Brook trout (*Salvelinus fontinalis*) Species and Conservation Assessment

Prepared for the Grand Mesa, Uncompahgre, and Gunnison National Forests

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INTRODUCTION

This report assesses the biology and population status of brook trout (*Salvelinus fontinalis*) on the Grand Mesa, Uncompahgre, and Gunnison National Forests (GMUG or Forest). The goal of this assessment is to summarize historical and current literature, and Forest-level resource data related to brook trout to provide land managers and the general public an objective overview of the status of the species within the Forest. Peer-reviewed scientific literature and summarized data are the primary information sources used in this report. Interpretation and extrapolation of studies conducted on other species of salmonids in the intermountain west has been used where relevant. Data from unpublished federal and state sources have been used to provide local information on the distribution, localized abundance, and habitat conditions on the Forest.

Areas of Uncertainty

There is difficulty in identifying total distribution and abundance of brook trout populations within the Forest due to limited funds for inventory and monitoring across an enormous landscape. The Forest has focused efforts on native fish species and subsequently has not identified the exact distribution and abundance of brook trout populations across the Forest. In addition, populations are dynamic, and depending on sampling effort, time of year and climatic factors, population estimates may fluctuate dramatically. Permanent sampling sites and long term monitoring will provide the most accurate description of brook trout populations on the Forest.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

• USDA Forest Service, Grand Mesa, Uncompahgre, and Gunnison National Forests, Management Indicator Species (USFS 2001a).
• Natural Heritage Ranking: G5 - Globally Ranked Secure (Nature Serve 2007)

Existing Regulatory Management Plan

• Grand Mesa, Uncompahgre, and Gunnison National Forests Amended Land and Resource Management Plan (USFS 1991).

The Grand Mesa, Uncompahgre, and Gunnison National Forests Amended Land and Resource Management Plan (LRMP) provides additional land management direction. The LRMP includes standards and guidelines for managing habitat for common trout species on the Forest (Table 1).

Table 1. Forest Plan direction related to fisheries management (USFS 1991).

Management Activities	General Direction	Standards and Guidelines
Aquatic and Terrestrial Habitat Management	03 Inventory aquatic habitats associated with perennial streams on the Forest. Maintain this aquatic habitat in at least its current condition with stable or improving trends. Improve aquatic systems to an overall upward trend. 04 Manage habitat for needs of macroinvertebrate and fish indicator species on all perennial streams, which provide potential fisheries. Manage waters capable of supporting self-sustaining trout populations to provide for these populations. 05 Prioritize streams for intensive management based on their current condition and ability to support self-sustaining trout populations and manage these streams to provide optimal habitat for trout populations.	f. Maintain fisheries habitat at a level, which reflects an improving trend. c. Manage stream habitat to improve habitat conditions. If alternatives to management activities, which cause unfavorable conditions, cannot be developed, then mitigation measures will be included in project proposals.

BIOLOGY AND ECOLOGY

Systematics/Taxonomy

Brook trout, *Salvelinus fontinalis*, is commonly called a trout despite actually being classified as a char. Brook trout have two basic ecological forms – the short lived, small form that typically inhabitat cold streams and lakes; and a long-lived large predaceous form usually associated with northern region lakes, large rivers and estuaries (Raleigh 1982). The genus *Salvelinus* includes lake trout, bull trout, Dolly Varden and the Arctic char. The Latin translation of *fontinalis* is fountain or spring, and refers to the habitat of the brook trout (Smith 1985). Brook trout can be artificially hybridized with lake trout to produce a fertile offspring called Splake trout (Raleigh 1982, Benhke 2002). Brook trout can also be artifically hybridized with brown trout (rare cases of natural hybrids occur) to producing a sterile offspring called Tiger trout (Raleigh 1982, Benhke 2002).

Identification

Brook trout have a long, streamlined body with a large mouth that extends past the eye. Color variations include olive, blue-gray, or black above with a silvery white belly. Brook trout have wavy, pale yellow wormlike markings, called vermiculations, along the dorsal surface and dorsal fin (Behnke 2002). They have small red spots often surrounded by bluish halos scattered on their sides among larger yellow spots (Behnke 2002). The lower fins have a white front edge with black and the remainder being reddish orange. The tail fin is square or rarely slightly forked (Behnke 2002). During breeding time in the fall male brook trout can become very bright orange-red along the sides (Figure 1).

Figure 1. Illustration of a "typical" brook trout found on the Grand Mesa, Uncompahgre, and Gunnison National Forests (Fish illustration by Joseph R. Tomelleri).

Range, Distribution and Abundance

The native range of brook trout comprises most of eastern Canada from Newfoundland to the western side of Hudson Bay along with the Atlantic, Great Lakes, and Mississippi River basins to Minnesota (Page and Burr 1991). Brook trout are also native to the Appalachian Mountains and extend as far south as northern Georgia (Behnke 2002). Since the late 1800's, brook trout have been introduced successfully outside their native range in North America and around the world primarily for sport fishing (Fuller 2008, Behnke 2002). Figure 2 identifies the native and introduced ranges of brook trout throughout the United States (Fuller 2008). Self-sustaining populations have proliferated throughout their introduced habitats. Brook trout are currently distributed throughout 41 states within the US, and all twelve provinces throughout Canada (Nature Serve 2007).

Within the Rocky Mountain Region (Region 2) of the Forest Service, brook trout are most widely distributed in Colorado and Wyoming. In Colorado, introductions have been made to the South Platte, North Platte, Republican, Arkansas, Rio Grande, Blue, Gunnison, Green, Yampa, and San Juan drainages and throughout Rocky Mountain National Park (Fuller 2008).

Across the Forest, quantitative population sampling has been conducted from 2000-2007. Brook trout were sampled in 141 of 339 total reaches (42%) from 46 sub-watersheds (6^{th} level HUC) across the Forest (Figure 3, Appendix Table 1). Thus, brook trout are considered widely-distributed throughout the Forest. Electrofishing surveys and professional observations indicate that brook trout are generally dispersed to higher elevations and steeper stream gradient sections of drainage basins (James, pers. comm. 2008).

The number of adult fish (>150mm) per stream mile range from a high of over 2,100 fish/mile in Curecanti Creek, compared to a low of 3 fish/mile in Upper Henson Creek. The large range in abundance may reflect different growth rates for brook trout populations across the Forest. Growth rates are largely determined by habitat conditions, stream size, and food availability.

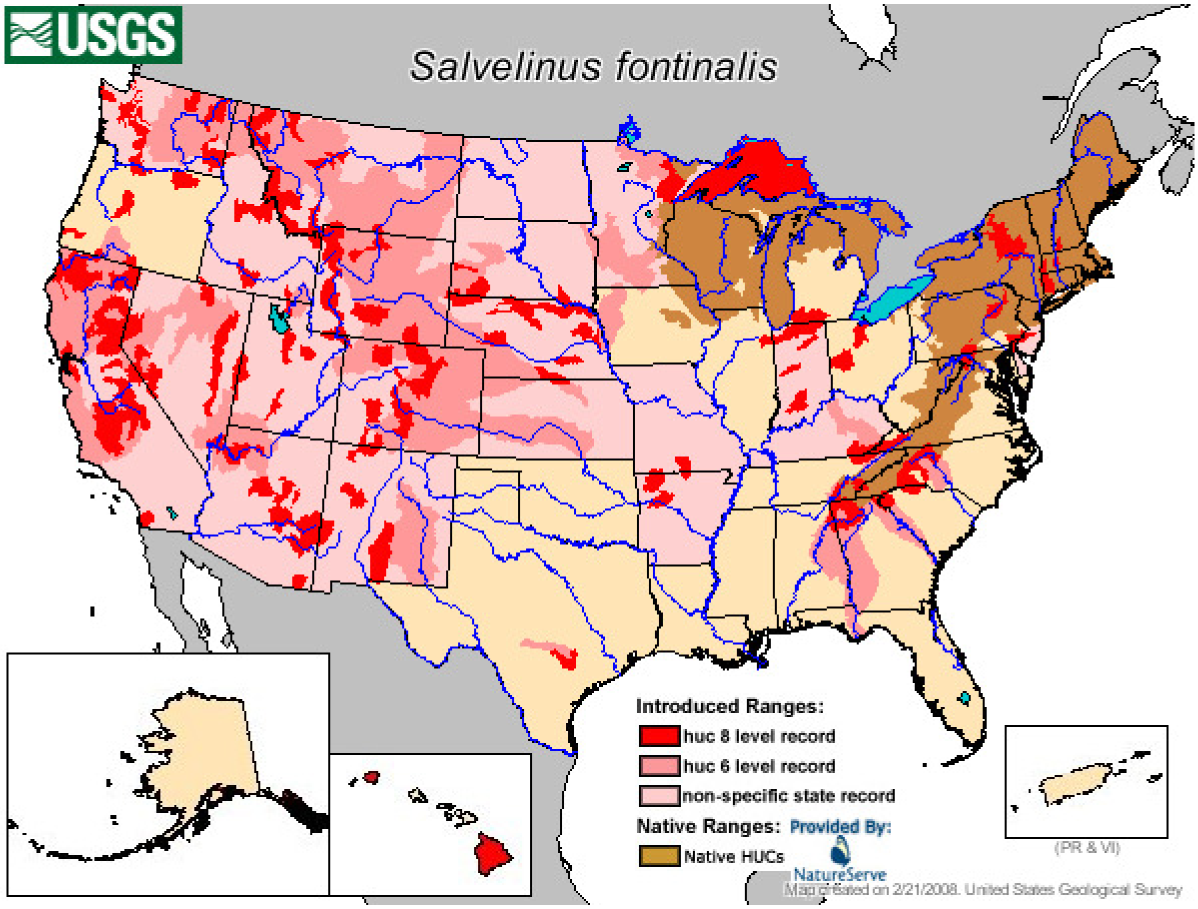

Figure 2. Brook trout distribution and introduced ranges across the United States. Mapping based on Nature Serve and US Geological Survey data (Fuller 2008).

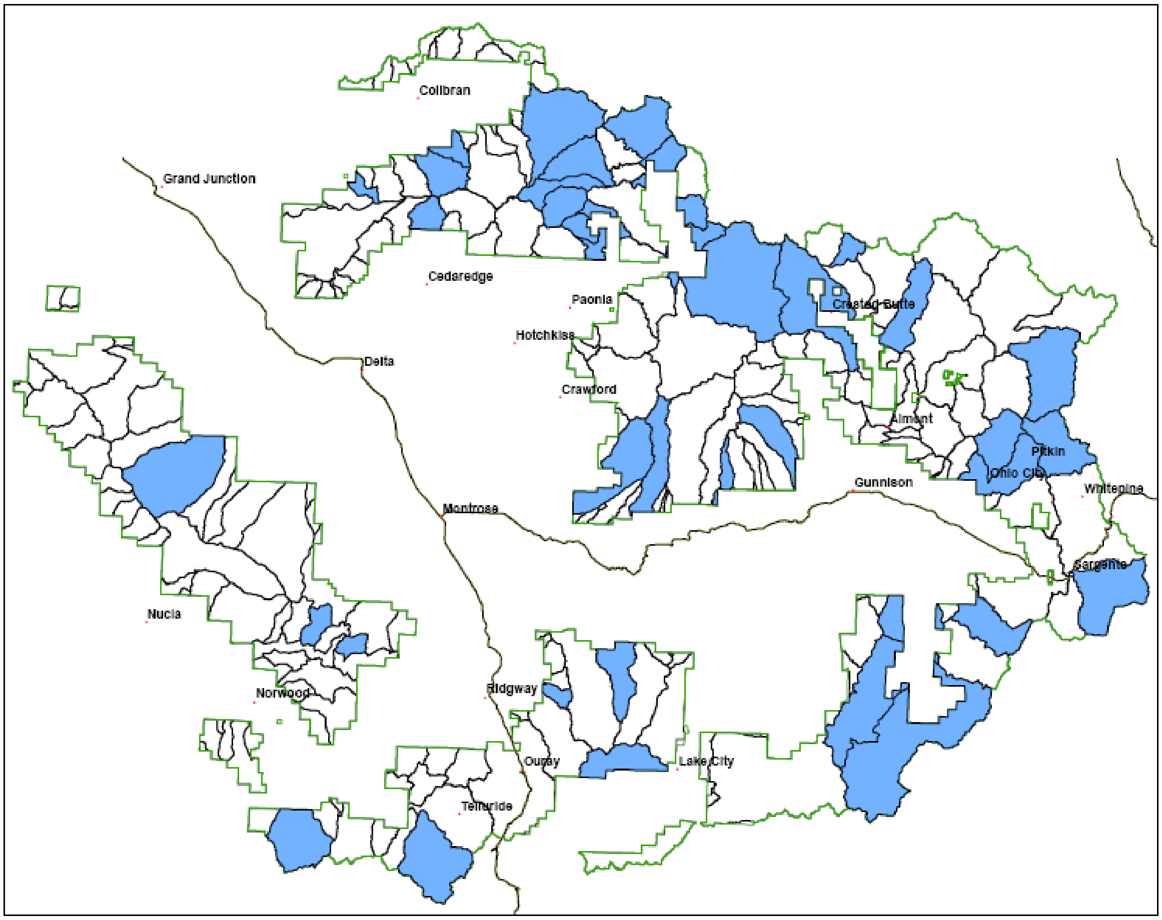

Figure 3. Sixth-level sub-watersheds (blue) within the Forest boundary, currently supporting brook trout populations. Distribution based on electrofishing surveys from 2000-2007.

Distribution relative to Watershed Integrity

The Forest recently completed an assessment that evaluated watershed sensitivity and intensity of management activity (past and current) occurring in 6th level watersheds across the Forest. A detailed description of the process can be found in the Aquatic, Riparian and Wetland Assessment currently being completed for revision of the Forest Plan (USFS, in draft). Watershed sensitivity is defined as the physical environmental factors that determine inherent response to disturbance (natural or management related). Activities include the variety of management activities or impacts that have or continue to occur on the Forest. To determine overall watershed integrity, watershed sensitivity and cumulative management activities were combined into a numeric rating. These ratings provide an overall characterization of watershed integrity. Ratings are relative ratings between watersheds on the Forest and should not be interpreted that the entire watershed is impaired or unstable.

Watersheds were divided into four integrity classes ranging from class I- highest integrity to class IV – lowest integrity (Figure 4). Class I watersheds are believed to reflect a range of on-the-ground conditions that indicate natural functions predominate and show little influence from past or current land management. Class IV contain watersheds having the greatest likelihood for specific areas or stream segments that have become degraded and could be affecting stream function and biotic integrity. Table 2 provides a summary of watershed sensitivity, activity level, and watershed integrity for 6th-level HUC's containing populations of brook trout. Twenty-eight of 46 (61%) 6th level watersheds with populations of brook trout were characterized by integrity class I or II.

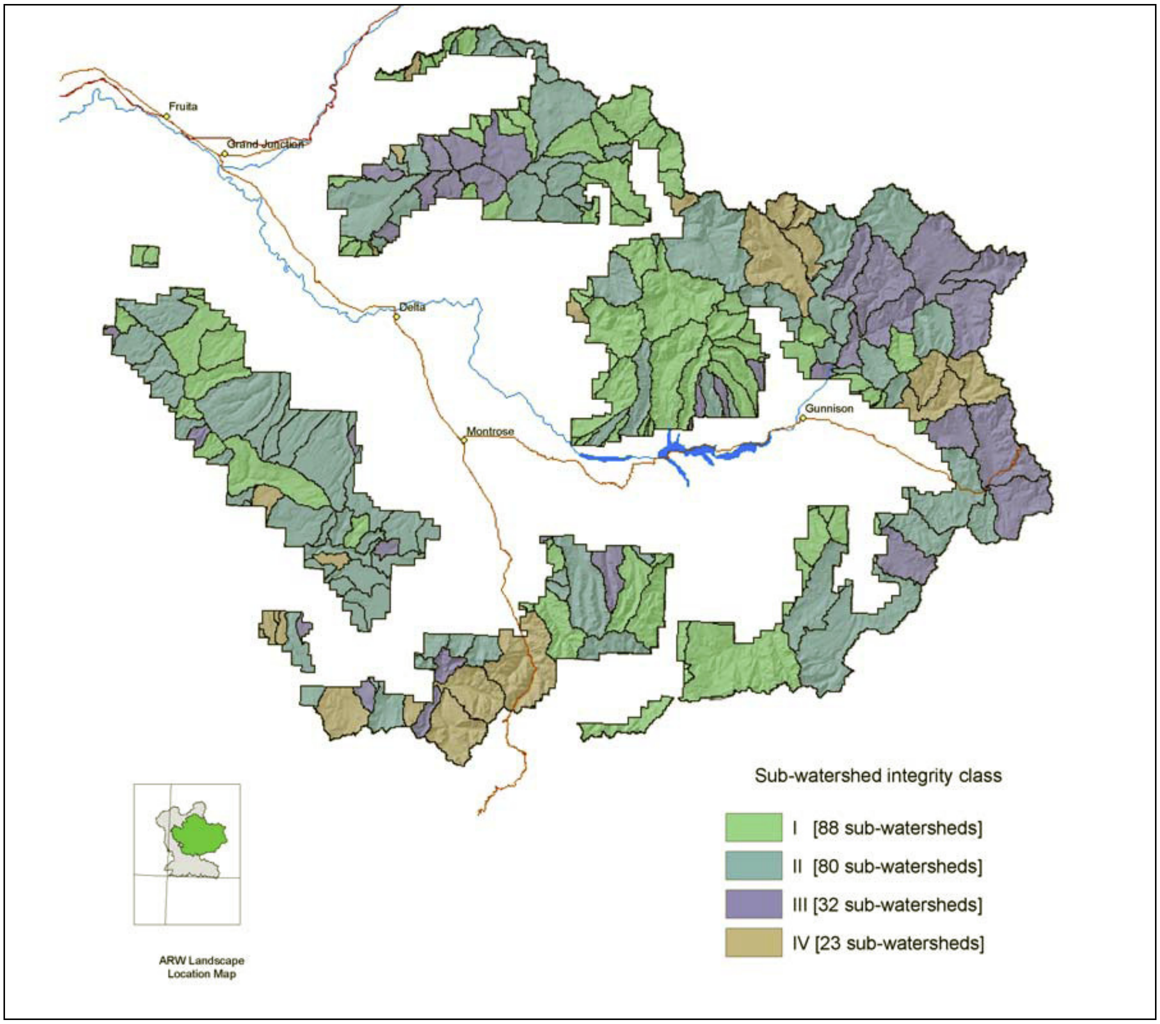

Figure 4. Sub-watershed integrity classes on the Forest.

Table 2. Watersheds (6th level HUC) with known brook trout populations are classified by overall activity class, sensitivity class, and integrity class rating.

HUC6	HUC_NAME	ACT_CLASS	SEN_CLASS	INT_CLASS
140200045603	Alder Ck	2	2	2
140200040701	Anthracite Ck	2	3	2
140200020310	Beaver Ck	1	4	1
140300034701	Beaver Ck	4	3	4
140100051710	Big Ck	4	3	3
140200019904	Cement Ck	4	4	3
140300036506	Clear Ck	4	1	3
140200040903	Clear Fk East Muddy Ck	1	3	1
140100051715	Coon Ck	2	2	2
140200019909	Copper Ck	4	4	4
140200045503	Cow Ck	3	2	2
140200025301	Crystal Ck C	2	2	1
140200025305	Curecanti Ck	2	4	2
140200057501	Escalante Ck	2	3	2
140200039303	Gold Ck	4	4	4
140100051709	Grove Ck	2	2	1
140200028302	Hensen Ck	2	4	2
140200051307	Kiser Ck	4	2	3
140200028102	Little Cimarron Rvr	3	3	3
140300036504	Little Red Canyon	2	1	1
140200038702	Los Pinos Ck	2	2	2
140200038704	Lower Cochetopa Ck C	2	1	1
140200038704	Lower Cochetopa Ck C	2	1	1
140200038704	Lower Cochetopa Ck C	2	1	1
140200040901	Lower East Muddy Ck C	1	3	1
140200040901	Lower East Muddy Ck C	1	3	1
140200040901	Lower East Muddy Ck C	1	3	1
140200045601	Lower Hubbard Ck C	2	3	1
140200045601	Lower Hubbard Ck C	2	3	1
140200045601	Lower Hubbard Ck C	2	3	1
140200039301	Lower Quartz Ck C	4	4	4
140200039102	Marshall Ck	3	3	3
140200064802	Owl Ck	2	3	2
140200041104	Paonia Reservoir C	4	3	4
140200041104	Paonia Reservoir C	4	3	4
140200020303	Red Ck	4	3	3
140200020303	Red Ck	4	3	3
140200019908	Slate Rvr	4	4	4
140300036304	South Fk San Miguel Rvr	4	4	4
140100051906	Upper Buzzard Ck	3	3	2
140200038701	Upper Cochetopa Ck	2	3	2
140200045602	Upper Hubbard Ck	2	3	2
140200039304	Upper Quartz Ck	4	4	4
140200035101	Upper Razor Ck	2	3	2
140200045502	Upper West Muddy Ck	2	2	1
140200019507	Willow Ck	3	4	3

Population Trend
Since 2000, the Colorado Division of Wildlife and Forest Service biologists have collected population data from many brook trout populations residing on the Forest. These population estimates serve as a baseline to track changes in distribution and abundance. However, temporal fluctuations in brook trout abundance may make population trends difficult to discern.

Though no fish scale or otolith data has been collected to determine age classes, brook trout populations across the Forest appear to represent various age classes. Both juveniles and adults are regularly sampled and sizes range from 9-372 mm in total length (GMUG 2008, unpublished data) (Figure 5). Fish larger than 200 mm were observed in 16% of the total fish sampled, with most fish ranging between 75-250 mm. The range in size may be attributed to different growth rates for populations residing in large streams/rivers (bankfull width >12m) compared to smaller streams.

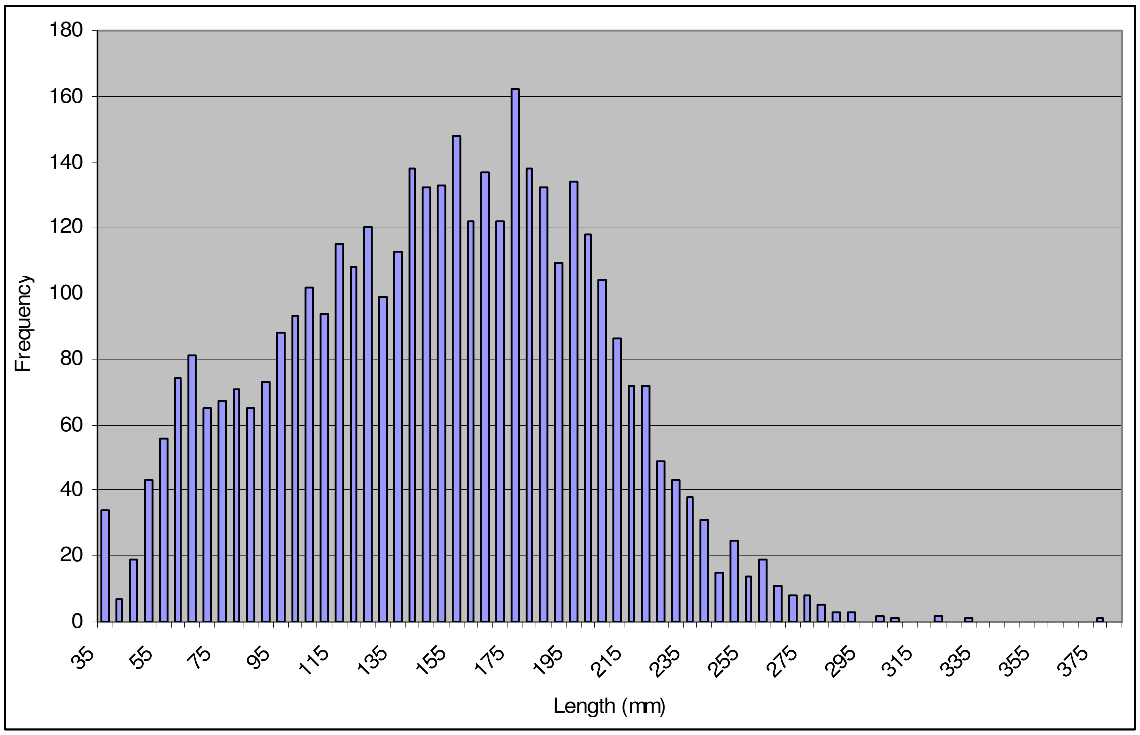

Figure 5. Frequency of occurrence of brook trout by total length on the Forest from 2000-2007.

Recent drought conditions in 2002-2004 have likely affected the brook trout populations throughout the Forest. However, since self-sustaining populations of brook trout are widely distributed across the Forest, there is inherent resilience to natural disturbances. Post drought population estimates indicate that brook trout on the Forest are in a stable and upward trend.

Activity Patterns and Movements
Brook trout can be found in suitable cold water habitats, including lakes, reservoirs and streams throughout the Forest. Literature suggests brook trout are common in headwater

streams, where they may live in relatively short reaches of the stream (Meehan and Bjornn 1991). Research has also found that individual brook trout are capable of moving moderate distances (>15km) and up steep slopes (>13%), which allows brook trout to establish in many stream networks (Adams *et al* 2000, Adams *et al* 2001, Dunham *et al* 2002). Brook trout invasion of native trout streams has been well researched. Studies suggest that brook trout invasion may occur in pulses when habitat conditions are degraded, rather than a steady process (Adams *et al.* 2001, Dunham *et al.* 2002).

On the Forest we have observed the trend of brook trout establishment in headwater areas, where they compete with native cutthroat trout for available resources. Brook trout invasion and establishment has caused native trout populations to significantly decline (Peterson *et al* 2004). On the GMUG, several native populations are being monitored for decreases in abundance, distribution, and opportunities for habitat improvement and reclamation.

Movement within and between water bodies is relatively unrestricted across the Forest, except by natural and man-made barriers. The GMUG has nearly completed a forest-wide survey of road/stream crossings to identify barriers to aquatic organism passage, and to prioritize efforts to re-connect existing populations. Approximately 11% of the surveyed crossings (n=200+) were deemed questionable for fish passage. The GMUG is making steady effort to replace culverts that act as barriers and promote habitat connectivity and movement. Currently, the Forest is implementing 1-2 road/stream crossing improvement projects per year.

Habitat

Intensive habitat inventories were completed during the 2001-2007 field seasons on approximately 62.3 miles of stream from 224 reaches. Three stream habitat assessment protocols were used to measure various stream habitat parameters: Stream Condition Inventory (SCI) (Frazier *et al.* 2005), R1/R4 fish habitat inventory method (R1/R4) (Overton *et al* 1997) and Pacfish Infish Biological Opinion (PIBO) (Heitke *et al* 2006). These protocols differ slightly in methodology. However, Forest fisheries biologists and hydrologists have determined that a core set of habitat variables were measured equivalently.

This data represent the best available information to date on fish habitat conditions, and likely provides the Forest with a good “cross-section” of current habitat conditions for brook trout. It should be noted that habitat conditions were assessed across the whole Forest, and reflect some streams not currently occupied by brook trout. Several important fish habitat parameters were sampled to determine the overall habitat conditions and requirements for brook trout.

Stream gradient data suggests that most fish-bearing streams on the Forest have gradients ranging between 1-7%. Bankfull width (BFW) data suggests that most streams on the Forest are small with an average BFW of 5.5m (n=216). Ninety-two percent of the sampled reaches have a BFW between 1-10m. Trout distribution in western mountain systems has been well documented as having brook trout and cutthroat trout predominating in the headwaters, and brown trout or rainbow trout in mid- and lower elevation stream sections or larger river habitats (Rahel and Nibbelink 1999, McHugh and Budy 2005). The data indicate that the ranges of stream gradient and size across the Forest provide suitable habitat for brook trout.

According to Reiser and Wesche (1977), optimal spawning substrate for brook trout range from 3-50mm in size. A laboratory study of the effects of fine sediment on brook trout eggs utilized substrate ranging from 6.33-24.9mm as suitable spawning gravel (Argent and Flebbe 1999). Pebble count data from 210 stream reaches indicate that substrate from 3-50mm in size make up about 25% of the average substrate composition of sampled reaches. The data suggest that suitable spawning gravel is available randomly throughout the sampled reaches. An assessment of stream habitat and fish populations in Upper Henson Creek indicated that brook trout appear to be spawning in substrate that is less than optimal for embryo survival (James 2001). Ocular estimates of brook trout redds in Upper Henson Creek indicated that spawning is occurring in areas less than $1.0m^2$, and with a composition of sand exceeding 20-30% of the total substrate (James 2001).

Fine sediment measurements from pool tails indicate that the percent fines less than 2mm comprise a high percentage of typical spawning sites, particularly in lower gradient stream reaches (GMUG 2008, unpublished data). In a California study, brook trout survival decreased when the volume of materials less than 2.5mm (diameter) increased (Burns 1970). Data from 189 stream reaches indicate that areas typically suited for spawning consist of approximately 20% fines less than 2mm. Hausle and Coble (1976) showed that the emergence of brook trout declined when 20% of spawning gravels were composed of material less than 2mm. Thus, the data suggest that fine sediment is likely a limiting factor to brook trout survival and recruitment on the Forest.

Literature suggests that optimal water temperatures for brook trout growth and survival is between 11-16 °C, though the overall tolerable temperature range is 0-20°C (Raleigh 1982, Meehan and Bjornn 1991). Mortality may occur when temperatures exceed 24°C (Raleigh 1982). Based on existing temperature data, water temperature requirements for brook trout are generally met from June-September; however, water temperatures begin to drop dramatically after September, and remain near 0°C during the months of November-March (GMUG 2008, unpublished data). Throughout the winter months, brook trout reduce their feeding and sustain the minimum level of metabolic activity needed to survive, since negligible growth occurs during the prolonged cold water temperatures (Raleigh 1982). For brook trout fry, if adequate substrate burial depth and acclimation to water temperature is not achieved, it is likely that the Forest temperature profile may impact growth rates or cause mortality.

Pool density and pool depth play an important role in the survival of all trout species, particularly during low flow periods (Meehan 1991). Pools comprise the majority of fish habitat in most small streams and pool depth appears to be one of the principal factors influencing the diversity and abundance of trout (USFS 1994). A Wyoming study of brook trout size structure and habitat indicated that more large brook trout were found in low gradients, meandering channels, and deep trench pools (Larscheid and Hubert 1992).

A general rule of thumb for quality pools is 1-2m in depth (USFS 1994, Raleigh *et al.* 1986). Across the Forest, residual pool depths ranged from 0.02-1.61m, with an average of 0.32m (Figure 6). Pools greater than 1m in depth occurred in only 1% of the total surveyed pools (n=2461), with the majority of these occurring in larger streams. The lack of optimal pool depth (≥1m) is a limiting factor for trout survival, particularly during low flow conditions in late summer and throughout the winter. Adequate pool depth is critical for maintaining trout populations; however, it should be noted that many of the streams on the Forest may not have the potential to achieve desired pool depths due to watershed geomorphology, basin area, and water production.

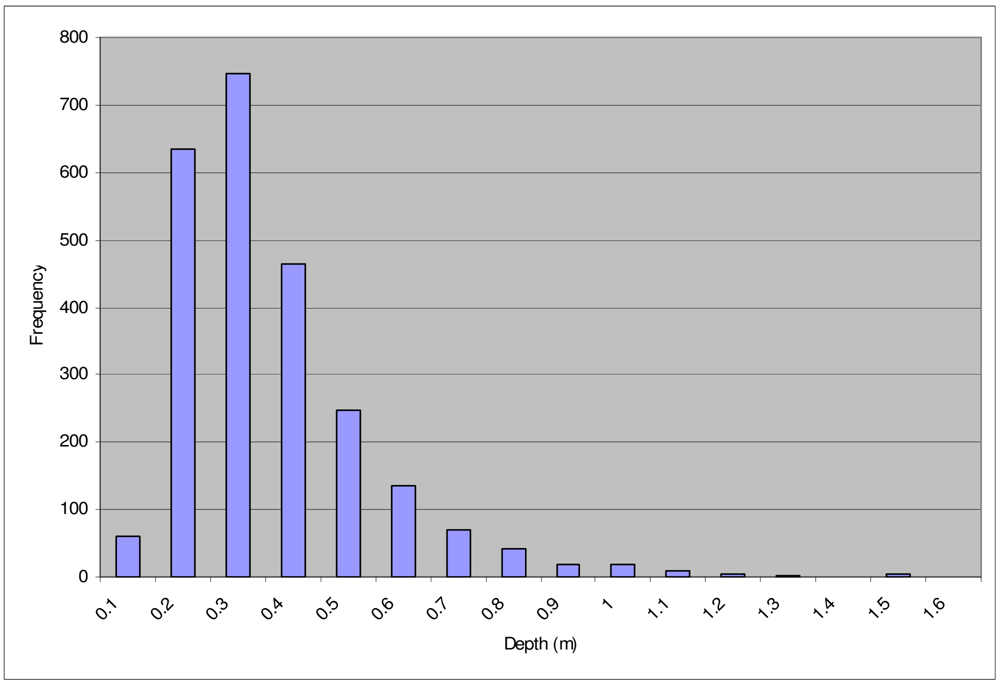

Figure 6. Histogram of residual pool depths across the Forest (n=2461).

Cover is an important feature for the survival of brook trout. Large woody debris (LWD), boulders, and undercut banks have been described as key cover components for trout (Bjornn and Reiser 1991, Raleigh 198). Of the 222 sampled stream reaches across the Forest, LWD densities range from 0-87 pieces per 100 meters of stream. The average was 13 pieces per 100m. Large woody debris is considered abundant across the Forest and provides excellent cover for brook trout. Pebble count data indicates that substrate such as small boulders (128-256mm) and larger comprise approximately 25% of the substrate composition (n=210). Therefore, boulders may provide good sources of cover for brook trout as well.

The amount of stable banks directly relate to the amount of cover provided by undercut banks. Of 152 reaches sampled with the R1R4 and SCI protocols, average bank stability was approximately 77%. On streams having a gradient less than 2% (response reaches) bank stability drops to 75%, which is not statistically different than the mean. Undercut banks were not frequently observed, comprising only 29% of the total stream banks sampled. Bank stability was qualitatively measured using the PIBO protocol by assessing the dominant stability type for the reach. Of the 64 reaches sampled with the PIBO protocol, 84% were classified as covered stable banks (>50% vegetated), while 14% were uncovered stable banks (<50% vegetated). On average, the percent of the reach containing undercut banks was approximately 30% with an average undercut depth of 24.6cm.

According to the Regional Watershed Conservation Practices Handbook, the extent of stable banks in each stream reach should be maintained at 74% or more of reference conditions (USFS 2006). The Forest is making an effort to determine the range of reference conditions across the Forest, but has not definitively established bank stability requirements (Adams 2006). Binns and Eiserman (1979) describe the best habitat rating for rainbow and brown trout in Wyoming as having >55% cover and 0-9% eroding banks. Based on observations across the Forest, brook trout utilize similar cover and bank requirements as rainbow and brown trout. Thus, biologists conclude that bank stability across the Forest is within the acceptable range for desired stream conditions.

Stable banks appear to be common across the Forest, but undercut banks and substantial undercut depth is limited. Since brook trout show preference for undercut banks and other cover components, it is likely that habitat improvements that target increased cover may also increase brook trout density and/or abundance. Binns and Eiserman (1979) found that as cover increased, rainbow and brown trout populations increased. Forest biologists have observed a similar cover relationship with brook trout on the GMUG.

Food Habits

Brook trout have been described as voracious feeders with the potential to consume large numbers of zooplankton, crustaceans, worms, fish, terrestrial insects, and aquatic insects (Nature Server 2007, Behnke 2002). Ephemeroptera, Trichoptera, and Diptera often make up a large component of their diet (Meehan and Bjornn 1991, DNR 2007). However, they will often feed on whatever is most readily available (DNR 2007). Behnke (2002) notes that brook trout have similar food habitats as brown trout and rainbow trout. When two or more of these species co-occur, brook trout tend to feed more on bottom-dwelling organisms while browns and rainbows will primarily feed on organisms in the water column and on the surface (Behnke 2002).

Breeding Biology

Locally, brook trout spawning occurs from mid-September through mid-November (Table 3). Spawning is initiated by decreasing day length, increased late fall flows, and drops in water temperature to <9°C (Meehan and Bjornn 1991, Raleigh 1982). Literature indicates that brook trout usually mature at age 2, but that males can reach maturity as early as age 1 (Behnke 2002). During spawning, mature females dig nests known as *redds*, where eggs are deposited, fertilized, and covered with gravel. Redds tend to be located where velocity, depth, and bottom configuration induce water flow though stream substrate (Young 1989). Incubation periods for brook trout range from 30-165 days at mean water temperatures ranging from 11.2 -1.9 °C respectively (Raleigh 1982). Brook trout larvae remain in redds for several weeks after hatching as they continue to develop.

Table 3. The timing of four major life history stages for brook trout. Variation and overlap in timing is accountable to variations in habitats occupied by this species.

	Autumn			**Winter**			**Spring**			**Summer**		
Life History Stage	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**
Spawning Period	X	X	X									
Egg Incubation Period		X	X	X	X	X	X					
Summer Rearing								X	X	X	X	X
Winter Rearing			X	X	X	X	X					

Rearing life history has been divided into summer and winter rearing stages given that different behavioral patterns are displayed. Cunjak and Power (1986) investigated winter habitat utilization by brook trout and brown trout. At all sample sites, brook trout showed strong preference for positions beneath cover, and tended to aggregate in pools and sources of groundwater discharge (Cunjak and Power 1986). Relative to summer, brook trout positions in winter were characterized by slower water velocities and greater overhead cover (Cunjak and Power 1986). Much of this change in behavior is triggered by cold-water temperatures, which lower the fish's metabolism and available energy. There are trade-offs between available food and preferred habitat. In general, the need for food overrides the need for cover in determining fish abundance in summer, but cover overrides food in winter months (Murphy and Meehan 1991). Lack of available winter rearing habitat can reduce the fish's ability to survive into the following summer.

The reproductive success rate of brook trout in terms of the number of individuals surviving to maturity is low, despite relatively high fecundity rates, given that offspring experience high mortality rates during early life stages. The period of highest mortality for young of the year (YOY) occurs during the first few months, when newly emerged fry establish territories (Murphy and Meehan 1991). When fish abundance is high, and habitat and/or food is limited, fry that cannot defend territories will be displaced and lost to predators (Murphy and Meehan 1991).

Demography

Many studies have identified gradients in salmonid distributions in western North American streams with brook trout and cutthroat trout predominating in the headwaters, while brown trout and rainbow trout reside in mid-lower elevation stream and river habitats (Rahel and Nibbelink 1999, McHugh and Budy 2005, Belica 2007). Brook trout produced from broodstocks are used to supplement natural recruitment of wild populations and put-and-take fisheries in some watersheds across the Forest. As an introduced species, the characteristics of brook trout populations are coupled with the species' ecology and the management of the species -both current and historic activities.

A synthesis of the basic life history characteristics of brook trout populations described by literature and Forest sampling (where possible) include: growth rate, maximum size, age of maturity, fecundity, life expectancy, population age structure, length-weight relationships.

Growth rate - Allen (1956) studied the age and growth of brook trout in a Wyoming beaver pond. Results indicated that there was no significant difference in growth rates for males and females and the typical growth rates were approximately 40mm (1.5 inches) per year for the first three years (Allen 1956).

Maximum size- The maximum size recorded on the Forest come from Los Pinos Creek, in the Gunnison River basin. Brook trout have been recorded at 37.2cm (14.6 inches) and weigh just over 1.0 lb.

Age of maturity - Age of sexual maturity is related in part to the environment that the population inhabits (Moyle and Cech 2000). In less predicable environments, where adult survival probabilities are low, natural selection favors females that reproduce as soon as possible (Moyle and Cech 2000). Generally, stream-resident brook trout mature at age 2, with males usually maturing before females (Behnke 2002). Males have been reported to mature as early as age 1 (Nature Server 2007).

Fecundity - Fecundity increases with fish size, with larger fish producing more eggs than smaller fish and the eggs are usually larger in size (Moyle and Cech 2000). There is relatively limited literature on the fecundity of brook trout in natural systems (Vladykov and Legendre 1940). One study that determined the number of eggs in ovaries of brook trout found that brook trout 5 inches in length produced over 100 eggs, while brook trout 13-15 inches in length produced over 1,000 eggs (Vladykov and Legendre 1940).

Life expectancy - In most North American streams, brook trout usually live about 3-5 years (Meehan and Bjornn 1991, Benhke 2002). In dense stream populations, brook trout rarely live past 3 years (Behnke 2002). In large rivers and lakes, brook trout have been recorded to live up to 9-10 years (Meehan and Bjornn 1991, Benhke 2002).

Population age structure – Forest sampling indicates that in general, brook trout populations are composed of various classes, being that a range of sizes for juveniles and adults are regularly sampled. Naturalized brook trout populations across the Forest suggest that in general, environmental factors are not specifically limiting certain age classes.

Length-Weight relationships - Fish larger than 200mm were observed in 16% of the total fish sampled, with most fish ranging between 75-250mm (Figure 7). Descriptive statistics indicate that the average total length was 148mm and the data ranged from 9-372mm. The average weight was 52g and the data ranged from 1-536g.

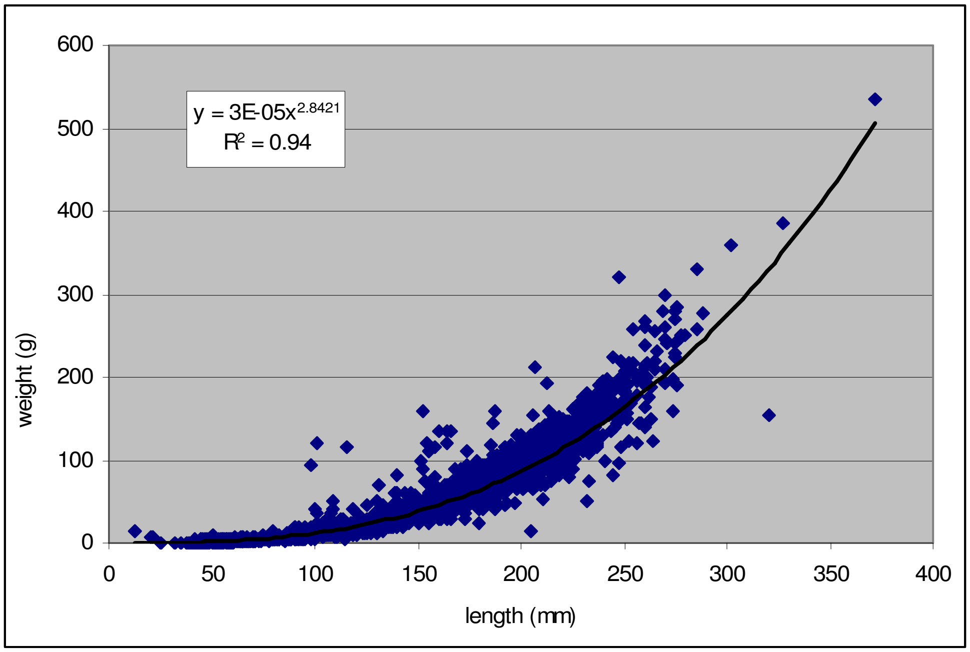

Figure 7. Length-weight relationship for brook trout on the Forest, 2000-2007

Community Ecology
Brook trout are often part of fish assemblages that include a variety of native and introduced salmonids (particularly cutthroat trout), cyprinids, catostomids, and cottids (sculpins) (Belica 2007). As a non-native species, brook trout can have numerous effects to the existing aquatic community. Dunham *et al.* (2004) described the range of impacts from non-native trout introductions, which include the decline of native fish populations as well as amphibians and invertebrates, alteration of ecosystem productivity and nutrient cycling, dispersal of pathogens and diseases, and additional indirect effects on the ecosystem.

Across the Forest, the most significant effect of brook trout to the existing community is the displacement and subsequent decline of the native cutthroat trout populations. Brook trout invasions have been well documented throughout the western U.S. However, the underlying population-level mechanisms that promote brook trout invasion and displace of native trout are not well understood (Peterson *et al.* 2004). Consequently, brook trout continue to be a major impediment to native trout recovery (Behnke 1992, Harig *et al.* 2000).

One study that investigates brook trout invasion processes showed that brook trout can rapidly displace or completely eliminate cutthroat trout by reducing their survival during the first two years of life (Fausch *et al.* 2006). The overall results suggest that brook trout invasion can impose a negative effect on cutthroat populations by reducing the survival of YOY (Fausch *et al.* 2006).

Predation and Disease

Mortality of brook trout is caused by predation, adverse environmental conditions, and disease. Piscivorous birds, mammals, and fish prey on brook trout, but as a popular sport fish, angling may be the predominant form of predation in some systems. Brook trout are susceptible to common salmonid diseases, including whirling disease, which is caused by a water born parasite (*Myxobolus cerebralis)* and a secondary host worm (*Tubifex tubifex*) (Markiw 1992). However, whirling disease is not a major threat to brook trout populations throughout the GMUG. Observations during electrofishing sampling suggest that in general, brook trout appear healthy and vigorous throughout the Forest.

CONSERVATION OF BROOK TROUT

Threats

The greatest threats to the viability of brook trout on the Forest include water development and depletion, habitat fragmentation via restriction of fish passage, livestock grazing, road design impacts, and to a lesser extent - angling pressure.

Changes in flow regime and water availability caused by water development appear to have the greatest extent of impacts to trout populations across the Forest. The potential detrimental effects of reduced stream flow on brook trout include limiting habitat and food resources, impeding movement, and increasing summer water temperature or decreasing water quality. Reduced flows also negatively affect the sediment transport regime. Since fine sediment appears to be a limiting factor in brook trout survival across the Forest, reduced flows may exacerbate an existing problem by diminishing natural flushing flows. Additionally, reduced flows can limit the formation of large deep pools and undercut banks, which are also considered limiting factors for brook trout survival across the Forest.

Many streams across the Forest have natural or man-made barriers to fish migration. These barriers limit the ability of trout to colonize sections of streams that may provide natal spawning areas or preferred habitat. Additionally, barriers restrict metapopulations dynamics and decrease brook trout viability when environmental conditions are poor (i.e. drought) or during habitat disturbances. Based on surveys of over 200 road/stream crossing sites, maximum velocity and minimum depth criteria are limiting factors in nearly all cases deemed questionable for fish passage. Local water depletions could magnify this problem when key flows needed for dispersal are removed from the hydrograph for domestic or agricultural use.

Often improper livestock grazing may result in the trampling of stream banks, loss of riparian vegetation, and sediment loading. Undercut banks are necessary components for survival, particularly with YOY, which require habitat with cover and lower water velocities along stream margins (Raleigh 1982). Historic livestock use has had dire impacts on riparian vegetation over the last 100 years (Platts 1991). When comparing recent photographs to historic photographs, rangeland and riparian conditions on the Forest have dramatically improved since the turn of the century (Bradford pers. comm.

2003). Still, despite significant changes in the timing, use, and duration of livestock grazing, low gradient/meadow streams are most susceptible to livestock use, and tend to be the locations where livestock pose the greatest risk for fish and other aquatic species.

Impacts from poor road design to salmonid species have been well documented in the Pacific Northwest (Furniss *et al.* 1991). Primary factors that affect fish habitat are surface erosion and increased runoff during storm events. Sediment delivery to a number of streams has been observed on many native surface roads and at stream crossings throughout the Forest. Excessive sediment loads can impact the survival of fish following spawning and may decrease macroinvertebrates, which are the primary food source for brook trout. Areas where the road system parallels the stream in close proximity have the greatest risk of impacting fish habitat, and causing downstream population impacts.

Recreational fishing can also contribute to major changes in brook trout populations. Angling pressure and harvest can reduce the number of fish capable of reproducing the following season, thereby reducing total abundance and density. However, active stocking can often compensate for over-fishing impacts.

Recommended Actions to Address Threats

One of the major components to address threats to brook trout includes prioritizing watersheds for maintenance and/or improvements of stream flows, riparian vegetation, and stream morphology needed to maintain brook trout populations. Watersheds that were identified as Class III and IV watersheds should be the focus for restoration efforts and habitat improvement. While watersheds in Class I or II watersheds, should focus on maintaining existing watershed conditions. Future land management activities in Class I watersheds should be carefully assessed to determine long-term impacts to the sustainability of brook trout populations.

Project level evaluation should determine allowable management activities in Class I watersheds. Only those actions that meet Forest Plan objectives, maintain high stream quality habitat or improve watershed function should be allowed. This strategy should help address cattle grazing and road design threats mentioned previously, since they are on-going multiple-use issues. Areas of management induced degradation should be evaluated and corrected to sustain high quality aquatic habitat and properly functioning watersheds. Standards and criteria identified in the Regional Watershed Conservation Practices Handbook (USFS 2001b) provide scientifically based direction for designing projects and managing riparian areas to protect, soil, aquatic, and riparian ecosystems.

Additional means to address the threats listed above include maintaining favorable flows, restoring habitat connectivity and restoring habitat attributes that were identified as limiting factors to brook trout populations. Maintaining favorable flows may be achieved by working with water users to provide by-pass flows or minimum pool depths during critical life history stages. This would require prioritization of watersheds, site specific evaluation of minimum flow requirements, and tremendous cooperation with water users.

Another approach to maintain favorable flows is to acquire in-stream flow water rights through the Colorado Water Conservation Board (CWCB). Starting in 2000, the Forest participated in a process, called the Pathfinder Project, which brought together many water resource stakeholder groups to help address in-stream flow needs and strategic protection (USFS 2004). The Forest should make use of the steering committee report to implement in-stream flow protection. The Forest should also collaborate with the Bureau of Land Management (BLM), being that their in-stream flow program is well established. Collaborating with the BLM will maximize the protection of federal habitat by establishing flows necessary for brook trout viability. It should be noted that in-stream flow protection is a long-term strategy. Immediate protection of favorable flows will require active participation and buy-in from water users.

Efforts to reduce habitat fragmentation across the Forest include replacing culverts and improving stream/road crossings that restrict brook trout movement. Using the extensive field surveys of stream crossings throughout the Forest, an assessment of which crossings are priority for improvements should be developed. Since maximum velocity and minimum depth criteria are factors for limiting fish passage on nearly all cases, projects should focus on aquatic organism passage for various trout life stages, not just adult forms. Focusing on efforts to restore habitat connectivity and favorable flows will help sustain brook trout populations across the Forest.

INFORMATION NEEDS

Locally, the Forest needs to continue to inventory current habitat conditions in brook trout occupied streams and monitor population abundance and distribution. Tracking the range and site-specific distribution of brook trout across the Forest will help identify areas where brook trout expansion may be impacting native trout through competition for suitable habitat. Understanding the population dynamics of brook trout invasion and establishment will allow Forest biologists to prioritize which areas may have the greatest success for native trout reclamation and/or enhancement.

Understanding the species interactions and ranges of overlap between brook trout and native trout may provide a framework to manage conflicts between sustaining native trout populations and providing sport fishing opportunities. Depending on site-specific conditions and the presence of native fish, the agency mission suggests that conservation of native species may be a priority over sport-fish management. Thus, expanding our knowledge of brook trout habitat requirements, locations of fish barriers, and overall stream conditions will help Forest biologist to more successfully manage fisheries resources. We need continued cooperation and dialogue with CDOW to maintain existing brook trout populations where appropriate, while meeting Forest Plan standards to protect native fish.

APPENDIX

Table 1. Brook trout (minimum 150mm) occupied reaches and population estimates with 95% confidence intervals, and fish per mile estimates with 95%CI intervals. Estimates based on Jakomatic version 1.9, 2008.

Site ID	Stream Name	Population Estimate	PopEst 95%CI	Fish/Mile Estimate	Fish/Mile 95%CI
ALDR2007-1	Alder Creek	1	0	23	0
BVR2006-2	Beaver Creek	28.14	6.12	538	117
BEAV2003-1	Beaver Creek	5	0	112	0
BVR2002-1	Beaver Creek	29.26	1.56	309	16
BVR2002-2	Beaver Creek	23.11	1.09	244	12
BVR2005-1	Beaver Creek	37.1	7.34	1390	275
BVR2006-4	Beaver Creek	23.75	11.5	413	200
BVR2005-2	Beaver Creek	11.29	2.39	181	38
CEMT2005-3	Cement Creek	35.06	0.8	386	9
CFMUD2005-4	CF Muddy Cr	12.25	2.12	204	35
CFMUD2005-5	CF Muddy Cr	21.92	3.61	381	63
CFMUD2005-3	CF Muddy Cr	11	11.8	192	180
CFMUD2005-2	CF Muddy Cr	7	9.6	164	119
CFMUD2005-1	CF Muddy Cr	5	1.95	68	27
CFMUD2005-6	CF Muddy Cr	11.5	8.13	162	115
CHAV2004-1	Chavez Creek	27.29	1.66	485	30
CHAV2004-2	Chavez Creek	32.2	37.4	444	383
CLEA2001-1	Clear Creek	5	1.95	54	21
CFMUD2005-7	Clear Fk Muddy Cr	18.33	5.19	313	89
CFMUD2005-11	Clear Fk Muddy Cr	22	6.57	433	130
CFMUD2005-10	Clear Fk Muddy Cr	12.25	2.12	207	36
CFMUD2005-8	Clear Fk Muddy Cr	16	8.15	222	113
CFMUD2005-9	Clear Fk Muddy Cr	5	1.95	47	18
COAL2006-7	Coal Creek	11	0	141	0
COAL2006-5	Coal Creek	23.35	1.95	411	34
COAL2006-4	Coal Creek	15.18	1.63	267	29
COAL2006-3	Coal Creek	20	0.51	352	9
COAL2006-6	Coal Creek	10	0	176	0
COCH2001-1	Cochetopa Creek	15.4	10.2	163	107
COON2006-1	Coon Cr	4	0	69	0
COPP2003-1	Copper Creek	61	7.34	644	77
COW2005-1	Cow Cr	3	0	39	0
CRYST2005-1	Crystal Creek	7	26.3	522	139
CRYST2005-2	Crystal Creek	17.55	2.81	269	43
CURE2005-2	Curecanti Creek	206.33	5.67	2179	60
CURE2005-1	Curecanti Creek	58.24	1.29	615	14
DEEP2006-2	Deep Cr	1	0	17	0
DEEP2005-1	Deep Cr	2	0	23	0
DYKE2003-3	Dyke Creek	5	0	82	0
DYKE2001-2	Dyke Creek	23.67	5.43	190	44
DYKE2001-3	Dyke Creek	13	62.2	501	105
DYKE2003-1	Dyke Creek	11	11.8	444	415

SiteID	StreamName	PopEst	PopEst 95%CI	Fish/Mile	Fish/Mile 95%CI
DYKE2003-2	Dyke Creek	15.4	10.2	264	174
DYKE2003-4	Dyke Creek	7	9.6	191	139
DYKE2001-1	Dyke Creek	39.67	6.27	319	50
DYKE2007-4	Dyke Creek	4	0	88	0
DYKE2007-3	Dyke Creek	10	0	248	0
EFWI2002-1	E Willow Creek	31	7.78	489	123
EFESC2005-2	East Fk Escalante Cr	3	6.79	112	50
EFESC2005-3	East Fk Escalante Cr	1	0	17	0
EFLPINOS2006-1	EF Los Pinos Cr	16	0.6	287	11
ELK2006-1	Elk Creek	1	0	35	0
GOLD2001-2	Gold Creek	37.11	7.34	653	129
GOLD2001-1	Gold Creek	72.63	6.41	767	68
GROVE2003-1	Grove Creek	7.67	5.76	109	82
HEND2006-1	Henderson Cr	16.17	1.52	362	34
HEND2006-2	Henderson Cr	2	0	42	0
HEND2006-3	Henderson Cr	4	0	134	0
HENS2001-3	Henson Creek	35	0.36	282	3
HENS2001-4	Henson Creek	35	23.9	282	192
HENS2001-2	Henson Creek	24.1	1.06	194	9
HENS2001-1	Henson Creek	95.09	11.1	765	89
HENS2005-1	Henson Creek	82.48	3.37	1328	54
HENS2005-2	Henson Creek	33.48	2.09	361	23
HENS2005-3	Henson Creek	7	1.24	67	12
JONES2005-1	Jones Creek	6	1.5	66	16
LCIM2002-1	Little Cimarron River	103.07	32.9	948	303
LCIM2002-2	Little Cimarron River	32.91	3.09	505	47
LRED2005-1	Little Red Canyon Cr	7	9.6	146	106
LRED2005-2	Little Red Canyon Cr	13	62.2	964	201
LPINOS2006-1	Los Pinos Cr	3	6.79	126	56
LPINOS2006-2	Los Pinos Cr	14.75	3.78	231	59
LPINOS2006-3	Los Pinos Cr	50.58	8.89	770	135
LPINOS2006-4	Los Pinos Cr	35.5	8.32	640	150
LPINOS2006-5	Los Pinos Cr	9.4	3.29	193	68
MFWI2002-1	M Willow Creek	17.15	1.43	276	23
MFBIG2005-1	MF Big Cr	1	0	18	0
MQUARTZ2006-1	Middle Quartz Cr	15	20.2	412	306
MILL2006-1	Millswitch Cr	22.11	1.13	374	19
MILL2006-2	Millswitch Cr	1	0	26	0
BVRN2004-1	North Beaver Creek	53.93	7.58	949	133
NQUARTZ2006-2	North Quartz Cr	19.86	9.9	365	182
NQUARTZ2006-1	North Quartz Cr	19	0.53	247	7
NTWIN2005-1	North Twin Creek	1	0	15	0
OWL2007-1	Owl Creek	1	0	13	0
PASS2001-1	Pass Creek	1	0	11	0
PAUL2006-2	Pauline Cr	15.4	10.2	314	207
PAUL2006-1	Pauline Cr	18.14	1.36	293	22
PAUL2006-5	Pauline Cr	13	0	371	0

SiteID	StreamName	PopEst	PopEst 95%CI	Fish/Mile	Fish/Mile 95%CI
PAUL2006-9	Pauline Cr	18.14	1.36	257	19
PAUL2006-3	Pauline Cr	24.1	1.06	293	13
PAUL2006-4	Pauline Cr	16.71	6.82	251	102
PERF2004-1	Perfecto Creek	20.09	4.24	371	78
RAZR2005-1	Razor Creek	16	8.15	169	86
RAZR2005-2	Razor Creek	42.17	1.15	445	12
RED2005-1	Red Cr	18.14	1.36	389	29
RED2005-2	Red Cr	29.11	3.68	451	57
RDBVR2003-1	Road Beaver Creek	3	0	32	0
RDBVR2005-1	Road Beaver Creek	7	0	160	0
RDBVR2005-2	Road Beaver Creek	1	0	20	0
RDBVR2005-3	Road Beaver Creek	5	1.95	88	34
RDBVR2005-4	Road Beaver Creek	3	0	53	0
RDBVR2005-5	Road Beaver Creek	5	0	75	0
RDBVR2003-2	Road Beaver Creek	7	9.6	74	101
ROCK2003-1	Rock Creek	2	0	32	0
SMIG2006-1	San Miguel, South Fk	1	0	10	0
SMIG2006-2	San Miguel, South Fk	8	0	79	0
SMIG2004-1	San Miguel, South Fk	2	0	26	0
SLAT2005-1	Slate River	6	0	70	0
SPLN2006-2	Splains Gulch	6	0	106	0
SPLN2006-1	Splains Gulch	13.22	1.92	233	34
WHUB2007-1	West Hubbard Creek	13	0.7	183	10
WMUD2005-1	West Muddy Cr	1	0	14	0
WMUD2007-1	West Muddy Creek	13.86	4.33	318	99
WIL2005-2	Willow Cr	22	59.4	796	295
YOUNGS2005-1	Young Creek	15.18	1.63	272	7
YOUNGS2005-2	Young Creek	22	59.4	990	366

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DEFINITIONS

Adfluvial: refers to fish behavior of lake/reservoir resident fish that migrate into rivers or streams to spawn.

Fluvial: refers to fish behavior of river resident fish that migrate upstream into streams to spawn.

Hydrograph: chart that depicts stream discharge rate versus time.

Introgression: reproduction between a native cutthroat trout subspecies and other cutthroat trout subspecies (intra-specific) or other salmonid species (inter-specific), and occurs in varying degrees among populations.

Life history: the series of living phenomena exhibited by a fish in the course of its development from conception to death.

Reach: section of a stream between two specified points that has a consistent slope and complement of habitat units.

Redd: nest made in gravel, consisting of a depression hydraulically dug by a fish for egg deposition (and then filled) and associated gravel mound.

Residual Pool Depth: depth of pool independent of flow. Obtained by subtracting the depth of the pool tail crest from the maximum pool depth.

Salmonid: fish of the family Salmonidae, including salmon, trout, chars, whitefish, ciscoes, and grayling. In general usage, the term most often refers to salmon, trout, and chars.

Sympatric: co-occurring in the same area.