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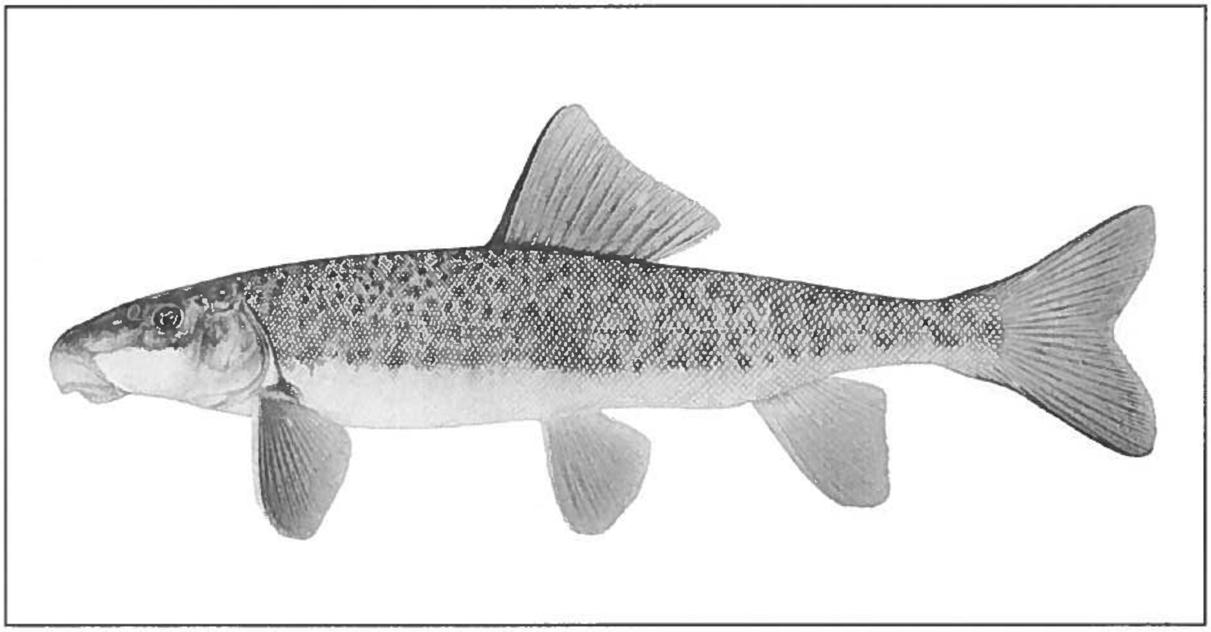
Flannelmouth Sucker (*Catostomus latipinnis*): A Technical Conservation Assessment



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

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David E. Rees, Jonathan A. Ptacek, Ryan J. Carr, and William J. Miller
Miller Ecological Consultants, Inc.
1113 Stoney Hill Drive, Suite A
Fort Collins, Colorado 80525-1275

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AUTHORS' BIOGRAPHIES

David E. Rees studied fishery biology, aquatic ecology, and ecotoxicology at Colorado State University where he received his B.S and then his M.S. in 1994. His specific areas of specialization include aquatic insect identification and ecology, and native fish movement and habitat use. He has been involved with and supervised extensive projects involving electrofishing and population studies on the native and nonnative fish in tributaries of the Colorado River drainage, and other various locations. He has supervised habitat use studies using radio telemetry to monitor Colorado pikeminnow and other native and nonnative fish in the Yampa River, San Juan River, and Colorado River. He has worked on projects in Colorado, Utah, New Mexico, Nevada, Arizona, Wyoming, Montana, and Puerto Rico. David is currently conducting research on the relationship between physical and ecological processes in the Colorado River, and the implications of these interactions on native fish species.

Jonathan A. Ptacek received his B.S. in Fishery Biology from Colorado State University in 1997. He has worked for Miller Ecological Consultants, Inc. since 1993. His work experience has focused primarily on native fish issues throughout the western United States. Currently, he is part of a team developing a mechanistic population model describing the aquatic environment of the San Juan River in Colorado, New Mexico, and Utah.

Ryan J. Carr received a B.S. in Zoology with a concentration in Entomology in 2001. He is currently a candidate for a Master of Science degree in Entomology with a concentration in Systematics. The focus of his studies has been Genetics, Evolutionary Biology and Systematics of Invertebrates. He also has experience working with Native and Nonnative fish populations in Arizona and Colorado. Current research focus includes the evolution, systematics, and biogeography of Diptera. Much of his work has focused on using invertebrates to monitor and model aquatic ecosystems.

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

COVER PHOTO CREDIT

Flannelmouth sucker (*Catostomus latipinnis*). © Joseph Tomelleri.

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SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF THE FLANNELMOUTH SUCKER

Status

The flannelmouth sucker (*Catostomus latipinnis*) is considered a sensitive species in USDA Forest Service (USFS), Rocky Mountain Region (Region 2). Flannelmouth sucker are endemic to the Colorado River Basin. Within Region 2, there are populations in western Colorado and south-central Wyoming, but few of these populations are located on USFS lands.

Primary Threats

The primary threats to the flannelmouth sucker are generally human-induced activities that divert water and change the flow regime in both tributary and mainstem streams. Specific threats include (a) construction of passage barriers (e.g., diversion dams and reservoirs) that disconnect habitats and cause habitat fragmentation and (b) introduction of non-native species that are both predators on and competitors with the flannelmouth sucker. Other threats include modification of streambeds through channelization, landscape changes resulting from land use, and local degradation of riparian zones that reduces the natural function of the stream ecosystem. Detailed information concerning the distribution, life history, population trends, and community ecology for this species is relatively limited. Specific local and regional information must be obtained prior to the development of management actions. Currently, management implications can be based only on the limited information regarding this species, which typically originates from outside the National Forest System.

Primary Conservation Elements, Management Implications and Considerations

The general lack of information for this species suggests that management should begin with a detailed survey of each drainage on USFS land that could potentially hold populations of flannelmouth sucker. This effort should be coordinated with relevant agencies (i.e., state game and fish departments, Bureau of Land Management, U.S. Fish and Wildlife Service) to obtain information concerning stream reaches that are off National Forest System land, yet may be influenced by USFS management activities. Flannelmouth sucker, like other endemic species in the Colorado River Basin, have not been well-studied until recent years. Those studies currently being undertaken are in conjunction with recovery efforts for the listed endangered fish in the Colorado River Basin. The information for other native nongame species, like the flannelmouth sucker, is only incidental to those primary studies. The USFS could use this information on habitats and populations to coordinate management activities on National Forest System lands in Region 2. Given the known threats to this species, conservation measures should concentrate on maintaining aquatic habitat diversity and natural temperature and flow regimes in stream reaches with existing and adjacent flannelmouth sucker populations.

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the USDA Forest Service (USFS), Rocky Mountain Region (Region 2), which encompasses the national forests and grasslands in Wyoming, Colorado, Kansas, Nebraska, and South Dakota (**Figure 1**). The flannelmouth sucker is the focus of this assessment because it is a sensitive species in Region 2. Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of substantial current or predicted downward trends in abundance and/or habitat capability that would reduce its distribution (FSM 2670.5 (19)). A sensitive species requires special management, so knowledge of its biology and ecology is critical. This assessment addresses the biology and ecology of flannelmouth sucker throughout its range in Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. Rather, it provides the ecological background upon which management must be based and focuses on the consequences of environmental changes that result from management (i.e., management implications). Furthermore, this assessment cites management recommendations proposed elsewhere and examines the success of those recommendations that have been implemented.

Scope

This assessment examines the biology, ecology, conservation status, and management of the flannelmouth sucker with focus on the geography and ecology of USFS Region 2. Although some of the literature on the species originates from field investigations outside the region, this document places that literature in the ecological and social context of the central Rocky Mountains. This assessment is concerned with reproductive behavior, population dynamics, and other characteristics of flannelmouth sucker in the context of the current environment rather than under historical conditions 200, 2000, or 2 million years ago. The evolutionary environment of the species is considered in conducting the synthesis, but placed in a current context.

In producing the assessment, we reviewed refereed literature and non-refereed publications, research reports, and data accumulated by resource management agencies. Not all publications on flannelmouth sucker are referenced in the assessment, nor were all published materials considered equally reliable. The assessment emphasizes refereed literature because this is the accepted standard in science. However, when information was unavailable elsewhere, we chose to use grey literature, but this was regarded with greater skepticism than refereed literature. Unpublished data (e.g., Natural Heritage Program records) were important in estimating the geographic distribution of this species, but these data required special attention because of the diversity of persons and methods used in collection.

Treatment of Uncertainty

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

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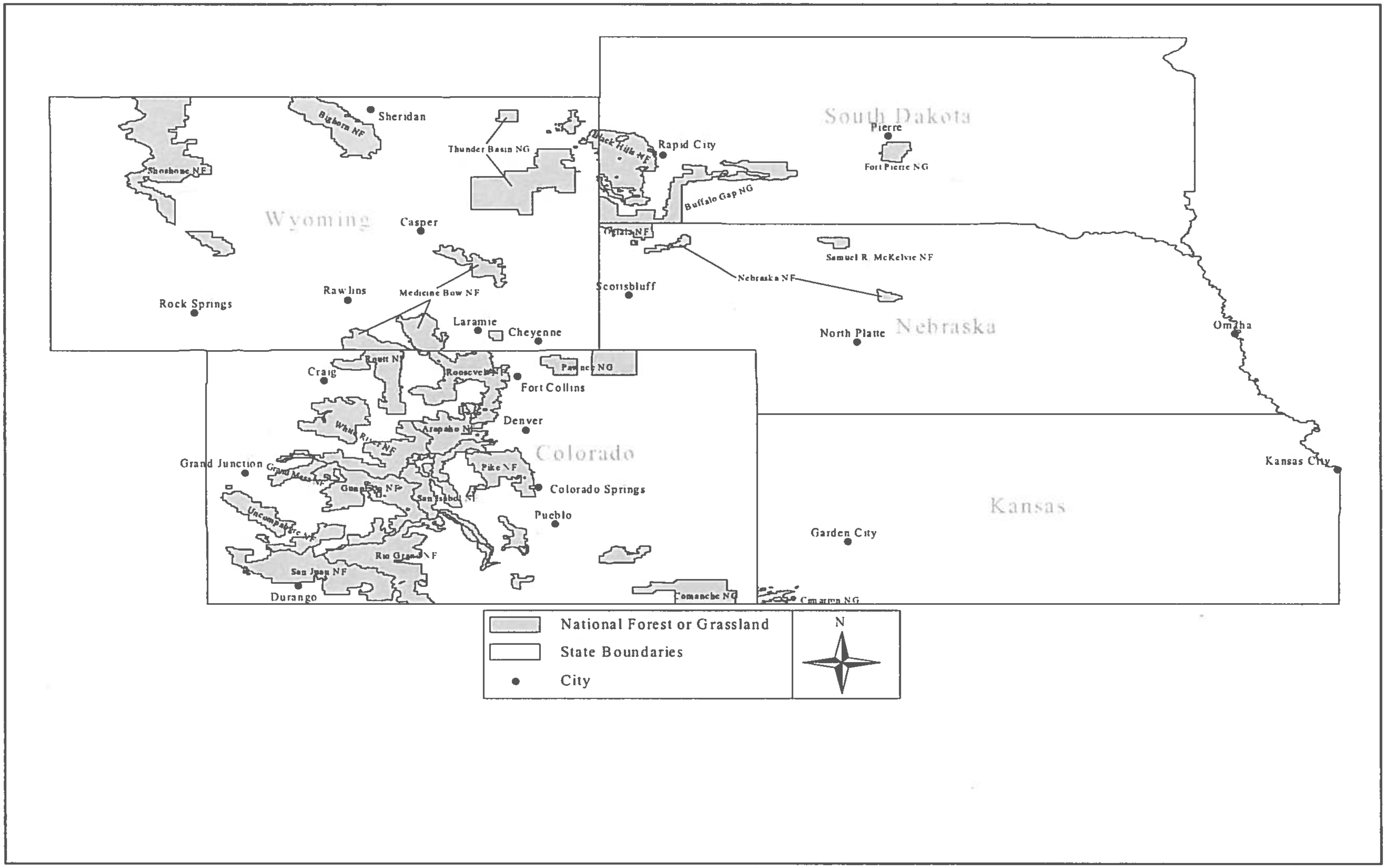

Figure 1. USDA Forest Service Region 2 national forests and grasslands.

necessitates that a wide variety of hypotheses or experiments be undertaken to test both the true or false nature of the uncertainties at hand (Vadas 1994).

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

The synthesis of material for the flannelmouth sucker included the use of the limited data sets that are available for distribution, abundance, movements, habitat requirements, and life history requisites of the species. This species, like many non-game native fish, has not been extensively studied within Region 2. Furthermore, it has not been extensively studied for all the parameters needed for this assessment. The limited data on key characteristics for the species and the lack of understanding concerning its resource needs create a great deal of uncertainty pertaining to the assessment for conservation of flannelmouth sucker. This species assessment has synthesized a wide range of available data throughout the Colorado River basin, including historical and current distribution, conservation strategies, habitat needs, and management requirements. The general lack of precise information regarding species distribution on or near National Forest System land limits the actual data that can be used for this assessment. We have inferred from available data, using a sound scientific approach, to present an understanding of the current needs of the species for the purpose of this assessment.

Application and Interpretation Limits of This Assessment

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

Publication of Assessment on the World Wide Web

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

Peer Review

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

Management Status and Natural History

Management Status

The flannelmouth sucker is not listed by Federal statute as threatened or endangered, but it has been given special status with other agencies. The flannelmouth sucker currently has Natural Heritage Program rank of G3G4 (globally vulnerable but apparently secure) and a state rank of S3 (vulnerable) in Colorado and Wyoming. In both of these states the Bureau of Land Management (BLM) considers the flannelmouth sucker a sensitive species. The Colorado Division of Wildlife (CDOW) additionally considers the flannelmouth sucker a species of concern, and Wyoming Fish and Game Department (WGFD) has assigned this species a state rank of NSS1, suggesting that its presence is extremely isolated and habitats are declining or vulnerable. This species does not occur in other states in Region 2 (Kansas, Nebraska or South Dakota).

In the remainder of its range, the BLM considers this species to be sensitive. In Arizona, the flannelmouth sucker has a state rank of S2 (rare). Utah considers flannelmouth sucker a species of concern due to declining populations. New Mexico gives this species no special status.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

The CDOW has no regulations specifically designed to protect flannelmouth sucker. However, several regulations are intended to protect native fish species and thus aid in the conservation of flannelmouth sucker. Restrictions regarding the live release of non-native fish species into rivers and lakes within the Upper Colorado River Basin are in place in Colorado. Another regulation indirectly assisting the conservation of flannelmouth sucker is Colorado's statute prohibiting the seining, netting, trapping, or dipping of fish for bait in natural streams. Flannelmouth sucker is largely unknown except to biologists (Bezzerides and Bestgen 2002).

The WGFD has regulations regarding flannelmouth sucker habitat loss. This agency's objective is to permit projects in a manner that avoids alteration and degradation of functioning flannelmouth sucker habitat (Weitzel 2002).

Ongoing recovery programs for federally listed fish (e.g., Colorado pikeminnow [*Ptychocheilus lucius*], razorback sucker [*Xyrauchen texanus*]) in the Upper Colorado River and San Juan River drainages should provide benefits for all native fish species. Recovery actions include flow recommendations to mimic a natural hydrograph and restriction on and recommendations of non-native fish stocking within the basins. Few, if any, anglers specifically target flannelmouth suckers, but incidental take probably does occur as fisherman attempt to catch gamefish species.

At this time, there are no existing management strategies that are specific to the flannelmouth sucker. Several states, including Colorado and Wyoming, are developing a "Range-wide conservation agreement and strategy" to direct management for this species. By 2005, the CDOW intends to develop a "Conservation/ management plan" for flannelmouth sucker. This plan will provide direction and goals for research and management projects. The range-wide conservation agreement and strategy has not currently been developed to a point where issues associated with this species have been identified. The success of management strategies and regulatory mechanisms will depend upon compliance by the public and the enforcement of management concerns, especially with habitat degradation and influence of non-native species interactions within the native range of the flannelmouth sucker.

Biology and Ecology

Systematics and general species description

The flannelmouth sucker belongs to the Family Catostomidae, the members of which are characterized by soft rays and a fleshy, subterminal protractile mouth. This family is comprised of 12 genera and 60 species in the United States and Canada (Robins et al. 1991). The flannelmouth sucker was described in 1853 by Baird and Girard from specimens taken from the San Pedro River in Arizona.

The following description follows that of Bezzerides and Bestgen (2002): "body streamlined; medium sized head; tapering body; narrow caudal peduncle; prominent snout; ventral mouth; large, well-developed lips, lower lip usually with one row papillae and deeply incised to jaw; upper lip with 5-8 rows of papillae; eyes small and high on head; fins large; pectoral fins (rays 16[14-18]) blunt tipped; origin of dorsal fin (rays 11- 13[10-14]) nearer snout than caudal peduncle and anterior to insertion of pelvic fins (rays 18[18-19]); trailing edge of dorsal fin concave; anal fin rays 7[7-8]; caudal fin deeply forked (rays 18[18-19]); fine scales (lateral line 90-116); vertebrae 44-50; pharyngeal teeth 36-37; adult coloration greenish brown to bluish gray dorsally to dorso-laterally, deep yellow to orange-red ventro-laterally, pale white ventrally, head may be pinkish ventrally; males in breeding season with tubercules from anal fin to lower lobe of caudal fin, females with tubercules only on ventral side of caudal peduncle."

Flannelmouth suckers are a large catostomid species with maximum total lengths upwards of 650 mm (25.6 inches). Average size of mature adult flannelmouth suckers is approximately 500 mm (19.7 inches). The relationship of length to weight during growth and development can be described by the following equation: log(weight gm) = 3.09((log total length) – 5.21) $R2=0.99$ (McAda 1977). Flannelmouth suckers are a long-lived species with a maximum life span of about 30 years (Scoppettone 1988, Minckley 1991, Weiss 1993).

The flannelmouth sucker can be distinguished from the native bluehead sucker (*Catostomus discobolus*) by the absence of a cartilaginous ridge on the upper lip. It can be distinguished from the introduced white sucker (*C. commersoni*) by finer scales along the lateral line that number 90 or more.

These are the only two species of *Catostomus* that occur sympatrically with flannelmouth sucker in Region 2. For a key to positively identify flannelmouth sucker, see Eddy and Underhill (1969). No analysis has been done to elucidate the phylogenetic relationships of species in the genus *Catostomus*.

Distribution and abundance

Historically, the flannelmouth sucker was commonly found in most, if not all, medium to large, lower elevation rivers of the Upper Colorado River drainage (upstream of Glen Canyon Dam). It was found in similar habitats of the Lower Colorado River drainage (downstream of Glen Canyon Dam), but in lesser numbers (Joseph et al. 1977). Although this species is typically associated with large rivers, it also occurs in smaller tributaries and occasionally in lakes and reservoirs (Bezzerides and Bestgen 2002).

The flannelmouth sucker is still widely distributed in medium to large streams in the Upper Colorado River Basin, which includes the mainstem of the Colorado River, numerous tributaries that drain a large portion of Colorado, Wyoming, and Utah, and the San Juan River drainage in New Mexico (**Figure 2**; Holden and Stalnaker 1975). However, in many areas of the upper basin populations are thought to be decreasing (Sigler and Sigler 1996). While the flannelmouth sucker is still found in most of its historical range in Colorado and Wyoming, it is less abundant and absent from its historical range in Nevada, Utah, Arizona, and California. Its distribution in the Lower Colorado River Basin is restricted to localized areas of suitable habitat (Sublette et al. 1990). It is believed that populations have become more restricted in the lower basin due to the severe impacts of dams and diversions on flow regimes, habitat availability, and habitat quality. In California this species is considered extirpated due to these impacts.

Within Region 2, flannelmouth sucker are currently present in streams and rivers of the Upper Colorado River drainage that are not heavily impacted by impoundments or other habitat degradation. Flannelmouth suckers have been reported from the San Juan River and the following tributaries that occur in the southern portion of Colorado: Animas, Florida, La Plata, Los Piños, Mancos, Navajo, and Piedra rivers, as well as McElmo Creek (Miller et al. 1995, Miller and Rees 2000, Whiteman 2000). Some of these tributaries are on San Juan National Forest lands. Flannelmouth sucker are also present in the Colorado River and numerous tributaries including the Gunnison River up to the Aspinall Unit reservoirs (Bezzerides and Bestgen 2002). Flannelmouth sucker are also present in the Yampa and White rivers in Colorado (Prewitt et al. 1976, Prewitt et al. 1978). They are considered common in the White River above and below Kenney Reservoir (Chart and Bergersen 1992). Flannelmouth suckers occur in the Uncompagre River and have been found in associated irrigation canals (Sigler and Miller 1963).

Flannelmouth suckers in Wyoming are known from the Green River and associated tributaries as well as streams within the Little Snake River drainage (Weitzel 2002). The only portion of this range that occurs in Region 2 in Wyoming is the Little Snake River drainage. Populations are present in the Little Snake River and the following tributaries: Muddy, Littlefield, and Savery creeks (Oberholtzer 1987). Flannelmouth suckers do not occur in the remaining Region 2 states (Kansas, Nebraska, or South Dakota).

Population trend

Flannelmouth sucker populations have declined in abundance and distribution throughout their historic range (Bezzerides and Bestgen 2002, Weitzel 2002). Most of the decline in the Lower Colorado River Basin has been attributed to flow manipulation and water development projects (Minckley 1973); however, Cross (1985) cited habitat loss, negative interaction with invasive species, and chemical pollution as the main reasons for the decline of flannelmouth sucker in the Virgin River in Arizona, Nevada, and Utah.

During the 1960s, two massive reductions occurred in large-river populations of flannelmouth sucker. In 1961, the San Juan River was poisoned with rotenone to eliminate non-game species from approximately 112 km (69.6 miles) of the river (Olson 1962). In 1962, 716 km (444.9 miles) of the Green River and many of its tributaries from the Colorado-Utah state line were poisoned in an attempt to eliminate "coarse" fish prior to the construction of Flaming Gorge and Fontenell dams (Binns 1967). Pre-treatment surveys indicated that flannelmouth suckers were abundant in the treatment areas; however, populations were completely eliminated following the treatments (Olsen 1962, Binns 1967). Flannelmouth suckers recolonized both rivers within a short time, but it is unknown what impact each of these events had on this species.

Dam construction and the associated alterations of the thermal and hydrological regimes have reduced flannelmouth sucker populations in both the Lower and Upper Colorado River Basins (Vanicek et al. 1970,

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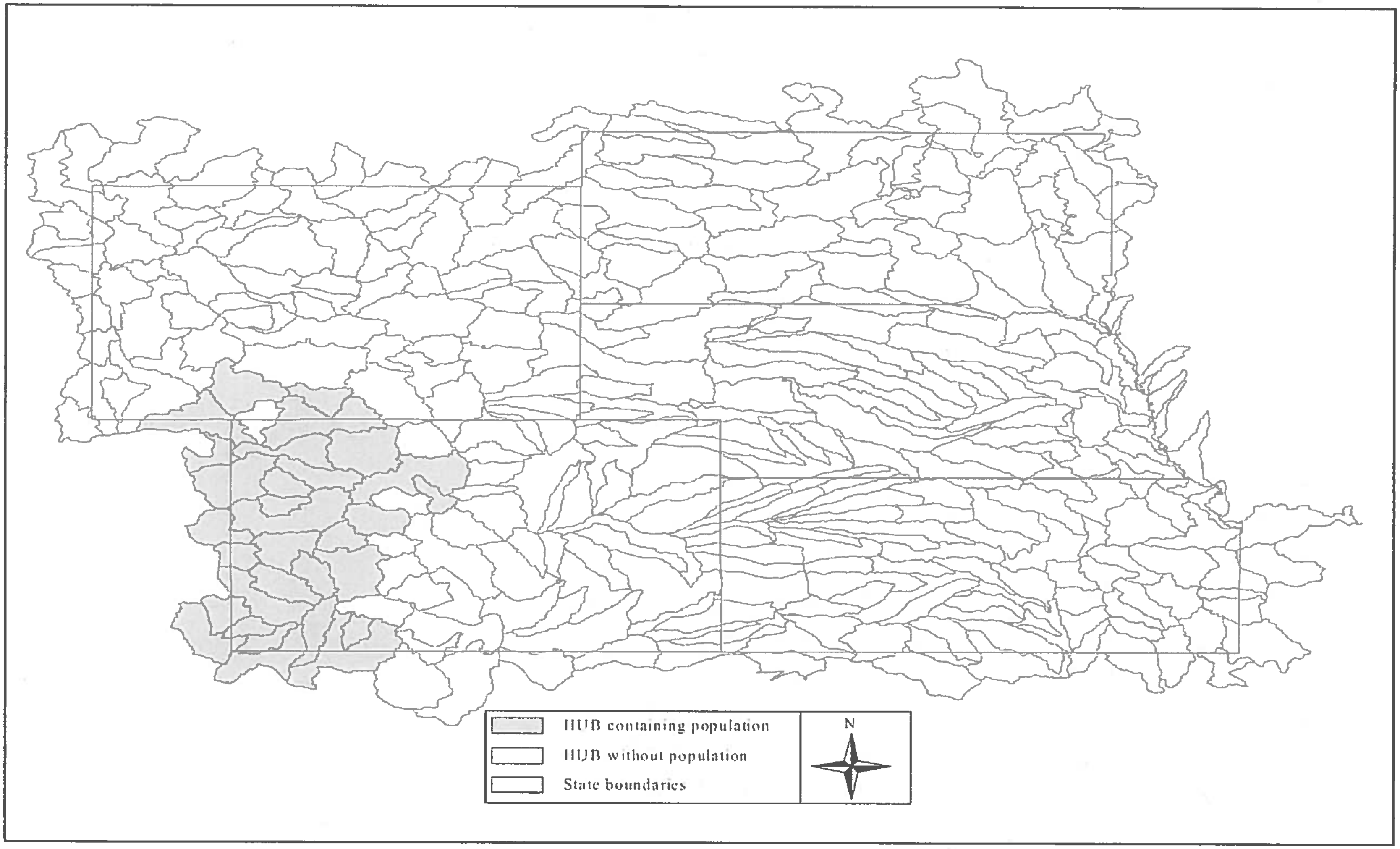

Figure 2. USDA Forest Service Region 2 hydrological unit boundaries (HUB) containing flannelmouth sucker populations.

Minckley 1991, Chart and Bergersen 1992, Robinson et al. 1998). Hypolimnetic releases below impoundments alter the thermal regime in the river downstream. The modified thermal regime is usually colder in the summer and warmer in the winter than historic conditions.

A variety of research has attempted to link the importance of flow regime to habitat requirements and survival of larval or young flannelmouth sucker (Haines and Tyus 1990, Weiss 1993, Robinson et al. 1998, Thieme et al. 2001). Weiss (1993) suggests that the altered hydrology of the Colorado River below Glen Canyon Dam may negatively impact young-of-the-year flannelmouth sucker. The poor representation of several year classes corresponded to the lack of turbid, flooded habitat in spring and early summer. Clarkson and Childs (2000) showed that lowered summer temperatures caused by hypolimnetic dam releases are responsible for slow growth, delayed transition to the juvenile stage, and possibly high larval mortality.

Flannelmouth suckers in the White River in Colorado were found to actively avoid newly created reservoir habitat and move upstream into the river (Chart and Bergersen 1992). Upon closure of the dam, adult fish moved upstream out of the reservoir and also avoided the area immediately below the dam. Vanicek et al. (1970) found that the resulting change in temperature and flow regime created by Flaming Gorge Dam displaced flannelmouth suckers to warmer locations during summer and reduced spawning success for more than 97 km (60.3 miles) downstream. However, some adults did tolerate the cold release regime at a location approximately 11 km (6.8 miles) downstream of Flaming Gorge Dam. Juvenile flannelmouth were collected 27 km (16.8 miles) downstream of the dam.

Activity pattern

Several researchers have reported on the movements of flannelmouth sucker and have found that most movement is associated with certain life stages (Bezzerides and Bestgen 2002). Flannelmouth sucker eggs are demersal and adhesive. After fertilization, they adhere to the substrate surface and hatch within several days of fertilization. After hatching, flannelmouth sucker larvae undergo a period where they drift with the current. Carter et al. (1986) and Robinson et al. (1998) suggest that larvae have the ability to actively enter and escape the drift. The drift mechanism likely accomplishes two separate objectives: population dispersal and location of suitable larval habitat.

Long distance movement has been detected in several flannelmouth sucker populations. However, portions of those populations were also classified as sedentary, remaining within the same general reach. Weiss (1993) reported flannelmouth sucker movement of over 200 km (124.3 miles) in the Colorado River and tributaries through the Grand Canyon. Chart and Bergersen (1992) detected highly mobile behavior in a portion of the flannelmouth sucker population in the White River in Colorado; however, a portion of this population was also classified as sedentary. In the Lee's Ferry section of the Colorado River, a portion of the flannelmouth sucker population was shown to be sedentary while other individuals were mobile, having a mean distance moved of 52 km (32.3 miles) and maximum of 231 km (143.5 miles) (McKinney et al. 1999). No correlation was observed between migration behavior in these fish and physical factors such as water chemistry, season, and flow regime. Both studies (Chart and Bergersen 1992, McKinney et al. 1999) were conducted over several years and therefore several spawning seasons. It is unclear if any of the documented movement was related to spawning migrations or as a mechanism of dispersal. Studies conducted from August through October on the Colorado River near Grand Junction, Colorado did not find substantial movement (maximum <3.2 km [2 miles]) of radio-tracked flannelmouth suckers (Beyers et al. 2001, Rees and Miller 2001). The consistency of migratory behavior and life stage relationships has not been studied.

Researchers have documented both diel and seasonal movement. Rees and Miller (2001) found that active movement and movement between major habitat types (e.g., riffle, pool, run) are most common at night. Chart and Bergersen (1992) suggest that long-distance seasonal migration for the flannelmouth sucker might be essential to the life history of this species. Bezzerides and Bestgen (2002) suggest that the occasional long-distance migration may be essential for maintenance of relatively isolated populations that occur in smaller tributaries at higher elevations. Further, upstream movement of juveniles and adults would be required to offset downstream drift of larvae.

Habitat

Flannelmouth suckers are typically found in slower, warmer rivers in plateau regions of the Colorado River drainage (Deacon and Mize 1997). They usually inhabit the mainstem of moderate to large rivers but are occasionally found in small streams. This species frequents pools and deep runs but can also be found in the mouths of tributaries, riffles, and backwaters. Flannelmouth suckers are occasionally found in lakes and reservoirs, but they generally react poorly to impounded habitats, or habitats influenced by impoundments (Minckley 1973, Chart and Bergersen 1992). Habitat association can be attributed to feeding strategies during specific life stages. Larval and young-of-the-year flannelmouth suckers are often associated with backwaters and shoreline areas of slow runs or pools (Holden and Stalnaker 1975, Joseph et al. 1977, Haines and Tyus 1990, Robinson et al. 1998). Larvae drift 8.6 km (5.3 miles) on average after hatching; during this time, they actively seek near-shore habitat (Robinson et al. 1998). Larvae then congregate in shallow pools and backwater areas. Haines and Tyus (1990) did not find a link between larval use and backwater temperature or size.

Juvenile (age 1 to adult) and adult flannelmouth suckers utilize most habitats and can be considered a habitat generalist. Juveniles and adults are most often found using run, pool, and eddy habitats (Joseph et al. 1977, McAda 1977, Tyus et al. 1982). This species appears to prefer temperatures around 25 °C (77 °F) (Sublette et al. 1990). Flannelmouth sucker are rare in cooler headwater streams. There has been no reported shift in habitat preference due to seasonal changes or changes in discharge cycles.

Studies have shown that flannelmouth suckers avoid cooler temperatures in headwater reaches and in the tailwaters of some dams. The effects of other physical parameters (e.g., dissolved oxygen, sediment, channel form) on the distribution and density of flannelmouth sucker have not been studied in detail and are not well understood.

Food habits

Flannelmouth suckers are omnivorous, benthic foragers that use their fleshy, protrusible lips to take in macroinvertebrates, algae, and debris. Like many native species within the Colorado River Basin, flannelmouth suckers demonstrate an ontogenetic shift in diet. Flannelmouth sucker diet shift parallels the previously discussed life stage specific habitat use. Larvae feed primarily on aquatic invertebrates, crustaceans, and organic/inorganic debris (Joseph et al. 1977, Maddux et al. 1987, Childs et al. 1998). Muth and Snyder (1995) found that young-of-the year flannelmouth suckers in backwater habitats feed on diptera larvae, crustaceans, algae, and organic/inorganic debris. As flannelmouth suckers become juvenile and adult fish, their diet shifts and becomes primarily composed of benthic matter including organic debris, algae, and aquatic invertebrates (Joseph et al. 1977, McAda 1977, Carothers and Minckley 1981, Brooks et al. 2000). The research to date reports no shift in food preference due to season, hydrological cycles, or migration, or between juvenile and adult stages.

Competition for food resources may exist between flannelmouth and bluehead suckers. The introduced white sucker may also compete with flannelmouth sucker in the many areas that they have invaded.

Breeding biology

Flannelmouth sucker typically spawn in the Upper Colorado River basin between April and June (McAda 1977, McAda and Wydoski 1980, Snyder and Muth 1990, Tyus and Karp 1990). Recently, Douglas and Douglas (2000) reported the occurrence of fall (October) spawning by flannelmouth sucker in Havasu Creek in Arizona. Robinson et al. (1998) reported evidence of year-round spawning by flannelmouth sucker in the Little Colorado River in Colorado.

Juvenile flannelmouth sucker may reach sexual maturity by age 4, but in most areas of the Upper Colorado River Basin, maturity is reached by age 5 or 6 (McAda and Wydoski 1985). By age 8, all individuals are mature (McAda 1977). Mature fish were 421 to 646 mm (16.6 to 25.4 inches) total length in the Colorado River in the Grand Canyon in Arizona (McKinney et al. 1999). Mature females tend to be slightly larger than mature males (McAda 1977).

Otis (1994) reports that spawning occurs at water temperatures ranging from 12 to 15 °C (53.6 °F to 59 °F), and that flannelmouth suckers in the lower Colorado River Basin spawn six to eight weeks earlier than those in the upper basin. McAda (1977) observed spawning in the upper basin at 6 to 12 °C (42.8 to 53.6 °F). In the Paria River in Arizona, Weiss (1993) found that timing of spawning was correlated with the receding limb of the hydrograph.

Flannelmouth spawning aggregations have been observed in tributaries of the Lower Colorado River in glides or slow riffles, over medium-coarse gravel substrate (Weiss 1993, Otis 1994). In the Grand Canyon, flannelmouth suckers were found to spawn in tributary creeks near the confluence with the Colorado River. In the Yampa and Colorado rivers (upper basin), McAda and Wydoski (1985) collected ripe (ready to

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spawn) females from areas with cobble substrate and an average velocity of 1 m per s (3.3 ft per s). Although actual spawning was not observed, it is likely that spawning occurred nearby.

Flannelmouth suckers are non-guarding, lithophilic breeders that leave their eggs on the surface of the substrate (Snyder and Muth 1990). Several fish congregate, closely spaced and in parallel. Eggs and sperm are released simultaneously in the water column, allowing fertilization of eggs while suspended. Once fertilized, the adhesive, demersal eggs sink and either adhere to gravel or fall into crevices (Snyder and Muth 1990, Sigler and Sigler 1996). Eggs typically incubate for six to seven days (Carlson et al. 1979). Fecundity depends on fish size and location. McAda (1977) reported a large difference in the number of eggs per female. Females typically lay from 4,000 to 40,000 eggs each spring, in the Colorado, Gunnison, Green, and Yampa rivers (McAda and Wydoski 1985). Sex ratios (male:female) are typically 2:1 or 3:1 (Weiss 1993, Otis 1994, McKinney et al. 1999).

Demography

Hybridization between flannelmouth suckers and other sucker species is a common occurrence throughout the range of this species. Flannelmouth sucker are known to hybridize with the following species of suckers: mountain (*Catostomus ardens*), bluehead, desert (*C. clarki*), razorback, and the introduced white suckers (Bezzerides and Bestgen 2002). Tyus and Karp (1990) observed flannelmouth sucker spawning on gravel beds near razorback sucker in the Yampa and Green rivers. Douglas and Marsh (1998) found that a small percentage of the fish taken in the Grand Canyon were hybrids of these two species, and most of the specimens were backcrosses to flannelmouth sucker. These fish were difficult to identify and were often repeatedly misidentified in a mark and recapture study (Douglas and Marsh 1998). In natural or minimally altered systems certain undefined mechanisms likely isolate spawning individuals of flannelmouth and bluehead suckers; however, hybrids between these two species do occur (Hubbs and Hubbs 1947, Hubbs and Miller 1953, Whiteman 2000, Authors' unpublished data).

The most common, and perhaps most detrimental, instance of hybridization occurs with the non-native white sucker. Hybrid specimens have been reported in the Animas, Colorado, Green, Gunnison, San Juan, Uncompagre, and Yampa river systems (Holden and Stalnaker 1975, Holden and Crist 1981, Anderson and Stewart 2000, Whiteman 2000, Authors' unpublished data). Wherever flannelmouth suckers and white suckers occur sympatrically, hybridization is likely to occur on some level. No information is available on the population-level genetics of flannelmouth sucker.

Natural flooding has been found to have a substantial influence on recruitment of juvenile flannelmouth suckers. Flooding in the Little Colorado River in Arizona caused a major decline in the larval flannelmouth sucker population in 1992 (Robinson et al. 1998). It is most likely that larvae were washed into the Colorado River where larval survival was probably low due to the cold summer temperature regime imposed by the Glen Canyon Dam (Robinson and Childs 2001). In contrast, pool formation and lack of flash-flooding led to higher larval populations and young-of-the-year (Age 0) recruitment in the Paria River during 1994 and 1996 (Thieme et al. 2001). Historically, ponding occurred in the mouths of tributaries of the Colorado River within the Grand Canyon when summer peak flows coincided with receding hydrographs in the tributaries (Robinson et al. 1998). The elimination of this process by reduction of summer flows might contribute to the loss of young-of-the-year recruitment.

General life history characteristics are reviewed in the Breeding biology section of this document and thus are not repeated here. The development of a meaningful lifecycle diagram for flannelmouth sucker requires life stage-specific data regarding survival rates, fecundity, and sex ratio. Existing data on flannelmouth sucker survival rates and fecundity (components necessary to construct a lifecycle diagram) are sparse and not validated in multiple studies. We include the following lifecycle description as illustration of data needed to refine the model (**Figure 3**).

Input data needed for a population projection matrix model consists of age-specific survival and fecundity rates. Very little data of this nature is available for flannelmouth sucker. We have used data from two studies, McAda (1977) and Douglas and Marsh (1998), to develop separate fecundity and survival rates for this species. The survival rate or fertility rate for specific gender of flannelmouth sucker has not been reported. To provide some information on survival and population dynamics, we have used the general survival rate for both males and females and the average number of eggs per mature female. The existing data presented in McAda (1977) show that the number of eggs per female ranges from approximately 10,000 for first-year maturity at age 5 to nearly 25,000 or higher for females age 8 and older. Age 8 was when all females collected show 100 percent maturity. The annual survival rates shown in **Table 1**

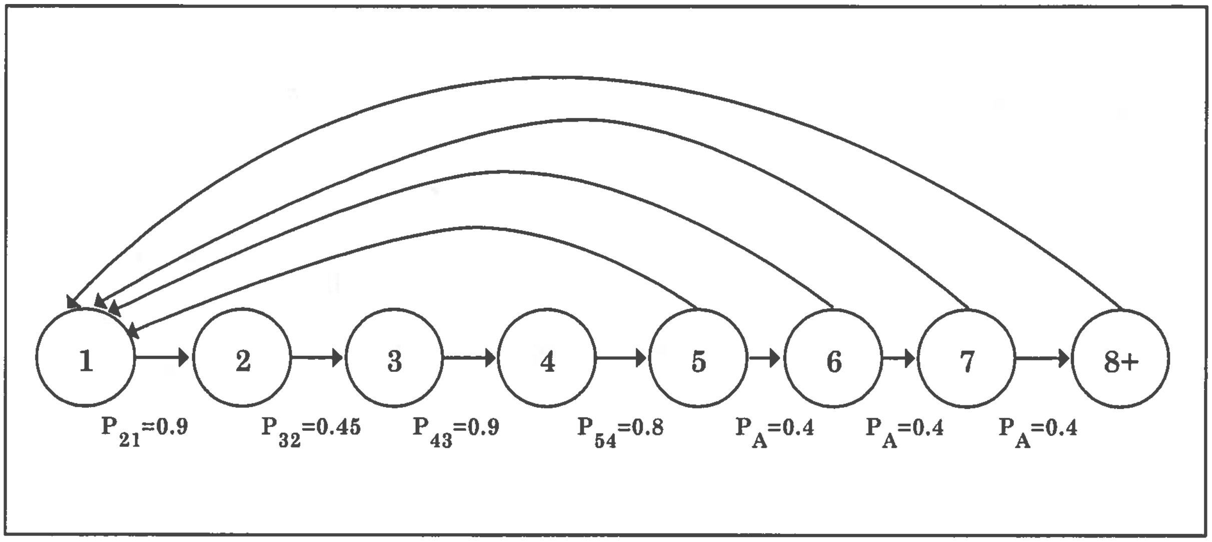

Figure 3. Lifecycle graph for flannelmouth sucker showing both the symbolic and numeric values for the vital rates. The circles denote the 8+ age classes in the life cycle, first year through adult females. Arrows denote survival rates. Survival and fertility rates provide the transition between age classes. Fertilities involve offspring production, mi, number of female eggs per female as well as survival of the female spawners.

Table 1. Parameter values for the component terms (Pi and mi) that make up the vital rates in the projection matrix for flannelmouth sucker. Parameters were estimated from data presented in McAda (1977) and Douglas and Marsh (1998).

Parameter	Numeric Value	Interpretation
P_{21}	0.9	First year survival rate
P_{32}	0.45	Survival from 2^{nd} to 3^{rd} year
P_{43}	0.9	Survival from 3^{rd} to 4^{th} year
P_{54}	0.8	Survival from 4^{th} to 5^{th} year
P_a	0.4	Survival for adults
m_{av}	17806	Average fecundity for mature females

and **Figure 3** provide longevity of the species to age 20 and higher, which has been noted in the literature as near the maximum age for flannelmouth sucker. Population dynamics of flannelmouth sucker likely have variable survival rates, depending on the flow regime and water quality characteristics at the time of spawning. Long-lived species, such as the flannelmouth sucker, would not recruit high numbers of individuals each year but likely have a high mortality rate from egg to surviving age 1 and then lower mortality rates and more constant mortality rates for the older age classes. This would provide large cohorts to infuse the population in years when flow conditions were optimal. It would also provide cohort strength that would carry over to the next period of favorable spawning conditions. Spawning and recruitment likely take place each year but with a very high rate of variability and success due to the variable conditions experienced in the widely fluctuating flows.

Community ecology

Historically, flannelmouth, bluehead, and razorback suckers comprised the medium to large river sucker population in the Upper Colorado River basin. It has been suggested that the flannelmouth sucker was the most abundant sucker species in the system (Holden and Stalnaker 1975, McAda 1977). Currently, distribution and abundance of flannelmouth suckers have diminished (Bezzerides and Bestgen 2002). Dams and diversions that isolate small populations in headwater reaches are the principal cause for the shrinking of the flannelmouth sucker's range. This

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species has been eliminated from areas inundated by reservoirs. Upstream migration is blocked by the dams. Fragmentation of populations in this way might lead to a decrease in genetic diversity in isolated populations and a higher risk of extirpation of isolated populations due to catastrophic events. Reduction of flannelmouth sucker range and abundance has been attributed in part to interactions with non-native species, changes in flow regime, sediment input, reduction in backwater and flooded habitats, habitat alteration, urban run-off, and various organic and inorganic pollutants.

Introduced white suckers compete with flannelmouth suckers for food resources. Both species have similar habitat associations and feeding habits. Channel catfish (*Ictalurus punctatus*) have a diet that partially overlaps with the diet of flannelmouth sucker, and this species should also be considered a competitor (Tyus and Nikirk 1990). In addition to competing with flannelmouth suckers, some non-native fishes prey on flannelmouth sucker. Tyus and Beard (1990) and Nesler (1995) documented northern pike (*Esox lucius*) predation on flannelmouth sucker in the Yampa River in Colorado, but the proportion of flannelmouth sucker in the diet of northern pike was relatively minor in both studies. It is also possible that flannelmouth suckers are taken as prey by brown trout (*Salmo trutta*), rainbow trout (*Oncorynchis mykiss*), red shiner (*Notropis lutrensis*), and smallmouth bass (*Micropterus dolomieu*).

In some river systems, flannelmouth suckers appear to have a high incidence of disease and abnormalities. Although flannelmouth sucker comprised 60 percent of the fish population in the San Juan River (Landye et al. 1999), they accounted for 80 percent of the abnormalities found in a fish health survey. Most of these abnormalities were common, unexplained lesions. The following parasites were counted among these abnormalities: Trichodina, Tetrahymena, Gyrodactylus, Hunterella, and Lernaea. Only opportunistic and secondarily infective bacteria were found (Landye et al. 1999). In the Fremont River and La Verkin Creek, both in Utah, all specimens of flannelmouth sucker collected were carrying parasites including protozoans, trematodes, cestodes, and hirudine (Brienholt and Heckmann 1980). Two of the trematodes and two of the cestodes were found in more than 75 percent of the fishes examined. No information is available on the effects of disease, parasites, or abnormalities on mortality. There are also no data on the effects of pollution on these maladies.

An envirogram for flannelmouth sucker was developed to help elucidate the relationships between land use practices/management and flannelmouth sucker population characteristics (**Figure 4**). The diagram provides a basic listing of variables affecting population structure with arrows depicting direct relationships between variables.

Conservation

Threats

The native fish community that evolved in the warm-water reaches of the Upper Colorado River basin has been greatly reduced as a result of human activities during the last 100 years. Flannelmouth sucker populations have suffered reductions in abundance and distribution from the same mechanisms that have caused the near extinction of other endemic fish species in this drainage. These mechanisms can be separated into two general categories: 1) habitat degradation through loss, modification, and/or fragmentation, and 2) interactions with non-native species (Tyus and Saunders 2000).

Both of these threats imperil the long-term persistence of flannelmouth sucker. Each may work independently or in conjunction with the other to create an environment where populations may be reduced or eliminated. The relative importance of each threat and the specific cause-effect relationship usually depend on location. The complexity of each threat requires further explanation.

Effects of habitat degradation may not be limited to localized areas but may cascade through the watershed. Therefore, activities or events occurring on National Forest System lands may have detrimental impacts on populations of flannelmouth suckers existing in rivers many kilometers downstream.

Habitat loss occurs when streams are dewatered or when dams block upstream migration for seasonal use or when currently occupied areas are inundated by reservoirs. Habitat modification occurs when the natural stream flow regime is changed or when stream channels are modified by channelization, scouring, or sedimentation from land use practices. Land use practices that can impact stream channels include construction of roads through highly erodible soils, improper timber harvest practices, and overgrazing in riparian areas that all lead to increased sediment load in the system and the subsequent change in stream channel

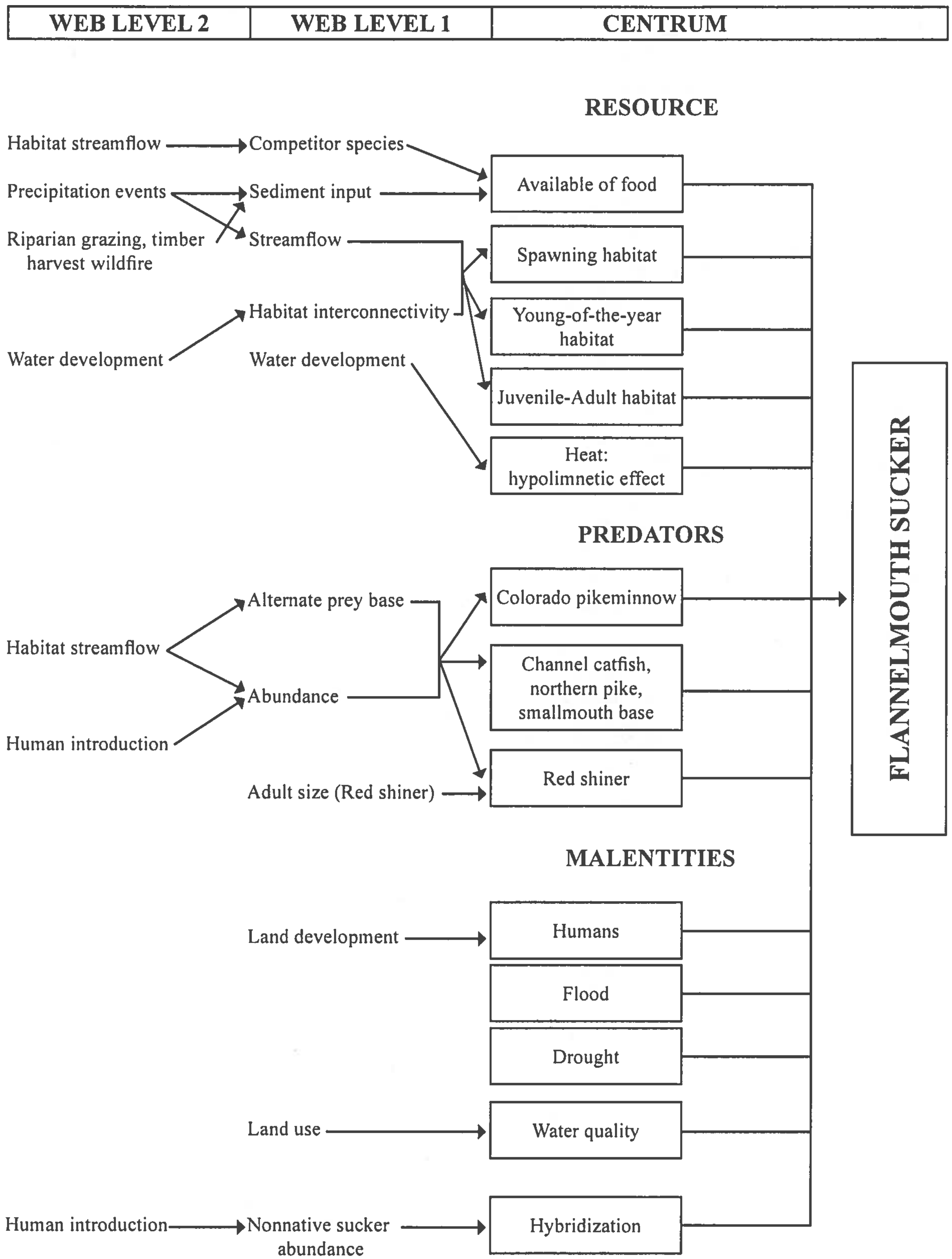

Figure 4. Flannelmouth sucker envirogram.

geometry (widening or incision). These modifications result in changes in width:depth ratios, pool:riffle ratios, pool depth, and other aspects that affect the quality of habitat occupied by flannelmouth suckers. Habitat fragmentation can be the result of dewatering of sections of river with populations occurring both upstream and downstream of the dewatered section, or reservoir or diversion construction that separates the exchange of individuals from separate populations throughout a river reach. The populations that become fragmented in some areas remain viable and reproduce and successfully recruit and maintain population levels at the same density or number as they were before the fragmentation occurred. This usually occurs in larger mainstem river sections. In smaller rivers and tributaries to a mainstem drainage, habitat fragmentation can eventually lead to habitat loss and extirpation of some of the populations.

Habitat fragmentation is often a result of dewatering, but it also results from the creation of barriers to fish passage such as dams and diversions. Large- and small-scale water development projects can profoundly impact the persistence of flannelmouth sucker populations. Irrigation diversions and small capacity irrigation reservoirs reduce streamflow, alter the natural hydrograph, and provide barriers to migration and normal population exchange. Barriers that preclude fish passage can cause population fragmentation and completely prevent or significantly reduce genetic exchange between populations. As habitat is fragmented and populations are isolated, the probability that "bottlenecks" will occur in the life history of the flannelmouth sucker become more pronounced and that single catastrophic events may extirpate populations from entire drainages.

Habitat modification contains aspects already discussed under fragmentation and degradation but also includes changes in temperature and flow regime, as well as alterations to water chemistry related to pollution. Severely reduced streamflows may lead to increased water temperatures and reduced dissolved oxygen levels, especially in smaller tributaries. Although specific tolerances to water quality parameters (i.e., temperature, dissolved oxygen, toxicants) are undefined for this species, it is likely that as water quality is reduced, flannelmouth sucker fitness also declines. For example, during periods of elevated summer water temperatures and decreased baseflows, flannelmouth sucker were observed in stressed conditions with evidence of adult mortality at higher levels than during times of normal summer temperatures and baseflows (Author's personal observation).

The effect of wildfire has little direct impact on quality of habitat. However, post-fire conditions can affect downstream populations. Input of large quantities of sediment into streams frequently occurs during storm events at recently burned areas. Once in the watershed, the increased sediment load can diminish suitable spawning habitat, reduce fitness through reduction of the prey base, and cause direct mortality through suffocation.

Water development, road construction, timber harvest, and grazing of riparian areas are likely to continue to impact flannelmouth sucker habitat in the future. Modification of land use management techniques to decrease the impact to flannelmouth sucker habitat may lessen the anthropogenic threats to this species. However, it is unlikely that all impacts or threats could be minimized or halted. Modifications of land use management techniques include the specification of fish passage at new or existing low head diversion to eliminate or reduce fragmentation of habitat and loss of habitat, and the specification of minimum flow regimes to promote connectivity of habitats and also maintenance of baseflow habitat during summer seasons or irrigation seasons. Other practices include specifications for buffer zones for road construction and timber harvest as well as grazing of riparian areas to promote healthy riparian growth and reduce sedimentation from upland areas.

Interaction with non-native species is another threat to flannelmouth sucker population health and viability. Non-native species prey upon, compete with, and hybridize with flannelmouth suckers when found sympatrically. Many introduced species tend to be well-adapted to a variety of environmental conditions, allowing a competitive advantage. Without fish passage barriers, the introduction of non-native fishes into stream reaches that do not contain flannelmouth sucker often results in the uncontrollable dispersal of these fishes into stream reaches containing flannelmouth suckers.

All life stages of the introduced white sucker have a competitive impact on flannelmouth sucker populations. However, the most serious threat imposed by the introduction of non-native suckers is perhaps hybridization. Distribution and abundance of white suckers is increasing within the Upper Colorado River Basin. These two species appear to lack any significant mechanism to isolate reproductive individuals. Further treatment of hybridization can be found in the Demography section.

The flannelmouth sucker is likely a desirable prey item for predatory non-native species. Large, non-native predators, including northern pike, channel catfish, and smallmouth bass, occur in many of the drainages containing flannelmouth sucker. In addition, red shiners have been reported to feed on native larval fish within the Upper Colorado River Basin. Preferred habitat for red shiners is slack water shoreline or backwater areas, which are the same habitats utilized by larval flannelmouth suckers.

The current distribution and the historical range-wide distribution of flannelmouth sucker indicate that few flannelmouth sucker populations occurred on National Forest System lands in Region 2. However, many sucker populations in the mainstem rivers likely occurred immediately downstream of adjacent National Forest System lands, and this proximity and the effects of some of the threats, such as increased sedimentation from grazing, timber practices, and road construction, could impact downstream populations. Fragmentation of populations or habitat loss could occur with barriers to migrations that occur on occupied National Forest System lands at water diversions without passage or impassable stream crossings. Both of those threats could be eliminated with inclusion of fish passage with construction of diversions and proper sizing of road crossings for culverts or bridges to allow natural passage conditions.

Conservation Status of the Species in Region 2

At present, there is concern regarding the status of flannelmouth sucker in the Colorado River drainage. Although the specific mechanisms of most threats to this species are poorly understood, the flannelmouth sucker appears to be vulnerable throughout its range in the Upper Colorado River Basin due to the combined impacts of habitat loss, habitat degradation, habitat fragmentation, and interactions with non-native species. A decrease in flannelmouth sucker populations has been documented or suggested throughout most of the basin.

Healthy populations of flannelmouth sucker, however, still exist in various locations in the Upper Colorado River Basin (e.g., San Juan, Green, Colorado rivers). These locations are usually defined by adequate habitat (as specified in the Habitat section of this report) and natural temperature and flow regimes. These areas often maintain healthy populations of other native fish species.

The flannelmouth sucker evolved in a system with a high natural disturbance regime. This disturbance regime included a large contrast between annual peak flows and base flows, and considerable sediment transport. Life history attributes and population dynamics allowed this species to persist during (or to recolonize after) a disturbance event. However, modifications to the physical and biological environment (e.g., loss of channel complexity, loss of refugia, introduction of non-native species, loss of benthic invertebrates) have reduced the species' ability to recover after such an event. Habitat fragmentation through streamflow reduction, passage barriers, and habitat degradation disconnects populations of flannelmouth suckers. Competition, predation, and hybridization associated with non-native species can depress or extirpate flannelmouth sucker populations.

Based on the impacts to flannelmouth sucker populations and distribution that have occurred in the last century, the potential for future declines in flannelmouth sucker distribution and abundance is high. Unless alleviated, habitat loss, habitat degradation, habitat fragmentation, and non-native species interactions will intensify and jeopardize the existence of flannelmouth sucker.

Potential Management of the Species in Region 2

Implications and potential conservation elements

Flannelmouth sucker populations are threatened due to the combined impacts of habitat loss, habitat degradation, habitat fragmentation, and interactions with non-native fish species. A brief description of threats is provided here to form a basis for the conservation elements; an in-depth discussion of threats to flannelmouth suckers can be found in the Conservation Threats section.

Management of flannelmouth sucker is based on an understanding of specific threats to the species. Habitat loss, degradation, and fragmentation due to land and water use practices are prime threats to flannelmouth sucker persistence in the Upper Colorado River Basin. Reduction of streamflows and creation of barriers to fish passage can severely degrade habitat to the extent that flannelmouth sucker populations are extirpated from the area. The degree of influence that population fragmentation has on flannelmouth sucker populations is speculative, but it could potentially impact the long-term persistence of this species. Creating isolated populations disrupts the natural exchange of genetic material between populations. Isolated populations are more vulnerable to extirpation from catastrophic events (e.g., lethal water quality conditions, extreme floods) because of the impediment to recolonization from other nearby populations. Loss of genetic diversity can also lead to the depression of fecundity and survival rates. The genetic exchange along a metapopulation framework within the flannelmouth sucker distribution can provide the required demographic variability and viability.

Other considerations for conservation elements should include:

- ❖ protection of riparian areas
- ❖ minimization of sediment input from anthropogenic causes (e.g., road building, timber harvest)
- ❖ management of non-native fish species.

Construction associated with road improvements or development, as well as timber harvesting, grazing, and fire activity, can cause increased sediment loads to adjacent streams. Increased sediment loads or sediment deposition could have a negative impact on flannelmouth sucker populations. Specific thresholds and mechanisms associated with this impact, however, have not been studied well enough to make precise predictions. In general, habitat loss or degradation from stream channel changes can reduce populations.

Management of non-native fish species requires strict adherence to existing regulations pertaining to the live release of fish. Interactions between flannelmouth suckers and non-native fish species threaten flannelmouth sucker populations. Specifically, competition and hybridization between flannelmouth sucker and introduced sucker species and predation by large non-native predatory species represent the two most deleterious effects of non-native interaction. Management strategies should limit further expansion of non-native fish on National Forest System lands in Region 2. These strategies should include strict enforcement of existing non-native stocking regulations and eradication programs for non-native fish in streams within the historical range of flannelmouth sucker.

The preservation of stream flows that are adequate to maintain complex habitat, interconnectivity of habitats, and instream cover should be a focal point of management policy or strategy. Conservation of flannelmouth sucker should address the function of the entire aquatic and riparian ecosystem, with particular attention to downstream populations. Any future plans for the conservation of flannelmouth sucker should take into account the entire native fish assemblage in the Colorado River Basin. This species assemblage evolved in and is adapted to a system with a high differential between peak spring runoff and fall baseflows. Native fish species of the Colorado River all require similar management considerations related to channel maintenance and restoration of historical flow regimes.

Tools and practices

The following review describes specific tools and techniques employed in the collection of flannelmouth sucker data. We are unaware of any management approaches implemented specifically for flannelmouth suckers in Region 2. Because little information exists or is being collected for this species, this portion will deal with techniques intended to gather the missing or needed information from the following Information Needs section.

The absence of distribution and abundance data for flannelmouth sucker on National Forest System lands in Region 2 is a concern. Because flannelmouth suckers are a benthic fish that is often found in riffle areas, electrofishing could be used to determine its distribution and abundance. The initial priority should be a complete survey of all streams on National Forest System lands that could contain flannelmouth suckers. General stream reach habitat surveys should be conducted concurrently with distribution surveys. Winters and Gallagher (1997) developed a basin-wide habitat inventory protocol that would be a cost-effective method to collect stream habitat characteristics. This protocol includes characterization of habitat type, quantity, channel type, substrates, and bank stability. All of these parameters assist in describing habitat quality.

Once basic distribution information has been gathered, intensive population estimates would provide baseline information to evaluate the effectiveness of future management strategies. Focus should be on areas where future management strategies could possibly impact flannelmouth sucker populations. However, the long-term monitoring goal should be population estimates and population trend data on all streams containing flannelmouth sucker populations on Region 2 lands. Several electrofishing techniques exist that would provide population estimates. These include mark/recapture and multiple-pass removal estimates. Each has its advantages, but due to the smaller size of many streams on Region 2 lands, estimating populations using depletion/removal techniques should be a cost-effective method to produce high quality data. Riley and Fausch (1992) recommend that a minimum of three passes be conducted when using the removal method. Use of a single pass method to develop a catch per unit of effort (CPUE) index is cost-effective on a time basis, but precision may be sacrificed and the introduction of bias is more likely, especially over long-term monitoring with researcher/technician turnover. With removal estimates, researchers are able to calculate confidence intervals, allowing insight into sampling quality and comparison over time.

A large data gap exists in the knowledge of flannelmouth sucker movement and use of streams on National Forest System lands. The implementation of a survey methodology such as the use of passive integrated transponder (PIT) tags to determine flannelmouth sucker distribution and abundance can also provide insight into movement. PIT tags are unobtrusive, long-lasting (indefinitely), uniquely coded tags that allow the efficient determination of movement with a minimum of disturbance. Establishment of a long-term monitoring program would be required. The time required to develop a robust data set depends on sample size, recapture rates, and survey frequency.

PIT tags could also be used for population estimates through mark and recapture over time to develop long-term population estimates on a broader basis for larger scale river areas. An alternate technique to develop habitat and movement information would be through the use of radio telemetry. Radio telemetry studies have been employed for flannelmouth sucker in the Colorado River and could be employed in other areas to develop more information on habitat. Radio telemetry would be limited mainly to larger juveniles, ages 3 and 4, and adults. PIT tags could be used for fish 120 mm (4.7 inches) total length and larger.

Habitat selection and preference can be determined through the use a variety of techniques. The simplest technique involves correlating capture locations to specific habitat types. Construction of habitat suitability curves is time intensive but could be used in conjunction with hydraulic modeling methodologies to estimate how habitat changes with streamflow. This would allow land managers to effectively compare the impacts of different flow regimes (due to water development projects) on flannelmouth sucker habitat. Data obtained could also be used to justify the acquisition of adequate instream flows for flannelmouth suckers and other native fishes.

Defining the relationship between habitat alteration and flannelmouth sucker population characteristics is a relatively difficult task. This process may require significant amounts of data, including research and quantitative analysis of temporal variation in prey base, habitat quality/function, abundance, and movement.

To effectively gather data valuable to the conservation of this species, managers need to coordinate with independent researchers and federal and state agencies that study or manage portions of streams downstream of Region 2 lands. This would help to determine or verify the distribution and abundance of flannelmouth sucker populations that exist downstream of Region 2 National Forest System land but are still affected by USFS management policies and strategies.

This coordinated effort could develop a regional knowledge base (i.e., interagency database) among biologists. This could be used to assess impacts from passage restrictions, barrier removal projects, and effects from water depletions. In addition, monitoring of physical attributes of streams downstream of Region 2 lands, in coordination with management practices on those federal lands, could develop cause and effect relationships over time to look at inputs of sediment or changes in discharge. Research and monitoring activities should enhance our understanding of these impacts on flannelmouth sucker populations (i.e., expansion or decline).

Information Needs

Most of the information that has been collected for flannelmouth sucker has been presented as a by-product of studies for federally listed fish in the Colorado River drainage. To attain adequate understanding to properly manage this species at a local level, specific studies must be conducted by drainage. General information needs for flannelmouth sucker include a wide range of information consisting of distribution, habitat requirements and associations, general attributes of life history and ecology, movement patterns, influence of non-native fish, and effects of human-induced habitat modification.

Specific knowledge of streams and watersheds containing flannelmouth sucker on National Forest System lands in Region 2 is essential for developing regional management strategies to preserve this species. Basic knowledge regarding locations of specific flannelmouth sucker populations is inadequate or obsolete. The research priority should be to survey all streams with potential habitat for the presence of flannelmouth sucker. Initial focus should be on streams with suspected populations or known populations downstream of National Forest System lands. During these surveys, information regarding the physical and chemical characteristics of the habitat should be obtained. Data collected should include:

- elevation
- water temperature
- dissolved oxygen
- dissolved solids (pollutants)
- discharge
- depth
- velocity
- turbidity
- substrate
- mesohabitat type.

This information will provide baseline data regarding habitat requirements and preferences for each physical parameter. Fish collected should be PIT-tagged to study movement, migration, and growth rates during continued monitoring.

In addition to general distribution and abundance information, additional data on seasonal distribution is required. Flannelmouth sucker may not establish resident populations in streams on National Forest System lands, but these tributaries may still provide important spawning habitat. The available data on habitat use emphasizes large river systems, and few studies have been conducted on smaller tributary systems. It is unknown whether flannelmouth sucker life history traits are uniform between large river and small tributary systems. Temporal and spatial changes in abundance, distribution, and age structure should be documented before implementing conservation strategies.

A data gap exists in basic life history information for the flannelmouth sucker. Habitat requirements and preferences are poorly understood for most life stages and life history events. Specific studies need to be designed to provide information on spawning behavior and habitat, larval biology, and the importance of larval drift. Habitat requirements and feeding habits at each life stage should also be addressed. Monitoring of tagged fish will also provide an estimate of survival rate that is a necessary component for refining the lifecycle diagram. Sex ratio and fecundity data should be collected to provide other components missing from the lifecycle diagram. It may be important to collect data from several sub-basins because much of the specific life history information may vary by drainage.

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

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

To ensure the long-term conservation of this species, research must examine techniques to minimize the impact of impoundments and diversions on flow regimes, temperature regimes, and movement of native fish. This research should focus on ways to modify existing impoundments, provide conservation guidelines for construction of future impoundments, and explore the use of off-channel impoundments. Other land use actions that affect habitat, such as road construction, water crossing (culverts), timber harvest, and grazing, should be studied. Specific scientific evidence to understand how habitat degradation affects flannelmouth sucker population attributes is missing. The development of a process-response model that links physical process (e.g., stream channel, gradient, substrate, sediment) to biological response (e.g., primary, secondary, productivity, reproductive success, and recruitment) would further identify flannelmouth sucker life history components that are not adequately understood.

DEFINITIONS

Endemic species – a species that is confined to a particular geographic region.

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

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

Lithophilic – associated with stony substrates.

Metapopulation – a genetically similar suite of populations defined by its expansive presence in accessible habitat, whereby its needs for sustainability are met through diversity of habitats, corridors for movement, and interconnection that allow adaptive straying.

Population viability – refers to the probability of species persistence over the temporal scale that defines a population or metapopulation. The dynamics of persistence take place at the level of the population (Wells and Richmond 1995), and the National Forest Management Act focuses on populations. Therefore, our process targets populations and species.

Process-response model – a conceptual or mechanistic model used to portray the biological response to physical factors.

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

Taxon – used in a broad sense to refer to a variety of taxonomic levels (i.e., genus, species, subspecies, variety).

Viability – a focus of the Species Conservation Project. Viability and persistence are used to represent the probability of continued existence rather than a binary variable (viable vs. not viable). We note this because of the difficulty in referring to 'probability of persistence' throughout the manuscript.

Web Level 1 – any component that affects the centrum.

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

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