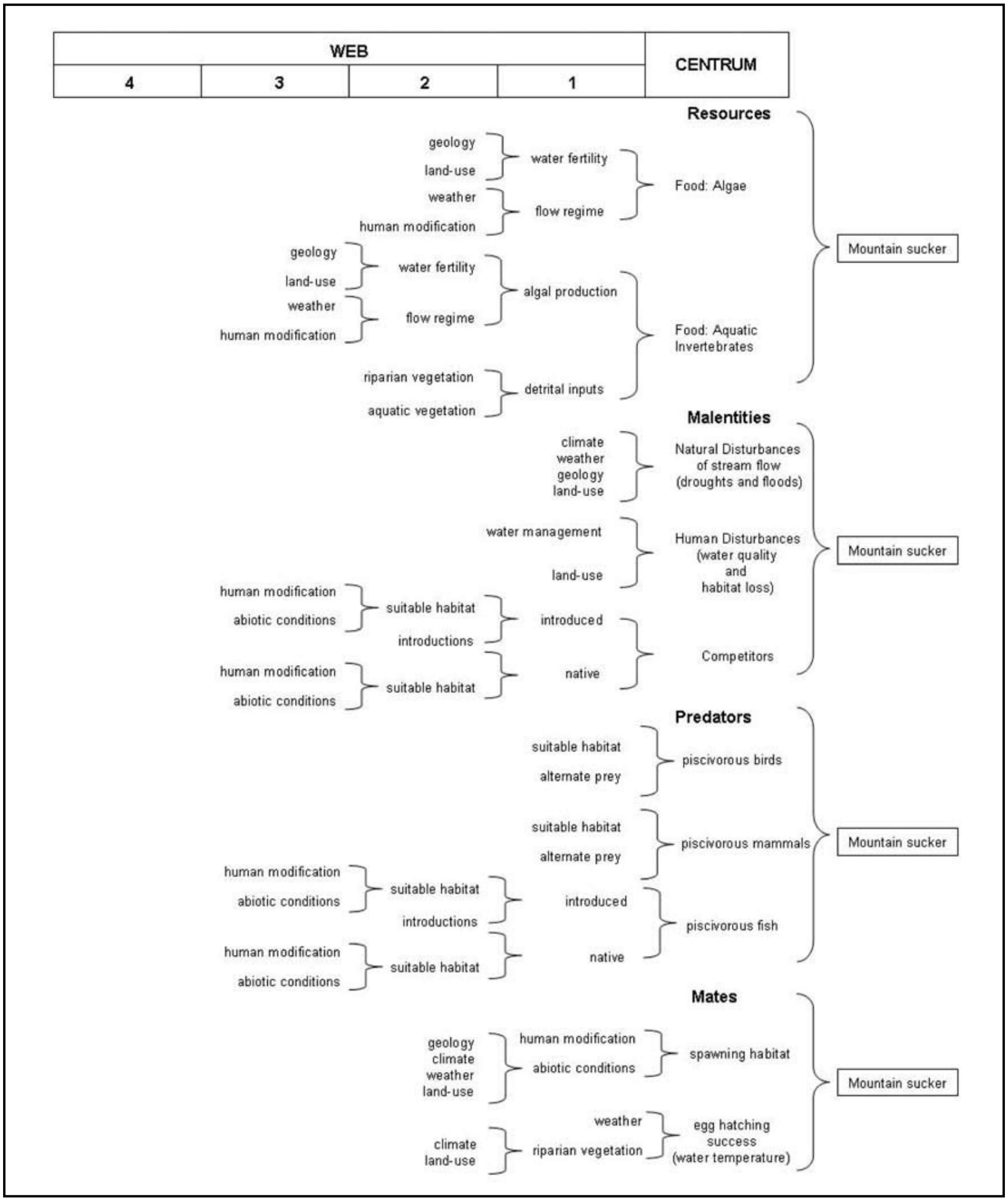

Figure 7. An envirogram for mountain sucker depicting ecological relationships influencing survival and reproductive success of the species. The centrum and the web together represent all major ecological relationships important to a species (Andrewartha and Birch 1984). The centrum consists of factors directly affecting the species. The web represents environmental factors affecting the species indirectly via their influence on centrum components.

mountain sucker population to shift to lentic waters of the impoundment to which the species was less well-adapted than the other sucker species present in the watershed (Decker and Erman 1992). The change in habitat conditions shifted the balance in favor of other sucker species, altered community structure, and likely contributed to increased hybridization between the two species that could result in effective elimination of the mountain sucker population from Sagehen Creek (Decker 1989, Decker and Erman 1992). Dams have also been documented to fragment mountain sucker populations. In one example, mountain sucker were extirpated above a dam, and the dam prevented recolonization of upstream habitats by the downstream population (Moyle and Vondracek 1985).

For populations downstream from dams, changes in peak flows and water temperatures may have deleterious effects on mountain sucker populations. Mountain sucker reproduce in mid to late summer (varying with latitude and elevation) during stable low flow conditions when water temperatures are around their annual maximums. Young-of-year mountain sucker require low velocity shallow habitats. Regulated flows that differ substantially from natural flow regimes, or that alter temperature or habitat availability during breeding and rearing periods, could adversely affect spawning success and young-of-year survivorship of mountain sucker, potentially threatening their long-term persistence.

Land management

Effects of water development on mountain sucker populations have been better studied than those of land-use. In forested headwater systems where the mountain sucker is often part of the native cold-water fish assemblage, impacts of timber harvest, roads, and livestock grazing on salmonids have received much study. Although such impacts on mountains sucker have not been investigated directly, the results of this research should apply to mountain sucker.

Land management activities that alter the timing and intensity of peak flows or base flow conditions could adversely affect the reproductive success of mountain sucker during the sensitive early life stages. Increased sediment delivery to streams, whatever the source, tends to result in less diverse physical habitats, decreases water quality, denudes spawning substrates, and decreases the availability of deep pools (Isaak et al. 2003). Because mountain sucker adults spawn over gravel riffles and use lower velocity, deeper habitats during non-breeding periods, and because young-of-year mountain sucker require shallow low velocity habitats, the availability of diverse stream habitats is important to the persistence of the species. Common land management activities such as timber harvest, road development, and livestock grazing pose threats to mountain sucker persistence if erosion rates and sediment delivery to streams are not managed and habitat heterogeneity is diminished.

The mountain sucker population in the Sagehen Creek watershed in California experienced sheep grazing, timber harvest, two forest fires, and road construction at different times in the last century (Erman 1986). Reportedly, the effects of the various disturbances on the water quality and channel morphology of Sagehen Creek were minimal, and by the 1960s sediment concentrations were reduced from previous levels and continued to remain low (Erman 1986). Although the disturbances appeared to minimally affect Sagehen Creek and its fish assemblage, variations in geology, topography, climate, vegetation cover, and the sequence and severity of disturbances would alter the effects of such disturbances on other fish assemblages. It is unclear how sensitive mountain sucker populations are to particular disturbances, but land management practices designed to protect salmonid habitats would likely benefit mountain sucker populations and other members of native cold-water fish assemblages.

There has not been much investigation into the tolerance of mountain sucker to various water quality conditions. Sigler and Sigler (1996) have suggested that water temperatures in excess of the mid to high 20s °C (upper 70s to low 80s °F) are harmful to mountain sucker. In headwater streams, summer water temperatures are correlated with solar incidence, so land management practices that result in removal of riparian vegetation can lead to increased water temperatures and potentially be detrimental to cold-water fishes (Isaak et al. 2003).

Industrial activities such as mining and smelting have likely affected mountain sucker populations in parts of their range. Contaminants from mining or smelting activities can reach streams via direct contaminant releases, tailing pond failures, drainage from mine tunnels, wind and water erosion of waste and tailing piles, and atmospheric deposition (Schmitt et al. 1984, Dwyer et al. 1988, Farag et al. 1995, Marr et al. 1995a, Clements and Rees 1997). Impacts of mining largely depend on the type of material being mined, the ore bodies in which mining occurs, the type of processing, and the age of the mine, since regulations have changed over time. Primary effects of mining are increased erosion, sediment delivery to streams, and impacts on water quality from acidic or toxic leachates (Isaak et al. 2003).

Mining activities have resulted in elevated concentrations of heavy metals in streams in several regions in North America, including the Rocky Mountains (Dwyer et al. 1988, Farag et al. 1995, Clements and Rees 1997). Hydrologic events influence stream fish exposure to heavy metals from both point and non-point sources in one of the following ways:

- chronic exposure to elevated concentrations during spring snowmelt runoff

- chronic exposure to comparatively low concentrations during winter low flows

- episodic exposure related to storm events in which pulses of extremely high concentrations of metals are accompanied by decreases in water pH and hardness (Marr et al. 1995a).

The toxicity of heavy metals to fish can be enhanced by acidic runoff from stream bank and floodplain sediments that increase the biologically available forms of some metals. Heavy metals can persist in stream environments for long periods in contaminated sediments and be released during high flows or ice break-up, even after point sources of pollutants are remediated (Clements and Rees 1997).

The effects of heavy metals on stream biota can include the reduction in benthic invertebrate community abundance, species richness, and community composition (Clements and Rees 1997), as well as detrimental impacts on fish health and abundance. Reduced biomass, population density, and survival observed in some brown trout populations were attributed to metals contamination (Marr et al. 1995a and b, Clements and Rees 1997). Another study indicated continuous low-level exposure of longear sunfish (*Lepomis megalotis*) to elevated lead concentrations affected heme synthesis (Dwyer et al. 1988). The same researchers suggested that changes in the mechanical and biochemical properties in bone were related to prolonged exposure of the fish to elevated concentrations of cadmium and lead (Dwyer et al. 1988).

Acid mine drainage (AMD) is caused by the oxidation of sulfide minerals through the exposure of ore and mine spoils to the atmosphere. Streams that receive AMD are usually characterized by low pH, high conductivity, and high metal and sulfate concentrations (Henry et al. 1999). Acid mine drainage from tunnels, or events such as failure of tailing ponds, can release contaminants in lethal amounts and decimate fish populations (Moore et al. 1991). An array of toxic metals may be dissolved in AMD, including aluminum, iron, manganese, zinc, copper, arsenic, and lead. Streams with AMD can impact the otherwise unaffected streams into which they flow by creating acid mixing zones that are typified by areas of rapidly changing pH and precipitation of the metals that were dissolved in the acidic discharge (Henry et al. 2001). Moore et al. (1991) found that concentrations of some metals (in bioavailable forms) persisted kilometers downstream of headwater contaminant sources in a Montana river. Although the concentration of contaminants in solute form decreased over shorter distances via precipitation or adsorption and many particulate contaminants were entrained in marshes, cadmium and zinc remained bioavailable over several kilometers of the river (Moore et al. 1991). Streams severely affected by AMD (pH <3.5) are usually fishless whereas less severely affected streams (pH = 4.5 to 6.0) may have low fish diversity and abundance (Henry et al. 1999). Fish mortality may be increased in mixing zones where toxic metals precipitate from the acidic water and may accumulate on fish gills (Henry et al. 2001). Research into the effects of acidic or toxic mining leachates on mountain sucker specifically has not been conducted to our knowledge. However, some of the effects of elevated lead levels in streams on mountain sucker have been studied. Schmitt et al. (2002) assessed the effects of lead on several fish species including mountain sucker. The study focused on areas where lead and other contaminants had been released into aquatic ecosystems directly when untreated wastewater from lead smelting activities was released to streams prior to the advent of regulation in the 1970s (Schmitt et al. 2002). Several of the lead smelters had been in operation for over 100 years at the time of study, and in the case of a smelter located on the Columbia River (in Canada just above the border), contaminants had been found as far as 240 km (149 miles) downstream at the Grand Coulee Dam, suggesting the impact of contaminant discharge can be extensive. Atmospheric deposition of contaminants from smelters (that eventually enter stream systems through runoff) was also considered a significant non-point source of contaminants (Schmitt et al. 2002). Because lead is entrained in stream sediments, suckers are thought to be more vulnerable to lead because of their association with benthos. Higher trophic level fish such as salmonids are not thought to be as vulnerable to lead poisoning because unlike other contaminants, lead does not bioaccumulate (Schmitt et al. 2002). The study found that lead levels were elevated in mountain sucker blood two-fold compared to the reference site, but these results were not statistically significant. The activity of an enzyme present in red blood cells, which is used as a biomarker of lead exposure, was significantly lower in mountain sucker (44 percent) (Schmitt et al. 2002). Symptoms of lead poisoning in fish include sub-lethal effects on heme synthesis and bone strength; 'black tail,' which is a precursor to spinal deformity; spinal deformity; and stippled blood cells (Schmitt et al. 2002).

Fisheries management

After habitat alterations, Miller et al. (1989) considered non-native fish introductions to be the second most frequent causal factor of extinction of fish species in North America during the last century. Of exotic fish species introduced throughout the range of mountain sucker, trout were most often mentioned as threats. Larger individuals of trout are piscivorous (Behnke 2002), and the small size of mountain sucker makes them susceptible to predation (Simon 1938, Sigler and Miller 1963, Wydoski and Wydoski 2002).

Mountain sucker have been found in the stomachs of most trout species, but the relative impact of different species on mountain sucker has not been assessed. Brown trout, which are considered particularly effective piscivores, were thought to be a threat to mountain sucker in the Black Hills of South Dakota, where brown trout populations were maintained by stocking to meet angler demands (Isaak et al. 2003). More recently, South Dakota Game, Fish, and Parks has modified its trout stocking program, such that large rainbow trout will be stocked in waters not able to support wild brown trout populations (South Dakota Department of Game, Fish, and Parks 2005 Fishing Handbook). In Wyoming, most streams are managed for self-sustaining trout populations, and the majority of trout stocking is directed toward lakes and tailwaters (Wyoming Game and Fish Commission Fishing Regulations 2004-2005), which reduces the potential impact of trout stocking on most mountain sucker populations. Generally, brown trout are no longer stocked in most waters in North America, and naturalized populations are managed to be self-sustaining (Behnke 2002). However, naturalized trout populations may have deleterious impacts on mountain sucker. The effects of trout fisheries management on mountain sucker populations are likely to vary among locations with differences in assemblage composition and management practices. For instance, mountain sucker and other small-bodied, non-game fish may experience increased predation in areas managed for the production of large trout, as trout become increasingly piscivorous at larger sizes (Behnke 2002).

Many species of cyprinids and a few catostomids have been introduced into mountain sucker waters as baitfishes and may be detrimental to mountain sucker through competition or egg predation, as reported for Lahontan redside. Mountain sucker eggs are more vulnerable to predation than salmonid eggs because mountain sucker do not construct nests or bury their eggs.

Fisheries management programs to control exotic species have threatened the persistence of some mountain sucker populations in the past. Several reports of piscicide applications to stream impoundments occupied by mountain sucker were encountered in the literature (Moyle and Vondracek 1985, Decker 1989, Wydoski and Wydoski 2002), although mountain sucker was never the reported target for removal. While some populations of mountain sucker populations recovered after chemical renovation (Wydoski and Wydoski 2002), populations were extirpated where recolonization of the treatment area was prevented by barriers (Moyle and Vondracek 1985). Management programs utilizing piscicides may extirpate mountain sucker populations if mountain sucker are not salvaged and re-established in the treatment areas. Fish passage barriers, or the absence of a nearby population, may prevent mountain sucker recolonization of treated areas.

Natural disturbances

Mountain sucker evolved with periodic natural disturbances such as fires, droughts, and floods. Such natural disturbances are not thought to threaten mountain sucker populations except in modified watersheds where factors like habitat loss and barriers to movement have isolated populations, impeding recovery and recolonization following a disturbance event (Isaak et al. 2003). Fish populations in isolated headwater streams are more susceptible to extirpation by floods, fires, and drought (Propst et al. 1992, Rinne 1996).

Forest fires can be detrimental to fish populations by increasing mortality rates from changes in water temperature and chemistry (Minshall and Brock 1991, Rinne 1996). Extreme degradation of water quality from toxic slurry or ash flows after fires causes high mortality among streamfish (Rinne 1996). Fire suppression methods may also cause fish mortality. Minshall and Brock (1991) reported that the inadvertent release of fire retardant (ammonium phosphate) on a stream resulted in almost total trout mortality in the affected section. After fire, increased erosion and higher peak and total discharge from burned slopes can degrade stream water quality and fish habitat (Minshall and Brock 1991). Runoff is likely to be more flashy, and variations in the timing and magnitude of flows may negatively affect stream biota unable to adjust, resulting in decreased biotic diversity and production (Minshall and Brock 1991). Populations of aquatic invertebrates can be markedly reduced post-fire, and recovery to pre-fire density and diversity can be slow (Rinne 1996).

As watershed recovery progresses, biotic productivity may increase with increased production of algae and invertebrates that are beneficial to fish (Minshall and Brock 1991). However, an extreme precipitation event may trigger debris flows from burned slopes or mobilize sediment from ephemeral channels and result in elevated suspended sediment concentration in streams, causing fish mortalities several years after fire (Bozek and Young 1994).

One report of the effects of forest fire on a stream containing mountain sucker indicated that effects may be minimal in some cases. In the Sagehen Creek watershed, 809 hectares (about 2000 acres) of forest burned in 1960 (one third of the watershed), but the burn had little effect on stream chemistry and discharge, and no notable effect on fish populations (Erman 1986). Although more information is needed on mountain sucker habitat preferences in the Sagehen Creek watershed, mountain sucker were found in the low gradient meadow reaches downstream, where the effects of fire tend to be less severe relative to impacts on small forested channels in the headwaters that have steeper and more erosive slopes (Minshall and Brock 1991). The extent of fire impact on mountain sucker populations will depend on numerous factors, including the spatial characteristics of the fire relative to the distribution of mountain sucker in the watershed, the size of the burn area, burn intensity, weather after the fire (which affects erosion and streamflow), the availability of downstream or other refugia for fish, and stream connectivity as it may provide for refugia and affect the potential for recolonization of fire affected reaches by fish from unaffected areas (Minshall and Brock 1991, Rinne 1996).

Conservation Status of Mountain Sucker in Region 2

Abundance and distribution trends

Information needed to assess abundance and distribution trends of mountain sucker is sparse. The distribution and abundance of mountain sucker are poorly known for several of the national forests in Region 2 on which mountain sucker are thought to occur. In the states encompassed by Region 2, mountain sucker trends in abundance vary among drainages.

In Wyoming, mountain sucker abundance and distribution vary among basins. This species is considered widespread in the Wind and Big Horn River drainages, spotty in the Salt and Snake River drainages, and it has not been collected recently from the North Platte drainage (Weitzel 2002). Patton (1997) determined that mountain sucker populations had decreased between the 1960s and 1990s in all five of the Missouri River drainages surveyed in Wyoming. Wheeler (1997) suggested that some mountain sucker populations may be decreasing in some southwestern Wyoming streams, although populations appear to be secure in the Green River drainage where the mountain sucker is widely distributed and in abundance (Weitzel 2002). Most mountain sucker in the Bighorn region occur on private holdings downstream of Bighorn National Forest. On the Bighorn National Forest, mountain sucker are restricted to two locations, one stream and one reservoir, and neither population has been monitored (W.Young personal communication 2006). On the Medicine Bow National Forest, mountain sucker distribution is thought to be limited and populations likely to be stable where it has been collected in recent years from two streams on the western side of the Continental Divide (G.T. Allison personal communication 2006).

Mountain sucker population trends appear mixed in the Black Hills of South Dakota. Mountain sucker distribution in the Black Hills appears to fluctuate, and changes may have occurred over the past several decades. At some sites, mountain sucker were found in the 1960s, but not in more recent surveys (Black Hills National Forest FY2004 Monitoring and Evaluation Report). At other sites, however, mountain sucker were not documented in past surveys but were found in the 1990s (Black Hills National Forest FY2004 Monitoring and Evaluation Report). Isaak et al. (2003) noted that the range of the mountain sucker may have contracted in the southern part of the Black Hills, as this species has not recently been collected from the upper Cheyenne River. However, the lack of recent collection may have been related to less frequent sampling. Isaak et al. (2003) indicated that populations appeared stable at four sites on three streams in the Black Hills, based on a trend analysis of samples collected over a six-year period. However, comparison of samples from the same sites limits the trend analysis to those locations, and short-term variations in abundance over the relatively short time period may have masked population trends. Within the Black Hills National Forest, some populations may be declining, but data are insufficient to detect trends. In a comparison of recent and past relative abundance data from 27 sites, fewer mountain sucker were collected in recent surveys at the majority of sites, and this may indicate a decline at those locations (**Table 3**; Black Hills National Forest FY2004 Monitoring and Evaluation Report; S. Hirtzel personal communication 2006). Unfortunately population trends for mountain sucker cannot be inferred with confidence given the limitations of the available data.

Population trends of mountain sucker in Colorado are unknown, but the species is not as widely distributed there as it is in Wyoming, being restricted to the northwestern part of the state, primarily in the Green, White, and Yampa River basins. There are incidental published reports of mountain sucker being found in abundance at several stream sites in Colorado, but the information is insufficient to infer abundance or population trends, and some of the reports are several decades old.

Intrinsic vulnerability

Mountain sucker populations are widely distributed in western North American and are well adapted to the habitats they occupy. They have life history characteristics and a reproductive strategy that is well suited for mountainous stream systems (Moyle 2002). However, mountain sucker population growth rates are sensitive to anthropogenic impacts that alter survivorship rates among sexually immature age classes or decrease the number of young-of-year (see Life cycle graph and model development section).

Mountain sucker are omnivores, but algae, the primary component of its diet, is widely abundant and relatively little exploited. While the effects of competition on mountain sucker have not been studied, competitors and predators may have detrimental impacts on mountain sucker populations. Mountain sucker are small and continue to be vulnerable to predation by piscivorous fish as young adults, although the effects of predation on mountain sucker by native predators is unknown.

Management of Mountain Sucker in Region 2

Implications and potential conservation elements

Mountain sucker are associated with low gradient stream reaches with high pool to riffle ratios. Although mountain sucker spawn in riffles, pools and runs are important habitats during the rest of the year. Habitat requirements of young mountain sucker are largely unknown, but young-of-year have been reported to use side channels and other slow water areas with abundant aquatic vegetation. Awareness of land or water management activities that have the potential to decrease or degrade mountain sucker habitats is an important conservation consideration. For instance, land or water management practices that alter flow regimes may affect mountain sucker populations by altering habitat availability or quality during sensitive life stages, such as spawning or larval emergence. Habitat connectivity may be important to the persistence of populations, and management activities that fragment populations or impede fish movements (such as dams or culverts associated with stream crossings) could be detrimental to mountain sucker populations. In areas where the mountain sucker is not widely distributed or abundant, or where populations are thought to be declining, awareness of mountain sucker habitat requirements and efforts to mitigate future habitat loss and to maintain stream habitat heterogeneity and connectivity are important aspects of conservation.

Competition with native and introduced species, and predation by piscivorous fishes, may adversely affect mountain sucker populations, but these potential impacts have not been studied. Fisheries management activities that alter fish assemblages are likely to adversely affect mountain sucker populations. On the other hand, native trout restoration projects that re-establish native fish assemblages may benefit mountain sucker populations. The potential benefits of such projects are likely to vary with the distribution of mountain sucker in the watershed and the habitat characteristics of the restored stream segments. For instance, native trout restoration projects conducted in headwater streams above natural or man-made barriers may have limited benefit to mountain sucker if most mountain sucker are found downstream or if barriers prevent exchange between upstream and downstream populations. A better understanding of mountain sucker habitat requirements (at all life stages), movement patterns, and interactions with other populations and other species would be helpful in evaluating the benefit of native trout restoration projects to mountain sucker conservation.

Other fisheries management activities that influence the composition of fish assemblages or the relative proportions of species (such as stocking game species) may affect mountain sucker populations. In areas where mountain sucker are not widely distributed or abundant, or where populations are in decline, consideration of the potential effects of fisheries management activities on mountain sucker populations is recommended. For instance, where mountain sucker are sparsely distributed and a population is found isolated in a restricted area, such as a single tributary, the potential impacts of trout management on the mountain sucker population should be considered. Similarly, where mountain sucker are widely distributed but many populations are in decline, fisheries managers could consider actions that would promote, or at least not severely detract from, mountain sucker population stability in a few locations (such as more remote areas less frequently visited by anglers). In locations where mountain sucker populations are stable or increasing, efforts should be made to understand the factors contributing to the population's success and to maintain those conditions.

Tools and practices

Inventory and monitoring of populations

We are aware of only one monitoring program for mountain sucker in Region 2, the Black Hills National Forest monitoring program (Black Hills National Forest 2005 Monitoring Implementation Guide, www.fs.fed.us/r2/blackhills/projects/planning/index.html). The mountain sucker is a Management Indicator Species on the Black Hills National Forest, and the program described in the 2005 Monitoring Implementation Guide focuses on monitoring mountain sucker persistence, distribution, recruitment, habitat connectivity, and habitat quality and quantity. Mountain sucker persistence, distribution, and recruitment are to be measured by surveying mountain sucker populations at "core" sites (established in fisheries survey work in the 1990s) every two to three years, in cooperation with state agencies. Other sampling sites where mountain sucker were historically collected (prior to 1990), but where they have not been recently documented, are to be sampled less frequently than core sites in order to monitor potential reoccupation of habitats and changes in distribution.

Information on mountain sucker distribution is more limited on other national forests in Region 2. The lack of information regarding the species, particularly basic information such as local occurrence and abundance estimates, on National Forest System lands presents a major impediment to managing mountain sucker populations and habitats for future persistence. The inability to evaluate distribution and abundance trends for mountain sucker in Region 2 with the available data underscores the need to inventory and monitor populations. In forests where mountain sucker distribution is not well documented, a foremost priority would be to establish mountain sucker occurrence and distribution. If currently available datasets are insufficient for establishing mountain sucker occurrence on forest lands, presence/absence surveys should be initiated. Initial efforts could focus on streams suspected to have mountain sucker based on historic collection records or, preferably, on more recent reports from other agencies or institutions. Documenting the occurrence (or absence) of mountain sucker on National Forest System lands is a critical first step needed for population monitoring and management. Once mountain sucker distribution on Region 2 lands is established, shifts in distributional patterns can be monitored.

Abundance statistics or population estimates for mountain sucker are needed to monitor population trends. Developing monitoring programs for mountain sucker populations, or for cold-water stream fish assemblages that include mountain sucker, would provide another basic and important conservation tool. Abundance statistics, such as catch per unit effort (CPUE), can be used to make temporal comparisons of fish abundance (Ney 1999). The CPUE is assumed to be directly proportional to the actual population size, but in reality variations in factors such as fish activity patterns, weather, and water quality affect the relationship (Ney 1999). The proportionality assumption can be validated by performing a population estimate and comparing it with CPUE, and if high correlation between the two was established, then CPUE could also be used to estimate population size (Ney 1999). CPUE statistics obtained for a single stock over time can be analyzed using simple linear regression to identify trends and to assess the impact of management actions or changes in environmental conditions on population sizes (Ney 1999). However, short-term variability may obscure trends in temporal patterns (Ney 1999). In order for comparisons to be made, sampling effort should be consistent and precisely measured (Ney 1999). Consistency in sampling effort includes standardization of sampling gear types, specifications, and operation, as well as sampling similar habitat types at similar times of year, and under similar weather and water conditions (Ney 1999).

Population size can be estimated using one of several population estimator methods for stream fishes, including mark-recapture (Ricker 1975) and removal methods (Zippin 1958, White et al. 1982) (Isaak et al. 2003). Although population estimates require more effort, they improve the ability to detect trends (Ney 1999, Van Den Avyle and Hayward 1999).

Mountain sucker populations could also be monitored in the context of an assemblage. Developing a fish assemblage monitoring program would not only provide detailed information on population trends for several species, but also other information (such as relative proportions of species) that would allow changes in assemblages to be easily identified and tracked over time. Additionally, information collected for a group of fishes would be valuable in evaluating the effects of management actions or natural disturbances. If mountain sucker are monitored in the context of an assemblage, consideration should be given to the temporal and spatial variability of assemblages. For instance, sampling an area with predominately riffle habitat in July would likely result in a different estimate of mountain sucker abundance than sampling the same area in September because of temporal changes in habitat use related to spawning. No single habitat type is best for obtaining a representative sample of stream fish assemblage. Sampling of segments long enough to include several habitat units, and selecting a sufficient number of random sites (or stratified random sites) will help ensure collection of representative samples of the fish assemblage. Similarly, no single sampling time is optimal for obtaining representative samples of assemblages, but Decker and Erman (1992) recommend that sampling be correlated to physical stream phenomena, such as water temperature or discharge level.

A consideration that pertains specifically to mountain sucker is that the species is reported to form shoals. As a result, numerous individuals may be concentrated in one area during one sampling period while few to none are sampled the following year. This could increase variability in abundance estimates and confound identification of population trends. Ensuring that sampling reaches are sufficiently long should help to offset the potential effect of shoals on abundance estimates. In addition, long-term monitoring will enable better detection of population trends despite short-run variations.

While state and federal agencies have collected data on mountain sucker occurrence and abundance, much of the data has been irregularly reported or remains difficult to access because it is not a managed species. Patton et al. (1998) described a method for assessing population trends from presence-absence data. The method is useful for non-game species that have been collected in past surveys but for which reliable data on abundance are lacking. The method also addresses differences in sampling methodologies between historic and current surveys (e.g., differences in seine versus electrofishing efficiencies) (Patton 1997, Patton et al. 1998). Presence-absence data were used by subtracting the number of sites from which the species was collected recently from the number of sites from which it had been collected in past surveys (Patton 1997, Patton et al. 1998). Species trends were evaluated in this manner at four different spatial scales (sites, streams, sub drainages, and drainages) using raw data and data adjusted for differences in gear efficiency between the survey periods (Patton 1997, Patton et al. 1998). A species was considered to have declined if it had declined in at least two of the four spatial scales, and there was no indication of increase at any of the spatial scales (Patton 1997, Patton et al. 1998).

Isaak et al. (2003) made recommendations for monitoring mountain sucker populations in the Black Hills, recommendations that could be considered for applicability across the region . The recommended monitoring protocol included sampling of several index reaches on a wide range of streams in the area every two to three years (Isaak et al. 2003). Annual sampling of index reaches was not considered necessary for Black Hills mountain sucker populations because they appeared stable, but annual sampling may be more appropriate in other areas. To maximize the utility of existing datasets, the authors also recommended establishing index reaches where surveys had previously been conducted by state agencies in a manner consistent with the plans for future monitoring (Isaak et al. 2003). If such a monitoring program is implemented, then including supplemental sampling of many random reaches, in addition to the index reaches, would allow conclusions regarding abundance trends to be applied to the population, rather than be restricted to only the index reaches.

In general, if population monitoring programs are implemented in Region 2 for mountain sucker, consideration should be given to selecting populations that have been previously surveyed in order to build on existing data sets. Finally, cooperation among agencies in an effort to compile and evaluate existing data, particularly on distribution and abundance, would provide much needed information and a better understanding of the species' status in Region 2, and benefit management efforts.

Population and habitat management

We did not find in the literature any population management activities directed specifically towards mountain sucker. The only regulatory mechanism that could be easily applied to manage mountain sucker populations would be to restrict their collection as baitfish in locations where there is concern that populations may be declining or where populations are isolated. When fisheries management projects require piscicide application in systems with mountain sucker, salvaging efforts should include mountain sucker where populations will be vulnerable to the piscicide. Where stream sections above a fish movement barrier are treated with piscicides, failure to reintroduce mountain sucker above the barrier could result in population fragmentation or extirpation. Other methods, such as electrofishing, should be considered as alternatives to accomplish targeted species removal objectives. The potential effects of cold water fisheries and stream management activities on mountain sucker populations should be considered and practices that could be beneficial to mountain sucker populations in specific locations should be identified and applied.

Recommendations for mountain sucker habitat management are constrained by the lack of information regarding their habitat use, especially in Region 2. Directed research into mountain sucker habitat use in Region 2 would be useful in developing habitat monitoring programs. The Black Hills National Forest monitoring program for mountain sucker includes stream habitat (using the Integrated Resource Inventory (IRI) Common Water Unit Inventory methodology), watershed, and riparian condition monitoring (Black Hills National Forest 2005 Monitoring Implementation Guide), information that could contribute to a better understanding of mountain sucker habitat use and requirements in Region 2. The Black Hills National Forest monitoring plan also includes establishing baseline information on stream habitat connectivity by documenting existing fish passage barriers using aerial photos, GIS data, and ground surveys and monitoring trends via the addition or removal of fish passage barriers.

Mountain sucker habitat management is not a defined priority in the majority of its range, but because the species is often part of cold-water fish assemblages throughout their range, mountain sucker will likely benefit from salmonid habitat management programs, particularly those that focus on maintaining stream habitat heterogeneity, connectivity, and water quality. Loss, degradation, or fragmentation of mountain sucker habitat should be prevented or mitigated to the extent possible.

Information Needs

There is little information available on the mountain sucker throughout its range and even less for populations found in Region 2. As often noted in this assessment, absence of information for mountain sucker limits the ability to understand how changes in habitat, environmental conditions, and management may affect populations and their long-term persistence.

Distribution information for mountain sucker on Region 2 lands is a primary information need. Mountain sucker are thought to occur on several Region 2 national forests, but recent information on local occurrence is lacking in many areas. Because of the paucity of data, changes in distribution patterns, such as local extirpations or range contractions, are nearly impossible to identify in much of Region 2. Monitoring programs for populations throughout Region 2 are needed to provide basic abundance data needed to identify population trends. The current inadequacy of distribution and population information for mountain sucker in Region 2 may result in management opportunities being missed.

It is worthy of note that South Dakota Game Fish and Park personnel have collected density estimates for mountain sucker at 59 sites over several years, and these estimates were used in the analyses by Isaak et al. (2003). Similar data sets may be available for mountain sucker from other state and federal agencies and should be compiled and analyzed. Comparisons of historic presence-absence data to data from recent sampling, using the method described by Patton (1997), could provide clues to changes in mountain sucker distributions and populations trends in Region 2 and suggest locations for further investigation.

While the biology and ecology of the mountain sucker has not been well-researched, a few directed investigations could fill important information gaps. Information on mountain sucker habitat requirements and movement patterns would provide much needed information for planning activities that may impact streams and fish habitat. Knowledge of mountain sucker habitat use in Region 2 is almost completely lacking. Information on the habitat use of larvae and juveniles is especially needed. Because mountain sucker females are not reproductively mature until age-3 to age-5, the availability of adequate larval and juvenile habitat may be a critical aspect of population persistence. In the case of reservoir dwelling populations of mountain sucker, research of habitat use within reservoirs and associated tributary streams (where spawning and possibly rearing habitats are located) is needed. A better understanding of habitat use and movement patterns of mountain sucker that utilize reservoirs may also yield insights on why some impoundments have more adverse impacts than others and explain the population declines associated with some stream impoundments. Research regarding mountain sucker habitat use and movement patterns at different life stages (including egg and larvae drift as well as adult movements) would provide a wealth of information needed to better understand everything from distribution patterns, habitat requirements, and population dynamics to the implications of movement barriers, habitat degradation or loss, and population fragmentation and isolation.

A better understanding of mountain sucker habitat use and movement patterns would also allow for the assessment of the potential effects of different land and water management activities on populations. The effects of land and water management practices that alter flow regimes, discharge, or habitat, or have other impacts on water quality (e.g., stream temperatures, suspended sediment, contaminants) have not been investigated for mountain sucker. Examining mountain sucker local distribution patterns in the context of its habitat requirements and movement patterns would yield insights into the effects management activities. For example, identifying fish passage barriers, stream segments that become seasonally dry, or areas of metals contaminated stream sediments could yield insights into local distribution and abundance patterns or extirpations.

Better information for basic demographic characteristics (e.g., mortality rates, fecundity and age or size relationships, and the sex ratio) is also needed. For instance, two studies have reported fecundity information, but sample sizes were relatively small and both studies were conducted several decades ago for populations outside of Region 2. Similarly, the sex ratio of mountain sucker populations is essentially unknown. Age-specific mortality rates and an understanding of how density-dependent and density-independent factors regulate population size are needed to understand population dynamics and the effects of environmental variation and anthropogenic activities on populations.

Information on spawning timing and water temperatures, and the corresponding variations along latitudinal and elevational gradients, is needed for the species across its range and especially in Region 2. Knowledge of spawning timing would fill a basic information gap for the species, but it would also provide useful information for managers. For example, flow regulation that considered mountain sucker spawning and incubation periods could benefit mountain sucker populations located downstream. Spawning timing information coupled with knowledge of the overlap between mountain sucker and other suckers species at smaller scales (i.e., at the stream segment rather than basin scale) would be useful in determining the potential threat of introgressive hybridization. Currently there is little information on how reproductive isolation among mountain sucker and other species of sucker is maintained where they occur together, but differences in spawning timing among species may be a mechanism.

The community ecology of the mountain sucker is poorly understood, and an improved understanding of interactions with other species would provide important insights into differences among populations. Research is needed to fill information gaps regarding mountain sucker competition with other species for food and habitat resources. Similarly, the impact of predation by piscivorous fish on mountain sucker populations, and whether native and non-native fish predators have different impacts, have not been studied. Given the wide distribution of trout throughout Region 2, knowledge of the effects of trout and trout fisheries management on mountain sucker is badly needed. Information on the interactions of mountain sucker with other species coupled with information on community composition may help to explain differences in population size or stability among locations.

Genetic investigation of the mountain sucker is long over-due, especially given the apparent threat of introgressive hybridization on persistence of some populations. Genetic investigations could also provide insight into geographic isolation of regional populations and whether the designation of distinct taxa or sub-species is merited, as well as provide important information regarding the degree of isolation among local populations.

The numerous information needs related to mountain sucker reflect the lack of research attention the species has received. The collection and analysis of information relating to the distribution, abundance, life-history characteristics, and ecology of mountain sucker could be accomplished in Region 2 through a combination of long-term monitoring programs and short-term studies. Efforts should be focused on updating information on the local distribution of mountain sucker on Region 2 lands, followed by establishing population monitoring programs. Distribution and population surveys could be designed to collect additional information, such as habitat associations, community composition, population age structure, and samples for genetic analyses. Directed research is needed to address some information gaps, but many of these gaps could be addressed by small studies in relatively short time frames, such as determining spawning timing, measuring the extent of egg and larval drift, or identifying passage barriers. Finally, all data collected (or records compiled) in efforts to address these information needs should be documented appropriately, archived and shared through publications or by providing state Natural Heritage Programs with data and records so that information is available and accessible to future users.

DEFINITIONS

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

Environmental fluctuations – changes in habitat conditions such as temperature, salinity, oxygen concentration, or the amount of water flowing in a stream.

Extirpated – the situation in which a species no longer exists in a particular location where it previously existed.

Fecundity – the number of ova produced by a female fish.

Habitat connectivity – the degree to which organisms can move throughout the area or system of interest.

Hybridization – the cross between individuals of different species and the production of hybrid offspring.

Introgressive hybridization – the infiltration of the genes of one species into the gene pool of another species through repeated backcrossing of an interspecific hybrid with one of its parents.

Lentic – standing or slow-flowing water habitats, such as lakes, ponds, or reservoirs.

Lotic – running water habitats, such as streams and rivers.

Malentities – factors that can harm or kill the species; other organisms can be malentities if they harm or kill the species of interest, but unlike predators, malentities do not benefit from harming or killing the species of interest.

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; frequently used to identify fish species using a taxonomic key.

Metapopulations – spatially isolated populations that function as independent populations but that can exchange occasional individuals; this exchange allows genetic exchange and the repopulation of extirpated populations or rescue of depressed populations.

Microhabitat – the specific combination of habitat elements in the place occupied by a fish for a specific use such as feeding, spawning, or resting.

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); used to identify fish species using a taxonomic key.

Papillae – small, round, cone-shaped, or finger-like protuberances or projections.

Pelvic axillary process – a small flap found at the base of a pelvic fin.

Peritoneum – the membrane lining the body cavity.

Piscivorous – "fish-eating".

Phylogenetic – relates to evolutionary descent.

Piscicide – any compound, natural or synthetic, that kills fish when applied to water.

Relative abundance – the term is used here to describe the numerical abundance of a fish stock relative to some measure of effort used to collect the sample (i.e., catch per unit effort, with effort measured in terms of gear deployed, sampling duration, sampled area, or some combination of the three); used in this context to differentiate from estimates of absolute abundance and not meant to imply the proportional numerical abundance of a species within a collection of species.

Shoals – any group of fishes that remains together for social reasons; a more general term than the term "school," which refers to one of several particular types of shoaling patterns.

Sink populations – populations in which the death rate exceeds the birth rate; require continual immigration from nearby populations if they are to avoid extinction.

Source populations – populations in which the birth rate exceeds the death rate; a source of emigrants to nearby areas and can provide immigrants to 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.

Tubercles – small, rounded, wart-like outgrowths or lumps; breeding tubercles refer to the bumps seen on the skin of breeding fishes.

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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