Brown trout (*Salmo trutta*) 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 brown trout (*Salmo trutta*) 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 brown 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 Data from unpublished federal and state sources have been used to provide local information on the distribution, localized abundance, and habitat condition on the Forest.

As part of the Rocky Mountain Region Species Conservation Program, a technical species conservation assessment for brown trout was developed in April 2007 by L. Belica. This comprehensive assessment synthesizes the extensive literature and population status of brown trout throughout the Rocky Mountain Region. The Forest assessment will tier to the Regional assessment (Belica 2007) as much as possible, while providing a Forest-level review of the population status of brown trout on the Forest.

Areas of Uncertainty

There is difficulty in identifying total distribution and abundance of brown trout populations on 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 brown trout populations across the Forest. In addition, populations are dynamic, and depending on sampling effort, time of year, stocking density and climatic factors, population estimates may fluctuate dramatically. Permanent sampling sites and long term monitoring will provide the most accurate description of brown 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 Forest 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

Belica (2007) provides a thorough discussion of the description and taxonomy of brown trout and other salmonids. The name *Salmo trutta* was included in the 1758 publication of the "System of Nature" by Linnaeus in reference to the form of brown trout found in large rivers, while the stream resident and sea-run forms of brown trout were differentiated as *S. fario* and *S. eriox* (Bachman 1991, Elliott 1994, Belica 2007). Due to variations in appearance, about 50 species of brown trout were originally described and classified, but were later consolidated into the single species *S. trutta* (Belica 2007, Behnke 2002).

Identification

The body coloration of brown trout in streams is typically olive, brownish yellow, to dark brown dorsally (Figure 1) (Belica 2007). Their caudal fin is not forked, and its appearance is described as squarish with few to no dark spots (Behnke 2002). The lack of dark spots on the caudal fin is considered a distinguishing characteristic of the species (Bachman 1991, Behnke 2002). Additionally, brown trout do not have white edges on their pelvic or anal fins (Page and Burr 1991). The spotting patterns and body coloration of brown trout in North America are diverse due to their mixed ancestry (Bachman 1991, Behnke 2002). Spotting patterns range from many irregularly shaped spots profusely distributed to larger rounded spots more sparsely distributed on the body (Behnke 2002). Brown trout inhabiting large lakes or marine waters are often silver and can have X-shaped marks dorsally (Bachman 1991, Page and Burr 1991). Brown trout living in clear streams have been described as having bright colors. Brown trout that inhabit lakes, particularly under ice in the winter, or undergoing smoltification have colors that are obscured by a silvery iridescence (Bachman 1991).

Figure 1. Illustration of a "typical" brown 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 brown trout includes Europe, western Asia, and northern Africa (Behnke 2002). Brown trout have been introduced all over the world and the first documented introduction of brown trout to North American occurred in Michigan in 1884 (Behnke 2002). Self-sustaining populations have proliferated world-wide (Belica 2007, Behnke 2002) and domestically, brown trout are currently distributed throughout 44 states within the US, and nine provinces throughout Canada (Nature Serve 2007) (Table 2).

Table 2. Distribution of brown trout in North America based on Nature Serve Explorer database, 2007.

CANADA:	AB , BC , MB , NB , NF , NS , ON , QC , SK
USA:	AL, AR, AZ, CA, CO, CT, DC, DE, GA, IA, ID, IL, IN, KY, MA, MD , ME , MI , MN, MO, MT , NC , ND, NE, NH, NJ, NM, NN, NV, NY, OH, OK, OR, PA, RI, SD, TN, UT, VA, VT, WA, WI, WV, WY

Within the Rocky Mountain Region (R2) of the Forest Service, brown trout are most widely distributed in Colorado and Wyoming. The Colorado Division of Wildlife has created maps to reflect their historic stocking efforts throughout the state (Figure 2). Through extensive stocking efforts, many brown trout populations are currently self-sustaining populations and provide excellent recreational fishing opportunities on the GMUG.

Quantitative population sampling has been conducted across the Forest from 2000-2007. Brown trout were sampled in 55 of 339 total reaches (16%), which represent approximately 30 of 69 sampled streams/rivers (43%), and are found in 23 6th level watersheds (Table 3, Figure 3). Thus, brown trout are considered widely-distributed throughout the Forest. Populations within the Upper Gunnison River basin are particularly well distributed, which is likely the result of fluvial and adfluvial behavior patterns and residualized populations in tributaries. Fish abundance and size also tends to be greater in the Upper Gunnison basin. The number of adult fish (>150mm) per stream mile range from a high of over 3,400 fish/mile in Spring Creek compared to the low of 11 fish/mile in Clear Creek.

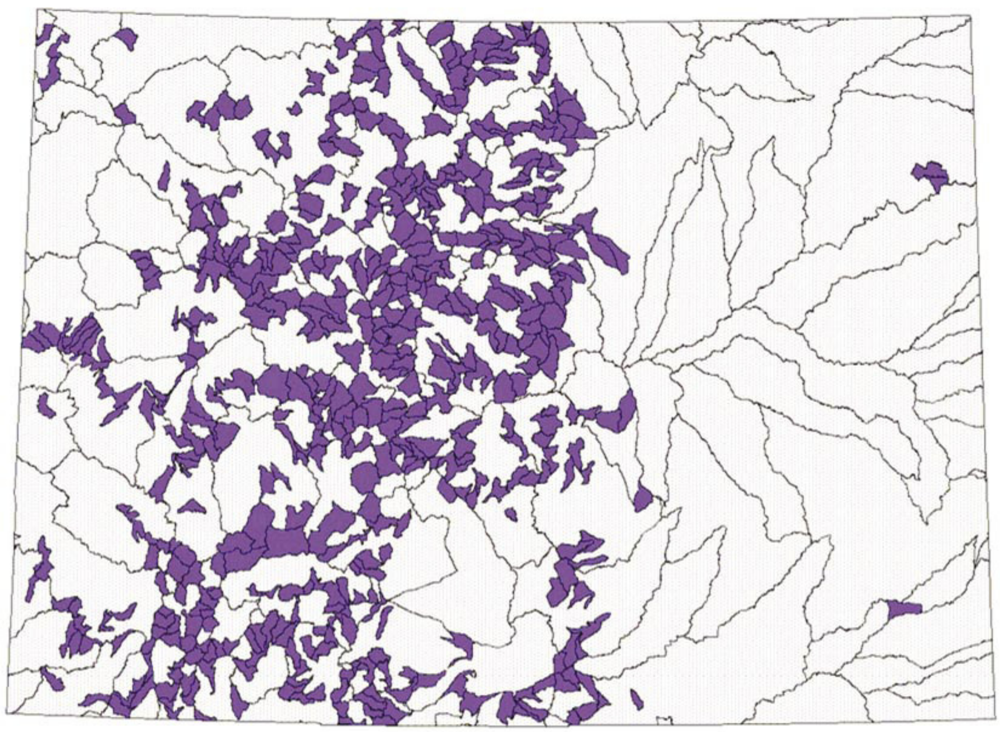

Figure 2. Brown trout stocking in Colorado by 6th level sub-watersheds (purple) displayed over 4th level sub-basins (USGS Hydrologic Unit Code) from 1985 to present (Belica 2007).

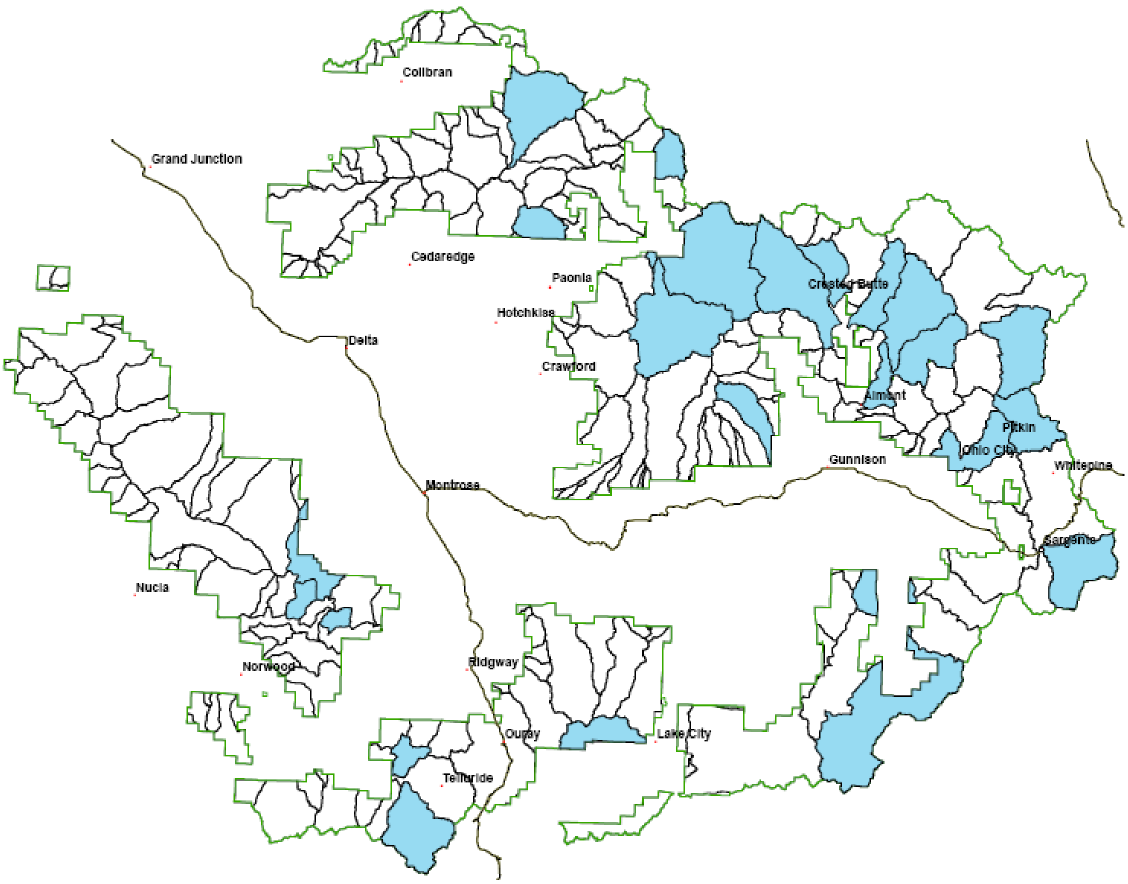

Figure 3. Sixth-level sub-watersheds (blue), within the Forest boundary, currently supporting brown trout populations. Distribution based on electrofishing surveys from 2000-2007.

Distribution relative to Watershed Integrity

The Forest recently completed an assessment that evaluated watershed sensitivity and the level of past and current management activities 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 Forest. To determine overall watershed integrity, watershed sensitivity and additive activities were combined into a numeric rating. These ratings provide a baseline 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 are watersheds 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 3 provides a summary of watershed sensitivity, activity level, and watershed integrity for 6th-level HUC's containing populations of brown trout. Eleven of 23 (48%) 6th level watersheds with populations of brown trout were characterized by integrity class I or II.

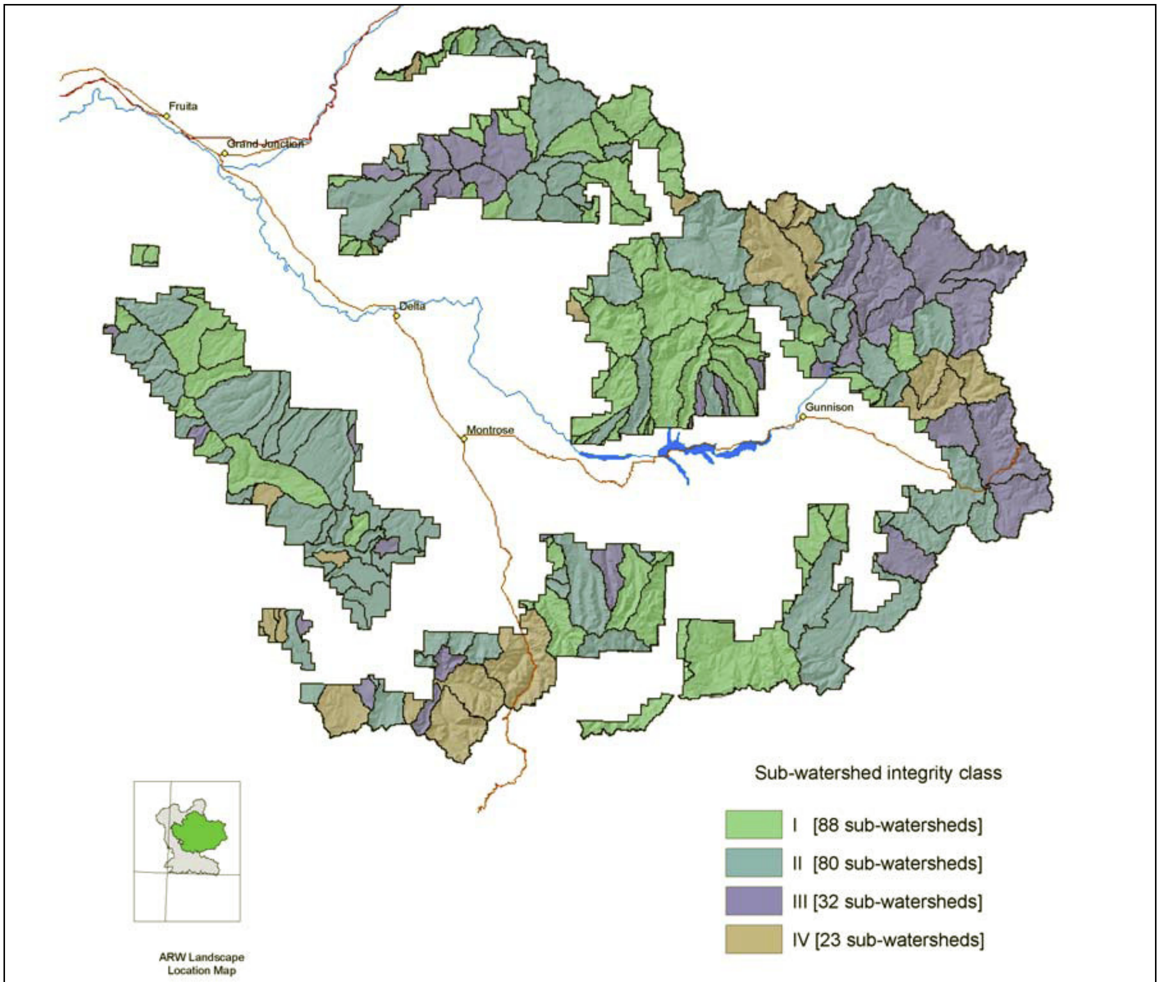

Figure 4. Sub-watershed (6th level HUC) integrity classes on the Forest.

Table 3. Brown trout occupied sub-watersheds (6th level HUC) by overall activity class, sensitivity class, and integrity class rating.

HUC6	HUC_NAME	ACT_CLASS	SEN_CLASS	INT_CLASS
140200040701	Anthracite Ck	2	3	2
140200020310	Beaver Ck	1	4	1
140200019904	Cement Ck	4	4	3
140300036506	Clear Ck	4	1	3
140200040702	Coal Ck	1	3	1
140300036305	Deep Ck	3	3	3
140200065001	East Fk Dry Ck	4	1	2
140200028302	Hensen Ck	2	4	2
140200040902	Lee Ck	1	3	1
140300036504	Little Red Canyon	2	1	1
140200038704	Lower Cochetopa Ck C	2	1	1
140200039301	Lower Quartz Ck C	4	4	4
140200019501	Lower Taylor River C	3	3	3
140200039102	Marshall Ck	3	3	3
140200019907	Mid East River C	4	4	4
140200019908	Slate River	4	4	4
140300036304	S. Fk San Miguel River	4	4	4
140200019505	Spring Ck	3	3	3
140200041103	Terror Ck	3	2	2
140100051906	Upper Buzzard Ck	3	3	2
140200038701	Upper Cochetopa Ck	2	3	2
140200039304	Upper Quartz Ck	4	4	4
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 brown trout populations residing on the Forest. These population estimates serve as a baseline to track changes in distribution and abundance. However, temporal fluctuations in brown trout abundance may make population trends difficult to discern (Belica, 2007).

Though no fish scale or otolith data has been collected to determine age classes, brown trout populations across the Forest appear to represent various age classes. Both juveniles and adults are regularly sampled and sizes range from 35-690 mm in total length (Figure 5) (GMUG 2008, unpublished data). Fish larger than 200 mm were observed in 33% of the total fish sampled, with most fish ranging between 50-300 mm. The large range in abundance and size reflect different growth rates for populations residing in large streams/rivers (bankfull width >12m) compared to smaller streams.

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

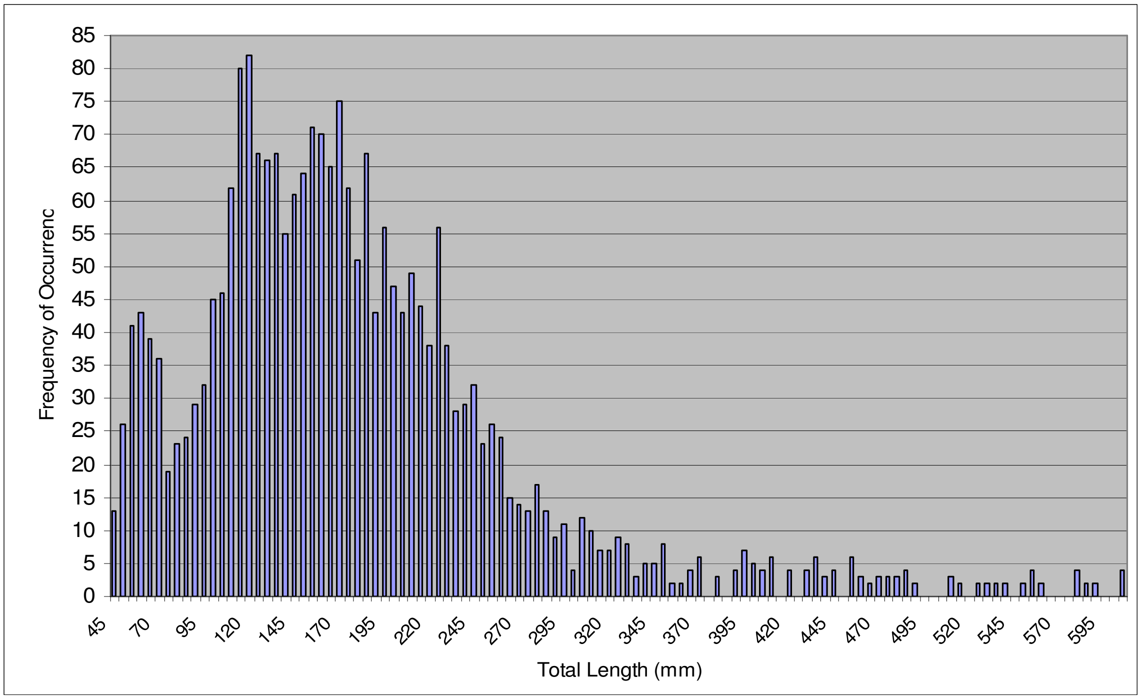

Figure 5. Frequency of occurrence of brown trout by total length on the Forest from 2000-2007.

Activity Patterns and Movements

Brown trout can be found in suitable cold water habitats, including lakes, reservoirs, streams and rivers. Throughout the Forest, the majority of brown trout are considered fluvial or resident populations. It is also suspected that several adfluvial populations of brown trout (fish that inhabit lakes and migrate into rivers/streams to spawn) exist in some of the larger drainages across the Forest. A few examples of adfluvial behavior have been observed in the Upper and Lower Taylor River, Lower Cochetopa Creek, Cebolla Creek, Slate River, Big Cimarron River, and the San Miguel River.

Life history adaptations of salmoinds, particularly anadromous fish species, have been well research. Literature indicates that juvenile movement and straying of adults are important factors that allow anadromous populations to persist through periods of catastrophic disturbances (Reeves *et al.* 1995). Similar to anadromous adaptations, Forest biologist consider adfluvial behavior to be a central mechanism for brown trout sustainability during disturbances. Additionally, fish habitat across the Forest is dynamic and patchy. In a study of spawning migration of adfluvial brown trout, the average minimum daily movement was 348m (0.22miles) and the furthest observation was 30km (18.6miles) upstream of the study site (Saraniemi *et al.* 2008). Potentially long distance movement and straying of brown trout during spawning may allow meta-populations to more successfully persist during periods of drought, other natural disturbances, and changes in habitat due to management activities.

Movement within and between water bodies is relatively unrestricted across the Forest, except by natural and man-made barriers. Since 2004, over 200 road/stream crossing sites have been surveyed across the Forest. Approximately 11% of the sampled crossings were deemed questionable for aquatic organism passage. In nearly all cases with restricted passage, maximum velocity and minimum depth were limiting factors. The surveys and data analysis have facilitated the prioritization of stream restoration efforts. 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 brown trout. It should be noted that habitat conditions were assessed across the whole Forest, and reflect some streams not currently occupied by brown trout. Several important fish habitat parameters were sampled to determine the overall habitat conditions and requirements for brown 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). Given the headwater location of the Forest, brown trout distribution is likely limited to those systems with lower gradients, lower elevation and larger widths across the Forest.

Spawning substrate utilized by brown trout range from 3-100 mm, with preference towards substrate between 10-70mm (Raleigh *et al.* 1986, Reiser and Wesche 1977). Pebble count data from 210 stream reaches indicate that substrate from 3-100mm in size make up about 56% of the substrate composition. Preferred spawning substrate size between 10-70mm consisted of approximately 46% of the total substrate composition. The data suggest that suitable spawning gravel is available randomly throughout the sampled reaches. Across the Forest, biologists agree that there is probably no shortage of suitable spawning gravel in larger streams occupied by brown trout.

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). Data from 189 stream reaches indicate that areas typically suited for spawning consist of approximately 20% fines less than 2mm. Raleigh *et al.* (1986) describe optimal spawning conditions for brown trout to contain less than 5% fines. As fines approach 30% of the spawning gravel, low survival of embryos and fry is expected (Raleigh *et al.* 1986). Thus, the data suggest that fine sediment is likely a limiting factor to brown trout survival and recruitment.

Literature suggests that optimum water temperatures for brown trout is between 12-19°C, and mortality may occur when temperatures exceed 27°C (Raleigh *et al.* 1986). Based on existing temperature data, optimum water temperature requirements for brown 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). For adult brown trout, research has suggested that in winter, stream fish can reduce their feeding to sustain the minimum level of metabolic activity required considering the reduction of metabolic rates in cold water and the negligible growth that occurs during the season (Raleigh *et al.* 1986). For brown trout fry, if adequate substrate burial depth and acclimation to water temperature are not achieved, it is likely that the Forest temperature profile may impact growth rates or cause mortality (Hartman 1963, Raleigh *et al.* 1986).

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 brown trout size structure and habitat indicated that more large brown 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.

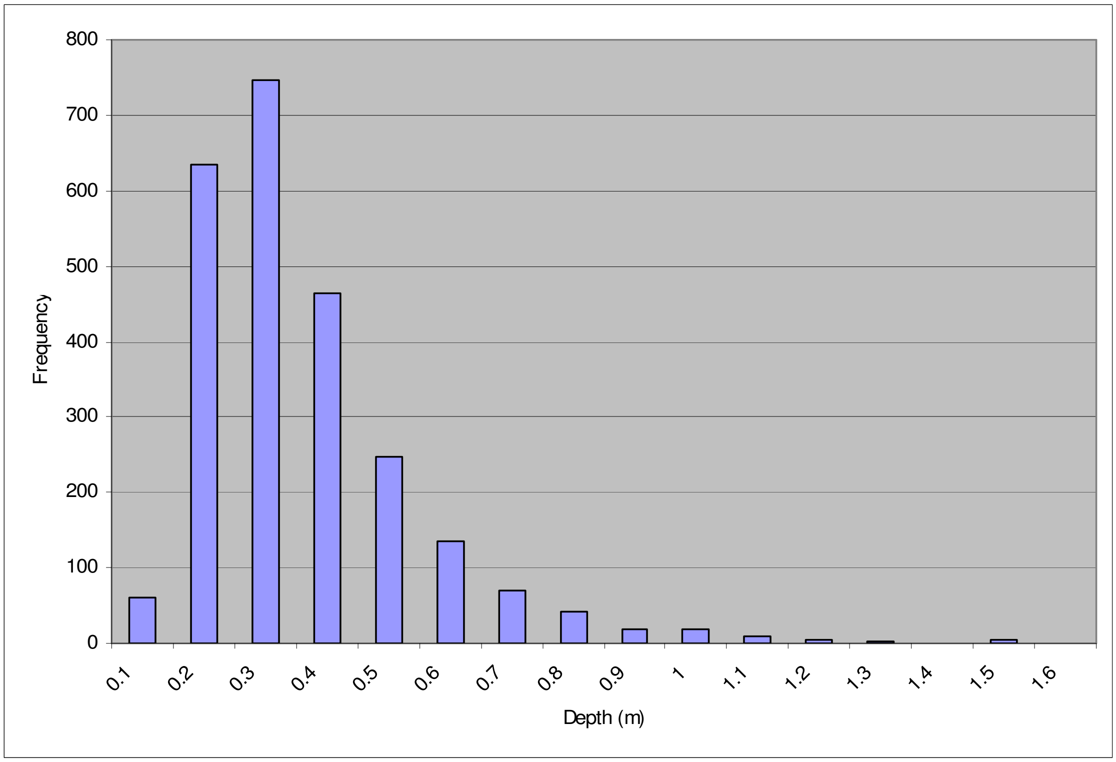

Figure 6. Histogram of residual pool depths across the Forest (n=2461).

Cover is an important component for trout survival, and brown trout seek cover more than any other trout species (Raleigh *et al.* 1986). Large woody debris (LWD), boulders, and undercut banks have been described as key cover components for trout (Giger 1972, Bjornn and Reiser 1991, Horan *et al*. 2000). 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 relatively abundant across the Forest and provides excellent cover for brown trout. Pebble count data suggests substrates such as small boulders (128-256 mm) and larger comprise approximately 25% of the substrate composition (n=210). Therefore, boulders may provide good sources of cover for brown 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 dominated by covered stable banks, while 14% were dominated by uncovered stable banks. 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 2001b). 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 rating characteristics for brown trout and rainbow trout in Wyoming as consisting of >55% cover and 0-9% eroding banks. Assuming that brown trout in Colorado require similar cover and bank requirements, 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 brown trout strongly prefer undercut banks and cover (Raleigh *et al.* 1986), it is likely that habitat improvements that target increased cover components may also increase brown trout density and/or abundance. Binns and Eiserman (1979) found that as cover increased, trout populations also increased.

Food Habits
Brown trout can be opportunistic feeders with more general food habitats or they can be specialized feeders (Belica 2007). Differences between specialist and generalist food habitats among brown trout have been attributed to differences in genetics and environmental factors experienced by populations (Bachman 1991, Belica 2007). In a Rocky Mountain stream in southwestern Colorado, Allan (1978) found that brown trout ranging in total length from 68-295 mm (2.7-11.6 inches) primarily fed on aquatic insects, terrestrial invertebrates, and non-insect aquatic invertebrates. In a study of brown trout in reservoirs, Kaeding and Kaya (1978) describes brown trout around 300 mm (11.8 inches) becoming piscivorous, feeding primarily on fish and crayfish, along with detritus and algae. Piscivorous brown trout (≥300 mm) in rivers and streams commonly consumed trout eggs during the fall and early winter (Kaeding and Kaya 1978).

Breeding Biology
A thorough assessment of the reproductive behavior of brown trout has been characterized in Belica (2007). Research suggests that spawning occurs at specific natal streams with low incidence of straying (Raleigh *et al.* 1986). Data from fish sampling suggests that brown trout likely mature at age 2-3 or approximately 100-150mm in length (Belica 2007). During spawning, mature females dig nests known as *redds* from gravel, and 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).

Locally, brown trout spawning occurs from mid-October through November (Table 4). Spawning is initiated by decreasing day length, increased late fall flows, and drops in water temperature to <9°C (Reiser and Wesche 1977, Raleigh *et al.* 1986). Incubation periods for brown trout range from 30-148 days at mean water temperatures ranging from 11.2 -1.9 °C respectively (Raleigh *et al.* 1986).

Table 4. The timing of four major life history stages for brown 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**									
Egg Incubation Period			**X**	**X**	**X**	**X**						
Summer Rearing	**X**							**X**	**X**	**X**	**X**	**X**
Winter Rearing			**X**	**X**	**X**	**X**	**X**					

Brown trout larvae remain in redds for several weeks after hatching as they continue to develop (Belica 2007). Larvae in redds are vulnerable to the same threats as eggs, but additional mortality occurs from the failure of some individuals to transition from feeding on yolks to feeding on live prey (Belica 2007).

Rearing life history has been divided into summer and winter rearing stages given that different behavioral patterns are displayed. During the late spring and early summer, brown trout generally occupy deep water in edge habitat types closer to cover and stream banks as they maintain drift-feeding behavior (Young 1995). In winter, when feeding activity declines, brown trout have been observed to aggregate more, particularly where pool habitat was limited (Cunjak and Power 1986, Belica 2007). Brown trout also tend to hide in the interstices of substrate or under banks in slow moving pools during winter (Belica 2007). Much of this change in behavior is triggered by cold-water temperatures, which lower the fish's metabolism and available energy. Lack of available winter rearing habitat can reduce the fish's ability to survive into the following summer.

The reproductive success rate of brown trout in terms of the number of young surviving to reproduce is low, despite high fecundity rates, given that offspring experience particularly high mortality rates during early life stages (Belica 2007). One study indicates that during the post-emergence period, survivorship rates for brown trout can be as low as 3% (Pender and Kwak 2002).

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). The genetic characteristics of naturalized and broodstock populations of brown trout in Region 2 of the Forest Service have been the subject of limited research (Belica 2007). As an introduced species, the spatial and genetic characteristics of brown trout populations are coupled with the species' ecology and the management of the species -both current and historic activities (Belica 2007).

Brown trout produced from broodstocks are used to supplement natural recruitment of wild populations and put-and-take fisheries in some systems across the Forest. There are also several recreational wild brown trout fisheries across the Forest which produce sizeable biomass. A synthesis of the basic life history characteristics of brown 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 - typical growth rates of brown trout are considered to be around 10cm (4 inches) per year for the first three years after which growth slows to roughly 5cm (2 inches) per year (Simpson and Wallace 1982).

Maximum size- The maximum size recorded on the Forest come from the Taylor River tail water fishery, which is supplemented by mysiss shrimp. Several brown trout have been recorded at 69cm (27 inches) and weigh over 10lbs.

Age of maturity/fecundity - 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 brown trout mature as early as age-2 or age-3, with males usually maturing before females (Bachman 1991, Elliott 1994). 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).

Life expectancy - In most North American streams, brown trout usually live 5-6 years, but can significantly extend their life span and attain larger sizes by shifting to a piscivorous diet (Behnke 2002). Brown trout on a predominately fish diet can extend their life span to 10-12 years (Behnke 2002).

Population age structure – Forest sampling indicates that in general, brown trout populations are composed of various classes and generally range from 35-600 mm in length. Naturalized brown 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 33% of the total fish sampled, with most fish ranging between 50-350 mm (Figure 7).

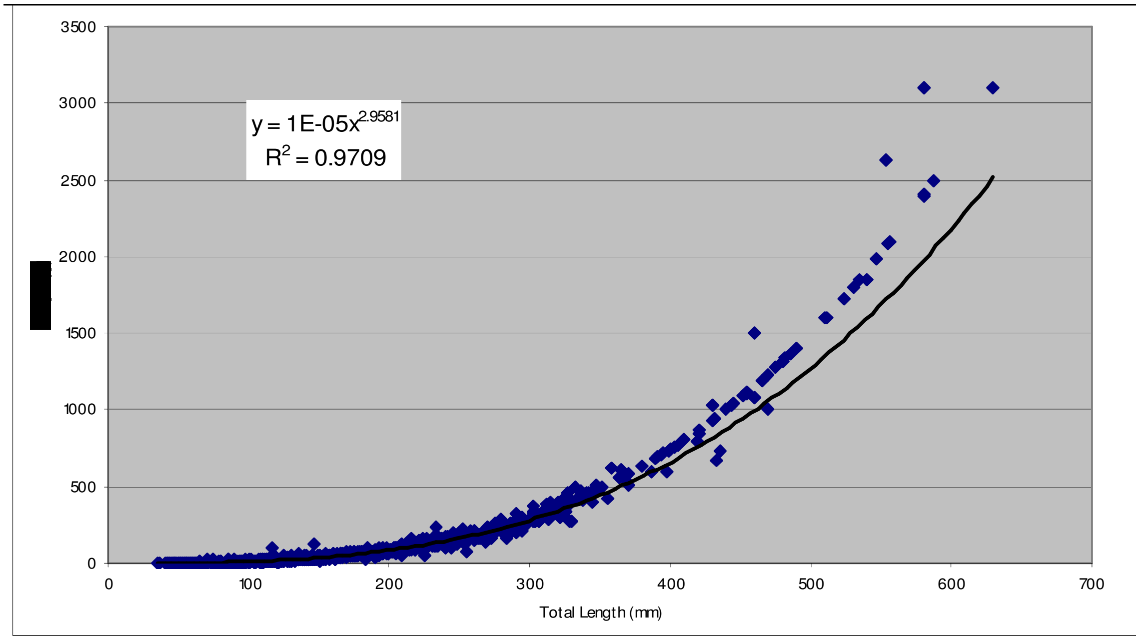

Figure 7. Length-weight relationship for brown trout on the Forest, 2000-2007

Community Ecology

Brown trout are often part of fish assemblages that include a variety of native and introduced salmonids (particularly rainbow trout), cyprinids, catostomids, and cottids (sculpins) (Belica 2007). As a non-native species, brown 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.

Brown trout also influence fish assemblage composition by preying intensively on the juvenile life stages of other salmonids more heavily than on their own (Fausch and White 1981). Where populations of native cutthroat trout or brook trout are found amongst brown trout, predation and displacement from preferred habitat by brown trout is common (McHugh *et al.* in press). In some cases, brown trout have completely replaced cutthroat trout in parts of their range, particularly in large rivers and lakes (Fuller *et al.* 1999, Behnke 2002).

Predation and Disease

Mortality of adult brown trout is caused by predation, adverse environmental conditions, and disease. Piscivorous birds, mammals, and fish prey on brown trout. However, as a popular sport fish, angling may be the predominant form of predation in some systems on the Forest.

Brown trout are susceptible to a range of fish parasites and bacterial diseases (Belica 2007). Whirling disease (WD) has become a widespread problem on the Forest, particularly in rainbow trout populations. WD is caused by the water-born parasite (*Myxobolus cerebralis)* and a secondary host worm (*Tubifex tubifex*) (Markiw 1992). Unlike rainbow trout that have high susceptibility to WD, brown trout are considered "partially resistant" to the disease (CDOW 2007). Laboratory studies have demonstrated that clinical signs of WD are rare among brown trout and only develop when fish are exposed to very high parasite doses (Belica 2007).

CONSERVATION OF BROWN TROUT

Threats

The greatest threats to the viability of brown 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 trout include limiting habitat and food resources, impeding movement, and increasing summer water temperature or decreasing water quality (Belica 2007). Reduced flows also negatively affect the sediment transport regime. Since fine sediment appears to be a limiting factor in brown trout survival across the Forest, reduced flows may exacerbate an existing problem by diminishing flushing flows. Additionally, reduced flows can limit the formation of large deep pools and undercut banks, which are also considered limiting factors for brown 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 brown trout to colonize sections of streams that may provide natal spawning areas or preferred habitat. 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 results in the trampling of stream banks and loss of riparian vegetation. For brown trout in particular, undercut banks are necessary components for survival, as they prefer habitat with cover and dim light (Behnke 2002). Historic livestock use has had dire impacts on riparian and 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 potentially 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 activities and effect macroinvertebrate density, which are the primary food sources for trout. Areas where the road system parallels the stream in close proximity have the greatest risk of impacting fish habitat, and causing downstream impacts.

Recreational fishing can also contribute to major changes in brown 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 brown trout includes prioritizing watersheds for maintenance and/or improvement of stream flow, riparian vegetation, and stream habitat needed to maintain brown 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 the existing watershed conditions. Future land management activities in Class I watersheds should be carefully assessed to determine long-term impacts to the sustainability of trout populations.

Only those activities, through project level evaluation, determined to be compatible with the goals and objectives of the Forest and maintain high quality habitat or improve degraded habitat or 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 provide 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 previously include maintaining favorable flows, restoring habitat connectivity and restoring habitat attributes that were identified as limiting factors to brown trout populations currently. 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, and site specific evaluation of minimum flow requirements.

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 various water resource stakeholder groups to help address in-stream flow needs and strategic protection. The Forest should make use of the steering committee report to implement in-stream flow protection (USFS 2004). The Forest could also collaborate with the Bureau of Land Management (BLM), as their in-stream flow program is well established.

Collaborating with the BLM will maximize the protection of federal habitat by establishing flows necessary for species diversity and abundance. It should be noted that in-stream flow protection is a long-term strategy and that to protect stream flow immediately active participation and buy-in from water users is absolutely necessary.

Efforts to reduce habitat fragmentation across the Forest should include replacing culverts and improving stream/road crossings that restrict 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 may create more sustainable brown trout populations across the Forest.

INFORMATION NEEDS

Locally, the Forest needs to continue to inventory current habitat conditions in brown trout occupied streams and monitor population abundance and distribution. Tracking the range and site-specific distribution of brown trout across the Forest will help identify areas where brown trout presence may be impacting native trout through predation and competition for suitable habitat.

Understanding the species interactions and ranges of overlap between brown 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 brown 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 brown trout populations where appropriate, while meeting Forest Plan standards to protect native fish.

APPENDIX

Table 1. List of brown trout (minimum 150mm) occupied reaches and population estimates with 95% confidence intervals, and fish per mile estimates with 95% confidence intervals. Estimates based on Jakomatic version 1.9, 2007.

SiteID	StreamName	PopEst	PopEst 95%CI	Fish/Mile	Fish/Mile 95% CI
MARSH2006-1	Marshall Cr	32.91	3.09	451	42
MQUARTZ2006-1	Middle Quartz Cr	28.18	3.88	574	79
PAUL2006-1	Pauline Cr	2	0	32	0
PAUL2006-2	Pauline Cr	7.67	5.76	156	117
PAUL2006-3	Pauline Cr	1	0	12	0
PAUL2006-9	Pauline Cr	2	0	28	0
TDEEP2004-1	Deep Cr	18.14	1.36	323	24
COAL2006-1	Coal Cr	4	2.94	64	47
NANT2002-1	North Anthracite Creek	8	1.08	258	35
NANT2002-2	North Anthracite Creek	6	0	193	0
NANT2002-3	North Anthracite Creek	6	1.5	193	48
NANT2002-4	North Anthracite Creek	7	9.6	309	225
NANT2002-5	North Anthracite Creek	1	0	32	0
NANT2002-6	North Anthracite Creek	1	0	32	0
EFDRY2003-1	EF Dry Creek	11.5	8.13	185	131
CLEA2001-1	Clear Creek	1	0	11	0
LRED2005-1	Little Red Canyon Cr	1	0	15	0
LRED2005-2	Little Red Canyon Cr	2	0	31	0
LEE2005-1	Lee Creek	3	6.79	112	50
CHAV2004-2	Chavez Creek	7	9.6	114	83
EFWI2002-1	E Willow Creek	3	6.79	107	47
MFWI2002-1	M Willow Creek	12	0	193	0
WFWI2002-1	W Willow Creek	39.75	4.55	374	43
WIL2005-1	Willow Cr	62.25	4.74	972	74
BVR2006-3	Beaver Creek	2	0	35	0
CEMT2005-3	Cement Creek	5	0	55	0
CEMT2005-4	Cement Creek	108.5	6.69	1160	72
COAL2006-7	Coal Creek	9.4	3.29	120	42
COCH2001-1	Cochetopa Creek	2	0	21	0
EAST2005-1	East River	23.8	3.18	140	19
HENS2005-3	Henson Creek	15	0.63	143	6
NANT2005-2	North Fk Anthracite Cr	7	26.3	348	93
PASS2001-1	Pass Creek	17.5	5.88	185	62
QUARTZ2002-1	Quartz Creek	113.59	4.53	1200	48
QUARTZ2003-1	Quartz Creek	127.98	5.89	1351	62
QUARTZ2004-1	Quartz Creek	133.8	4.62	14143	49
QUARTZ2005-1	Quartz Creek	83.29	6.97	879	74
SLAT2005-1	Slate River	16	0.6	188	7
SMIG2004-1	San Miguel South Fork	5	1.95	65	25
SMIG2004-2	San Miguel South Fork	17.55	2.81	171	27
SMIG2006-1	San Miguel South Fork	16.71	6.82	162	66
SMIG2006-2	San Miguel South Fork	5	0	49	0

SiteID	StreamName	PopEst	PopEst 95%CI	Fish/Mile	Fish/Mile 95% CI
SPRG2001-1	Spring Creek	6	0	63	0
SPRG2003-1	Spring Creek	246.4	4.73	3424	66
SPRG2003-2	Spring Creek	156.63	8.06	2432	125
SPRG2003-3	Spring Creek	309.4	8.16	3025	8
TAYL2005-1	Taylor River	93.81	21.4	991	226
TAYL2005-2	Taylor River	69.88	17.2	738	182
TAYL2006-1	Taylor River	52.74	10.7	381	77
TAYL2006-2	Taylor River	152.59	19.2	448	56
TAYL2006-3	Taylor River	99.34	16	561	90
TDEEP2004-2	Deep Creek	18.14	1.36	323	24
WILO2006-1	Willow Creek	1	0	20	0

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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.