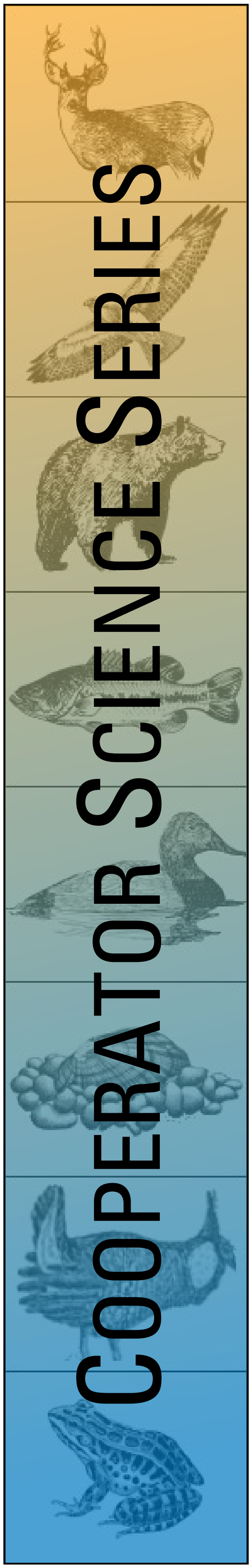

U.S. Fish and Wildlife Service

Restoration of Rio Grande Cutthroat Trout Oncorhynchus clarkii virginalis to the Mescalero Apache Reservation

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Cooperator Science Series # 111-2014

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Restoration of Rio Grande Cutthroat Trout *Oncorhynchus clarkii virginalis* to the Mescalero Apache Reservation

Final Report
USFWS Cooperator Science Series # 110-2014

Mescalero Apache Reservation

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Executive Summary

Rio Grande Cutthroat trout *Oncorhynchus clarkii virginalis* (RGCT) represents the most southern subspecies of cutthroat trout, endemic to Rio Grande, Canadian, and Pecos basins of New Mexico and southern Colorado. The subspecies currently occupies less than 12% of its historic range. The Mescalero Apache Tribe has partnered with U.S. Geological Survey-New Mexico Cooperative Fish and Wildlife Research Unit, New Mexico State University, U.S. Fish and Wildlife Service, and New Mexico Department of Game and Fish to meet mutually shared goals of restoring and maintaining a Pecos strain of RGCT to Tribal lands. The goal of this project was to assess the suitability of the Rio Ruidoso within the Mescalero Apache Reservation to support a self-sustaining RGCT population by conducting a systematic and comprehensive survey. We conducted three surveys (fall 2010, spring 2011 and 2012) to characterize water quality, macroinvertebrate assemblages, fish communities, and physical habitat (stream size, channel gradient, channel substrate, habitat complexity, riparian vegetation cover and structure, migration barriers to movement).

Seven-100 m reaches throughout three major tributaries of the Rio Ruidoso within the Tribal lands were sampled during baseflow conditions October 2010, May 2011, and June 2012. Despite the onset of severe drought in 2011, water quality, physical habitat, and fish populations revealed that the Rio Ruidoso and its three tributaries would most likely support a self-sustaining RGCT population. Pools were abundant (mean, 8.9 pools/100 m), instream woody debris was present (range, 3.8-45.6 pieces/100 m), and instream dataloggers revealed daily maximum stream temperatures rarely exceeded criteria established in New Mexico for coldwater fishes, however, presence of frazil and anchor ice may limit fish distribution in the winter. Aquatic macroinvertebrate samples revealed a community of benthic invertebrates reflective of high quality cool to cold water. Overall densities of brown trout, rainbow trout and brook trout were high (overall mean, 0.23 fish/m^2) and in relatively good condition (range of mean relative weight, 84-117).

Should the Mescalero Apache Tribe decide to introduce RGCT, prior to chemical treatment, a barrier placed below the confluence of Middle and South forks of the Rio Ruidoso would create approximately 12 km of perennial flow and help protect against invasion of non-native fishes. The North Fork of the Rio Ruidoso is not a good candidate for reintroduction because of easy access by the public to reintroduce non-native fishes into the watershed. Lastly, an annual, long-term monitoring program of RGCT would help document that there was no subsequent incursion of non-native fishes.

Introduction

With the completion of the New Mexico Comprehensive Wildlife Conservation Strategy, 37 native fishes were listed as *Species of Greatest Conservation Need* (NMDGF 2006). These species were considered vulnerable, imperiled, or critically imperiled at both the state and federal level. One coldwater fish receiving considerable attention in New Mexico is the state-protected Rio Grande cutthroat trout *Oncorhynchus clarkii virginalis* (RGCT). The subspecies represents the southernmost cutthroat trout and is endemic to northern New Mexico and southern Colorado. Factors contributing to its decline include hydrologic modifications, competition/hybridization of non-native fishes, and habitat degradation related to livestock grazing, logging, roads, mining and water diversion. Approximately 120 populations of RGCT are self-sustaining throughout the Rio Grande, Pecos, and Canadian watersheds, representing less than 12% of its presumed historic range (Alves et al. 2008). Many of these remaining populations are at risk of extirpation due to climate warming (Zeigler et al. 2012) and low discharge (less than 1.0 cubic feet per second; Zeigler et al. 2013). Stream lengths as short as 3 km and the presence of barriers increase their vulnerability to environmental perturbations, such as drought, fire, and climate change. The subspecies was petitioned and warranted for listing under the Endangered Species Act of 1973 but precluded by higher listing priorities and actions (U.S. Federal Register 2008).

The New Mexico Department of Game and Fish currently manages broodstock for three lineages that belong to Rio Grande, Pecos, and Canadian drainages. The most representative of the three is the Rio Grande lineage with 97 populations (Alves et al. 2008). In contrast, the Pecos drainage has 11 populations, with one population on the west facing slopes of the Sacramento Mountains (Alves et al. 2008). Bachhuber (1971) suggested that Estancia, Pinos Wells, and Encino basins provided a route for fish movement during pluvial periods 10,000 - 15,000 year ago. To this day, White and Sacramento mountains maintain a surface connection to the Pecos drainage via Rio Ruidoso, Rio Hondo, and Rio Peñasco. A report from 1854 described a faunal and floral survey of the Sacramento River (tributary of the Pecos in southeastern New Mexico) and identified the presence of trout (Garrett and Matlock 1991). Koster (1957) believed at one time these fish were probably *O. clarkii*. Although the southeastern extent of RGCT range is unknown, anecdotal evidence indicates *O. clarkii* may have existed as far east as the Limpia River (Davis Mountains, Texas) and Devil's River (Del Rio, Texas).

Over the past twenty years, the Mescalero Apache Tribe (Tribe) has managed a series of watersheds on the Mescalero Apache Reservation as a native trout fishery, accepting accounts that a pure strain of RGCT existed at one time. However, a study revealed cutthroat trout within their drainage were not a pure strain (Pritchard and Cowley 2005). Pritchard and Cowley (2005) found many of the New Mexico populations of RGCT were introgressed with introduced rainbow trout *O. mykiss*, Yellowstone cutthroat trout *O. c. bouvieri,* and Snake River Fine-spotted cutthroat trout *O. c. behnkei*. In particular, Pritchard and Cowley (2005) described the Indian Creek population within the Three Rivers Watershed was related to Yellowstone cutthroat trout and postulated fish in the Tularosa basin originated from stockings of various subspecies of *O. clarkii*. The authors stated that large numbers of non-native trout were transplanted throughout the subspecies' range since the late 1800s and hence, RGCT populations were replaced with hybrid swarms or lost completely.

Regardless of these findings, the long-term goal of the Tribe is to restore native RGCT to its Reservation streams. While this goal represents a long term endeavor by the Tribe, the near-term objectives were to characterize and recommend restoration of habitat suitable for self-sustaining populations of RGCT. The Tribe and its Council agreed to partner with U.S. Geological Survey-New Mexico Cooperative Fish and Wildlife Research Unit, New Mexico State University, U.S. Fish and Wildlife Service, and New Mexico Department of Game and Fish to meet mutually shared goals of expanding, restoring, and maintaining a population of RGCT within its historic range. If necessary, the Tribe will consider restoring streams within their lands to serve as refugia for the Pecos strain of RGCT. These populations will be obtained from either local populations in the Pecos drainage or from a State hatchery.

The goal of this project was to assess the suitability of the Rio Ruidoso and its three main tributaries to support a self-sustaining RGCT population (Pecos strain) on the Reservation. The objective was to conduct a systematic and comprehensive survey of the main stem, North Fork, Middle Fork, and South Fork of the Rio Ruidoso to characterize water quality, physical habitat (i.e., stream size, channel gradient, channel substrate, habitat complexity, riparian vegetation cover and structure, migration barriers), macroinvertebrate assemblages, and fish communities. A final objective was to provide management recommendations to the Tribe regarding conservation measures to establish a self-sustaining RGCT population.

Study Area

Mescalero Apache Reservation is approximately 186,483 hectares and located in south-central New Mexico on the eastern edge of the Sacramento Mountains (Otero County). Elevation ranges from 1,650 to 3,650 m at the highest peak, Sierra Blanca. From this summit, flow three watersheds (Three Rivers, Riconada, and Ruidoso). Within the Rio Ruidoso, an estimated 30 km of perennial headwater streams is contained within Reservation boundaries. Three tributaries feed into the main stem of the Rio Ruidoso. These include South Fork (6 km), Middle Fork (6 km), and North Fork (14 km) which all flow into the main stem (4 km) before flowing east off the Reservation to the Rio Hondo (Figure 1). Road access to the watershed is limited to the first 2.5 km of the main stem and at the headwaters of the North Fork where a ski resort is located. During early reconnaissance surveys, one barrier on the South Fork and two barriers on the Middle Fork were identified (Figure 1).

Methods

Study Sites

Due to time restraints and the difficulty in accessing much of the Rio Ruidoso watershed, two 100 m sites were established on each tributary (North Fork, Middle Fork, South Fork) as well as one-100 m site on the main stem of the Rio Ruidoso (Figure 1). Sites were non-randomly selected based on representativeness of the stream length exhibiting a combination of pools, runs and adequate riffles for assessing the distribution of fish and macroinvertebrate community. All sites were sampled during base flow conditions October 2010 (fall 2010), May 2011 (spring 2011), and June 2012 (spring 2012).

Water Quality

Water temperature (°C), pH, dissolved oxygen (mg/L), and conductivity (µmho/S) were collected at each site at the time of fish and macroinvertebrate collections using a Hach HQd meter (Hach Company, Loveland, Colorado). Water samples were also collected in 500 ml Nalgene™ bottles and chilled until analyzed by New Mexico State University Soil, Water, and Agricultural Testing Laboratory. Samples were analyzed for alkalinity (mg/L as total $CaCO_3$), total dissolved solids (mg/L), calcium (meq/L), magnesium (meq/L), and hardness (mg/L as total $CaCO_3$). During fall 2011, samples from North Fork were also tested for nitrate/nitrite levels (mg/L) because of elevated nutrients potentially deposited from the Ski Apache Resort into

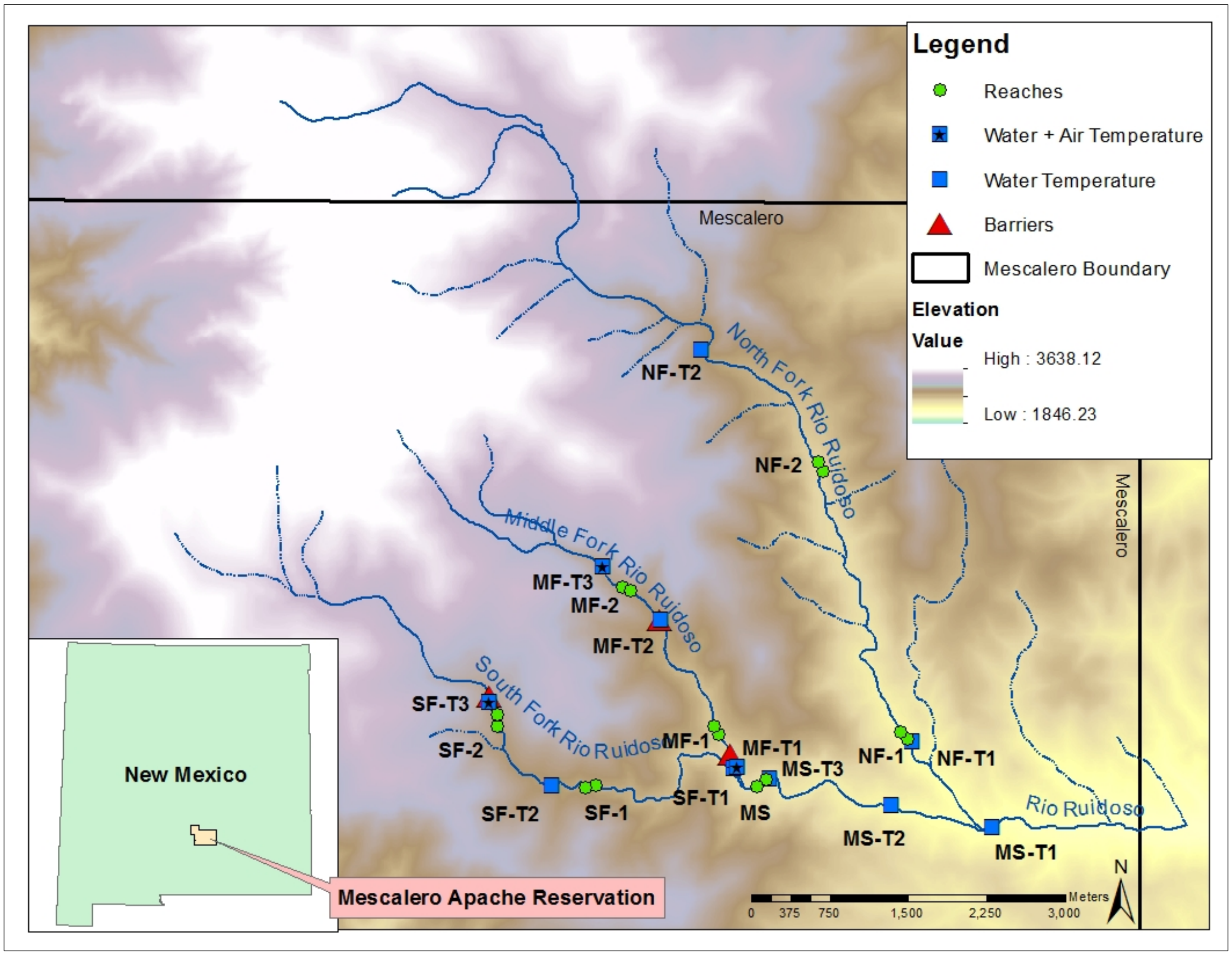

Figure 1. Map of the headwaters of the Rio Ruidoso Watershed in south-central New Mexico showing the streams (solid lines are perennial streams and dashed lines are ephemeral streams), Mescalero Apache Reservation boundary (solid black line), fish barriers (triangles), study sites (green circles), paired air and water temperature loggers (squares with stars), and unpaired water temperature loggers (squares without stars).

the upstream reaches. Samples, however, were not tested for these nutrients in subsequent collections.

Stream Temperatures

Eleven instream data loggers (Onset Computer Corporation HOBO U22 ProV2 Water Temperature Data Loggers; resolution ± 0.02°C, accuracy ± 0.2°C) were placed throughout the study area May 2010 and additional units were placed further upstream into the headwaters August 2010 (Figure 1). Four instream data loggers were paired with air data loggers placed near the stream to record air temperatures at hourly intervals with one air logger paired with both Middle (MF-T1) and South (SF-T1; Figure 1) forks. Data loggers were placed in a PVC housing to reduce the influence of direct solar radiation on the logger and attached to a metal stake driven into the thalweg of the stream. Data loggers were set to record hourly stream temperatures which were then used to compute daily mean, maximum, and minimum temperatures. Prior to use, all data loggers were tested for proper function and to ensure loggers were within the manufacture's stated accuracy using water baths maintained at 0°C and 25°C.

Stream Morphology and Fish Habitat

Baseline stream morphological data were collected from four cross-sectional transects spaced 25 m apart within each study site. Bankfull width, wetted width, and bankfull depths were measured at 10 equally spaced points across each transect. Flood prone width, defined as the width at two times the maximum bankfull depth (Rosgen 1994) was also measured. Bankfull state was assessed using morphological, botanical, and topographical indicators (Leopold 1994). Width-depth and entrenchment ratios were calculated for each sample site according to Rosgen (1994). The gradient of each study reach was measured using a clinometer over distances of 20-25 m along the surface of each site. A weighted average was then computed to get the overall gradient of each sample site. Large woody debris, defined at least 10 cm in diameter at the base and at least 1 m in length (Kaufmann et al. 1999) were tallied throughout each sample site. Discharge was calculated using a Marsh-McBirney Flow-mate portable velocity meter (Hach Company) from velocity measurements at 10 equally spaced points across the stream transect at 60% of the stream depth.

Stream bank stability and cover were measured at each transect (two samples per transect for a total of eight samples per sample site) according to methods described by Platts et al. (1987) and modified by Bauer and Burton (1993). Cover was visually estimated on left and right stream banks for areas 0.5 m on the upstream and downstream sides of each transect from the stream margin to bankfull. Stream banks were classified as ‘covered’ if any of the following criteria were met: 1) greater than 50% live vegetation covering the stream bank; 2) sedge or deeply rooted vegetation with roots covering greater than 50% of the stream bank; 3) minimum of 50% of the stream bank covered by substrate equal to or larger than 10 cm; or 4) minimum of 50% of the stream bank covered by large wood greater than 10 cm in diameter (Bauer and Burton 1993). If none of the above criteria were met, stream banks were classified as ‘uncovered’. Stream banks were classified as ‘unstable’ if any of the following features were exhibited: 1) depositional features classified as uncovered; 2) fractured bank with slump block still attached classified as uncovered above the slump block; 3) visible fracture in the top of the stream bank; or 4) fractured stream bank with unattached slump block (Kershner et al. 2004). Stream banks not exhibiting any of the above criteria were classified as ‘stable’. Stream banks were classified into one of four groups based on the combination of cover and stability: 1) covered/stable; 2) uncovered/stable; 3) covered/unstable; or 4) uncovered/unstable. Each group was then assigned a rating to determine erosion potential based on the combination of cover and stability (McInnis and McIver 2001):

Cover/Stability	Erosion Index
Covered/Stable	1
Uncovered/Stable	2
Covered/Unstable	2
Uncovered/Unstable	3

Erosion potential was then estimated for each sample site using the following equation:

$$ErosionPotential = \frac{\sum_{i=1}^{8} EI_i}{N_{total}}$$

where, EI_i = erosion potential for samples i = 1-8 and N_{total} = total number of samples per reach. The erosion potential could vary from 1.0 (least erosion potential) to 3.0 (highest erosion potential). Reaches rated 2.0 were vulnerable to erosion because they lacked either cover or stability.

Left and right bank angles were measured at each transect by laying a stadia rod perpendicular to stream flow on the bank and setting a clinometer along the length of the rod. Undercut bank depth was measured at any transect intersecting an undercut bank according to methods described by Kershner et al. (2004). The following criteria had to be met for banks to be considered undercut: 1) minimum depth of 5 cm; 2) minimum height of 10 cm; and 3) minimum length of 10 cm. These criteria were used to identify undercut stream banks providing instream cover to salmonids. Stream banks meeting these criteria were then measured by probing the bank for maximum depth of the undercut. Prevalence of undercut banks was also estimated as the number of observed undercut banks divided by the total number of transects within each sample site.

Overhead riparian vegetation cover was estimated at each transect following the methods by Kaufmann et al. (1999) using a spherical densitometer modified according to Mulvey et al. (1992). Overhead cover was combined along each transect to obtain percent overhead cover for each transect. The four transects were averaged to calculate the mean percent overhead cover for each reach.

Habitat units within each study reach were categorized as either pool or riffle/run, and then measured to the nearest decimeter along the length of the thalweg (deepest channel). Riffles and runs were defined as areas of shallow to moderate depth, moderate to broad surface agitation, and a mean water column velocity of greater than 10 cm/s (Herger et al. 1996). Both riffles and runs were combined into one category because it is often difficult to discern the difference between the two; especially when what may appear to be a run at high flows is actually a riffle at lower flows (Platts et al. 1983). Pools were defined as deep water habitats relative to adjacent habitats, little or no surface flow, substrate consisting of sediments finer than adjacent faster-flowing habitats, and a mean water column velocity of less than 10 cm/s (Herger et al. 1996). Maximum pool depth was measured for all pools within the reach as well as the maximum depth of the riffle crest at the tail of the pool to obtain residual pool depth, which was calculated as the difference between the maximum pool depth and the maximum depth of the riffle crest. Pool-riffle ratios were calculated by dividing the combined pool lengths by the combined riffle/run lengths.

Instream substrate was assessed using zig-zag pebble count method described by Bevenger and King (1995) and classified according to the modified Wentworth particle size scale of Cummins (1962). Fine sediments were defined to be material less than 2 mm and percent fines was calculated by dividing the number of particles less than 2 mm by the total number of particles measured.

Aquatic Benthic Macroinvertebrate Assemblage

Within each 100-m sample site, three benthic macroinvertebrate collections were obtained from riffles using a Surber sampler. Samples were preserved in Whirl-Paks^{TM} containing 95% ethanol and processed at New Mexico State University (NMSU), Department of Fish, Wildlife and Conservation Ecology. Benthic macroinvertebrates were removed from debris and preserved in vials containing 95% ethanol for identification to the lowest possible taxon using taxonomic keys (Merritt and Cummins 1996; Pennak 1978; Ward and Kondratieff 1992).

Benthic macroinvertebrates were tabulated and summary statistics (mean and standard error, SE) were computed for total standing crop (total number of organisms/m^2) and taxa or species richness (total number of taxa) within season (fall 2010, spring 2011 and 2012). To characterize ecological responses of the macroinvertebrate community, multimetric assessments of Plafkin et al. (1989), Barbour et al. (1992, 1999) as modified by Jacobi et al. (1998) were conducted and compared across sites within season. The multimetric assessments included an analysis of community structure, community balance, and functional feeding guilds for each site and from these, a biological condition rating was assessed (Winget and Mangum 1979; Plafkin et al. 1989) (Table 1). In addition, the multimetric assessments provided a visual analysis of changes in the composition of the macroinvertebrate community. The Biotic Condition Index (BCI) was used as an assessment of community structure because it is specific to the Rocky Mountain Region and has proved effective in assessing biotic resilience to disturbances that includes, but does not differentiate from, disturbances such as fire, drought, and nutrient input (Jacobi et al. 1998). Of importance, numerical rankings for each multimetric score represent the percentage of actual conditions compared to the rating of the reference stream; thus a stream's condition in relation to its own potential was evaluated and not that of another theoretical reference stream. The main stem of the Rio Ruidoso was used as the reference stream from which all sites were compared against. Scores closer to the Biological Condition Rating of 100% indicated better than predicted biotic conditions and scores further from 100% indicate a stream site was not performing at its biological potential. Scoring criteria and interpretation of scores followed the technique described by Jacobi et al. (1998) and Barbour et al. (1992). The biological condition rating (BCR) has a possible score of 66.

Fish Assemblage and Population Structural Indices

Fish were collected within the same 100-m site sample sites as the benthic macroinvertebrates. Two block nets (6 mm mesh seines) were placed at upstream and downstream boundaries to prevent immigration and emigration during electrofishing. Two consecutive upstream electrofishing passes were conducted using Model LR-24, Smith-Root backpack unit. Fish were removed from the stream and held in a live car upstream of the site until completion of the second pass. Fish were measured for total length (TL) to the nearest 1.0 mm and weighed to the nearest 1.0 g using a hanging scale (Pesola, Kapuskasing, Ontario). In spring 2011, all trout were tagged with floy tags in the dorsal musculature to determine fish growth and movement.

Population estimates were calculated for each species using MicroFish 3.0 software (Van Deventer and Platts 1989), which uses the Burnham maximum likelihood population estimate formula (Van Deventer and Platts 1983). Densities (fish/m^2) were estimated separately for adult (age-1+) and age-0 fish to minimize potential overestimation of population abundance due to differential catchability among size classes. Density and standing crop (kg/ha) estimates were calculated using mean stream wetted width collected from cross-sectional transects of each study site. Brown trout *Salmo trutta*, brook trout *Salvelinus fontinalis*, and rainbow trout *Oncorhynchus mykiss* recruitment was estimated as the number of age-0 individuals collected in the fall following spawning (i.e., 2010 brown trout and brook trout recruitment refers to the 2009 spawning class, and 2010 rainbow trout recruitment refers to the 2010 spawning class).

Age analysis was assessed for each sampling occasion (spring and fall) within each study site using length-frequency distributions constructed using TL data to identify age-0 fish and age-1+ fish. Total lengths for fish were partitioned into 5 mm intervals with the initial interval being the minimum observed TL length and the final interval being the maximum TL observed among all individuals.

Table 1. Metrics used in multimetric bioassessment of the macroinvertebrate community throughout study reaches on the Rio Ruidoso to assess community structure (1-3), community balance (4-5), and functional feeding guilds (6-11) as modified by Jacobi et al. (1998).

Metric	Description
(1) Total number of organisms/m^2	Total standing crop
(2) Total number of different taxa	Taxa richness
(3) Biological Condition Index	Assesses biotic resilience of the communities to disturbance
(4) Hilsenhoff Biotic Index	Measures sensitivity to perturbation; as sites become more ‘disturbed’ through nutrient input, the suite of more tolerant organisms will be represented
(5) EPT Index	Ephemeroptera (mayflies) + Plecoptera (stoneflies) + Trichoptera (caddisflies)
(6) EPT/(EPT + Chironomidae)	An even distribution among all four functional groups indicates good biotic condition versus a shift to a lower ratio indicates a disproportionate number of tolerant Chironomidae
(7) Community Loss	Difference in total taxa between reference and treatment sites; an increase reflects a greater difference (or loss) in the total taxa when compared to the reference site
(8) Dominant Taxa (%)	Percent abundance of a single taxon / total number of organisms in sample; reflects the imbalance of the community; the larger the number, greater representation of a single taxon
(9) Diversity Index	Distribution richness among all taxa; the larger the number, the greater the diversity of the representative organisms
(10) Scrapers/Scrapers + Filterers	Greater number of filterers indicates a filamentous algae food base presumably in response to increased nutrients; the smaller the number, the greater representation of filterers compared to scrapers
(11) Total shredders/Total organisms	Ratio reflecting riparian and in-stream vegetation contribution to the aquatic food base; the larger the number, the greater the representation of shredders with respect to the total organisms.

Total length and weight data were used to estimate a condition index using standardized relative weight (W_r) formulas developed by other researchers. Relative weight is often preferred by managers over the condition factor (K_{TL}) because comparisons are often not valid between populations or even between length groups within a species (Ney 1999). The use of relative weights allows managers to make comparisons of fish condition to other populations of the same species. Relative weight values near 100 or greater indicate a fish is in excellent condition (e.g., plump) and food is available. Relative weight values less than 100 indicate a fish is not in optimum condition and food is limited. The relative weight formula of Simpkins and Hubert (1996) was used for rainbow trout greater than 120 mm:

$$\log_{10} W_s = -5.023 + 3.024 \log_{10} TL$$

The relative weight formula of Milewski and Brown (1994) was used for brown trout greater than 140 mm:

$$\log_{10} W_s = -4.867 + 2.960 \log_{10} TL$$

The relative weight formula of Hyatt and Hubert (2001) was used for brook trout greater than 120 mm:

$$\log_{10} W_s = -5.186 + 3.103 \log_{10} TL$$

where, W_s is the standard weight (g) for a specimen of the measured total length (TL; mm) for all equations.

Results and Discussion

Water Quality

The Rio Ruidoso upstream of U.S. Highway 70 Bridge has been classified as a high quality coldwater fishery by New Mexico Environment Department's Water Quality Control Commission (NMWCC 2011). Specific standards for high quality coldwater streams include pH between 6.6 and 8.8, turbidity less than 10 NTU, dissolved oxygen greater than 6.0 mg/L, and conductivity less than 400 µmhos/S. Although one of the worst droughts on record began during our study (http://www.droughtmonitor.unl.edu/archive.html, accessed on August 5, 2012), water quality in Rio Ruidoso watershed was within acceptable limits for cold water fishes at all sites (Table 2).

Stream Temperature

Stream temperatures increased during summer months due to reduced discharge rates that may have been exacerbated by drought conditions beginning 2011 and continued through to the end of the study (see Appendices 1-5). Current temperature criteria in New Mexico has designated portions of the Rio Ruidoso as "high quality coldwater" where maximum stream temperatures are not to exceed 23°C, and not to exceed 20°C for four or more consecutive hours in a 24 hour period for more than three consecutive days (4T3) (NMWQCC 2011). Summer water temperatures in 2010 never exceeded 23°C at any location; however, four sites exceeded 23°C in 2012 with the SF-T2 logger in the South Fork reflected stream temperatures exceeding 23°C for 27 days (Table 3). Additionally, five sites in 2012 exceeded the 4T3 criteria and would be classified as thermally impaired. Stream temperatures at all three Middle Fork sites and at one North Fork site (NF-T2) never exceeded the New Mexico water quality temperature standards indicating these sites were thermally stable. Zeigler et al. (2013) reported 7-d ultimate upper incipient lethal temperature (UUILT; temperature lethal to 50% of the population) was 24.7°C for RGCT fry and 23.4°C for juvenile RGCT. While these thermal tolerance thresholds represent laboratory-derived values, stream temperatures throughout the majority of the Rio Ruidoso appear thermally suitable for early life stages of RGCT.

Table 2. Water quality collected fall 2010, spring 2011 and 2012 throughout sample sites of the Rio Ruidoso watershed. Sample sites are Main Stem (MS), North Fork site 1 (NF-1) and site 2 (NF-2), Middle Fork site 1 (MF-1) and site 2 (MF-2), and South Fork site 1 (SF-1) and site 2 (SF-2). TDS (mg/L) is total dissolved solids.

Site	Year	Dissolved Oxygen (mg/L)	pH	Conductivity (µmho/S)	Alkalinity (mg/L)	TDS (mg/L)	Calcium (meq/L)	Magnesium (meq/L)	Hardness (mg/L)	Nitrate/ Nitrite as N (mg/L)[a]
MS	Fall 2010	9.2	7.2	173	42	115	1.0	0.2	62	-
	Spring 2011	7.4	7.9	281	68	180	1.8	0.4	111	-
	Spring 2012	6.9	7.8	282	78	186	1.7	0.4	106	-
NF-1	Fall 2010	10.3	7.4	215	50	143	1.1	0.3	71	0.8
	Spring 2011	8.7	8.2	353	80	226	2.0	0.5	128	-
	Spring 2012	7.5	7.7	294	64	191	1.5	0.4	95	-
NF-2	Fall 2010	9.6	7.3	176	39	119	0.9	0.2	55	0.7
	Spring 2011	8.1	8.2	250	54	169	1.3	0.3	84	-
	Spring 2012	7.9	7.3	247	48	161	1.2	0.3	74	-
MF-1	Fall 2010	8.8	7.2	141	32	94	0.8	0.2	50	-
	Spring 2011	7.8	7.9	267	67	172	1.7	0.4	102	-
	Spring 2012	8.1	8.3	254	60	165	1.4	0.4	90	-
MF-2	Fall 2010	9.4	7.1	120	26	82	0.6	0.2	40	-
	Spring 2011	8.1	8.1	167	32	107	1.0	0.2	60	-
	Spring 2012	7.9	7.5	174	32	119	1.0	0.2	60	-
SF-1	Fall 2010	10.0	7.2	148	34	98	0.9	0.2	54	-
	Spring 2011	7.5	7.9	198	43	128	1.3	0.3	80	-
	Spring 2012	6.2	8.2	221	45	135	1.2	0.3	72	-
SF-2	Fall 2010	9.5	7.0	135	30	90	0.8	0.2	46	-
	Spring 2011	8.8	8.0	157	30	112	1.0	0.2	60	-
	Spring 2012	7.8	7.9	192	34	120	1.0	0.2	58	-

[a] Nitrate/Nitrate levels were only tested Fall 2010 on the North Fork sample sites.

Table 3. The number of days the temperature logger exceeded 20°C for four or more consecutive hours in a 24-h period for more than three consecutive days (4T3), and the number of days where the maximum stream temperatures exceeded 23°C for each year between May 14, 2010 and April 12, 2013. Stream temperature from three instream dataloggers on the Main Stem (MS-T1, MS-T2, MS-T3), two data loggers on the North Fork (NF-T1, NF-T2), three data loggers on the Middle Fork (MF-T1, MF-T2, MF-T3), and three data loggers on the South Fork (SF-T1, SF-T2, SF-T3) within the Rio Ruidoso watershed.

		2010		2011		2012	
Site	Elevation (m)	Days exceeding 4T3	Days exceeding 23°C	Days exceeding 4T3	Days exceeding 23°C	Days exceeding 4T3	Days exceeding 23°C
MS-T1	2251	0	0	2	1	11	13
MS-T2	2308	0	0	0	0	9	4
MS-T3[a]	2412	0	0	-	-	-	-
NF-T1	2306	0	0	1	0	7	4
NF-T2[b]	2633	0	0	0	0	0	0
MF-T1	2460	0	0	0	0	0	0
MF-T2[b]	2631	0	0	0	0	0	0
MF-T3[b]	2726	0	0	0	0	0	0
SF-T1	2450	0	0	0	0	1	0
SF-T2[b]	2637	0	0	2	5	14	27
SF-T3[b]	2729	0	0	0	1	0	0

[a] temperatures recorded from May 14, 2010 to May 24, 2011 due to losing logger

[b] temperatures recorded from August 12, 2010 to April 12, 2013

Stream temperatures during the winter revealed that daily minimum water temperatures fell below 0°C with the exception of one site on the Middle Fork (MF-T2) which never fell below 0°C (Table 4). Temperatures below 0°C indicated supercooling resulting in frazil and anchor ice which could detrimentally affect resident fishes. Brown et al. (1999) observed juvenile rainbow trout exposed to supercooled waters with frazil and anchor ice experienced reduced plasma ions or salts and increased plasma glucose indicating a general stress response was elicited in the fishes. As stress is energetically demanding for a fish (Barton and Schreck 1987), frazil and anchor ice formations could affect the survival of salmonids that may already experience metabolic demands during the winter (Cunjak et al. 1987). Additionally, small frazil ice crystals abrade gills causing hemorrhage and aggregate on the gill rakers potentially leading to suffocation (Brown et al. 1993). Several studies have cited downstream migration of salmonids occur with the onset of frazil or anchor ice (Jakober et al. 1998; Brown et al. 2000; Simpkins et al. 2000). A recent study by the co-author of this report demonstrated that rainbow trout within the Middle Fork of the Rio Ruidoso located thermal refugia that are as much as 3°C cooler than the ambient stream temperature during the summer months and as much as 3°C warmer during the winter months (Kalb 2013). These refugia are likely created by groundwater upwelling and presumably expand the thermal habitat available to RGCT.

Stream Morphology and Fish Habitat

Due to the timing and severity of the drought that began winter 2010-2011, discharge and wetted-width at all sites decreased during spring 2011 and 2012 compared to fall 2010 (Table 5). The entrenchment ratio was higher in the South Fork than the Rosgen system reports and was likely due to four or fewer flood prone width measurements which influenced the accuracy of the entrenchment ratio. Therefore, Rosgen classification was based primarily on width/depth ratios, stream gradients, and dominant substrate (Table 5). Except for Middle Fork site 2 (MF-2), the remainder of the sites had width/depth ratios greater than 12 and gradients greater than 4% resulting in a Type B stream classification. These streams are reflected by stable banks and a very stable profile (Rosgen 1994). Sample sites characterized as a B3 stream type exhibited a low sensitivity to disturbance, excellent recovery potential, low sediment supply, low stream bank erosion potential, and moderate vegetation control (Rosgen 1994). Type B4a streams have

Table 4. The number of daily mean and minimum (min) stream temperatures less than 0°C observed for each winter (e.g., 2010-2011 reflects November 2010 - March 2011) between May 14, 2010 and April 12, 2013. Stream temperature from three instream dataloggers on the Main Stem (MS-T1, MS-T2, MS-T3), two data loggers on the North Fork (NF-T1, NF-T2), three data loggers on the Middle Fork (MF-T1, MF-T2, MF-T3), and three data loggers on the South Fork (SF-T1, SF-T2, SF-T3) within the Rio Ruidoso watershed.

		2010-2011		2011-2012		2012-2013	
Site	Elevation (m)	Daily mean < 0°C	Daily min < 0°C	Daily mean < 0°C	Daily min < 0°C	Daily mean < 0°C	Daily min < 0°C
MS-T1	2251	1	19	0	13	0	21
MS-T2	2308	1	7	0	4	0	0
MS-T3[a]	2412	15	39	-	-	-	-
NF-T1	2306	0	27	12	79	16	45
NF-T2[b]	2633	0	10	0	0	0	0
MF-T1	2460	26	58	5	44	10	14
MF-T2[b]	2631	0	0	0	0	0	0
MF-T3[b]	2726	0	10	0	0	0	0
SF-T1	2450	0	16	0	49	0	0
SF-T2[b]	2637	5	39	0	33	1	46
SF-T3[b]	2729	6	89	2	80	0	6

[a] temperatures recorded from May 14, 2010 to May 24, 2011 due to losing logger

[b] temperatures recorded from August 12, 2010 to April 12, 2013

Table 5. Discharge, physical morphological measurements (mean ± standard error), and Rosgen classification of all sample sites fall 2010, spring 2011 and 2012 within the Rio Ruidoso watershed. Sample sites are Main Stem (MS), North Fork site 1 (NF-1) and site 2 (NF-2), Middle Fork site 1 (MF-1) and site 2 (MF-2), and South Fork site 1 (SF-1) and site 2 (SF-2).

Site	Year	Discharge (m^3/s)	Wetted Width (m)	Bankfull Width (m)	Flood Prone Width (m)	Entrenchment Ratio	Width-Depth Ratio	Gradient (%)	Dominant Substrate (D50)	Rosgen Classification
MS	Fall 2010	0.039	5.0 (1.44)	12.5 (1.44)	-	-	25.8	4.9	Cobble (67)	-
	Spring 2011	0.005	3.6 (0.41)	8.3 (1.70)	16.7 (6.88)	1.5	20.5	5.3	Cobble (91)	B3a
	Spring 2012	0.005	2.4 (0.81)	3.9 (0.76)	7.5 (2.10)	1.9	24.3	4.1	Gravel (54)	B4a
NF-1	Fall 2010	0.071	4.7 (0.57)	7.4 (0.66)	-	-	26.5	5.4	Cobble (98)	-
	Spring 2011	0.012	3.3 (0.41)	6.8 (0.67)	9.4 (0.20)	1.4	32.5	4.4	Cobble (78)	B3a
	Spring 2012	0.025	4.0 (0.71)	6.4 (0.98)	8.7 (1.39)	1.4	18.7	4.8	Gravel (49)	B4a
NF-2	Fall 2010	0.124	4.2 (0.87)	8.7 (1.46)	-	-	16.7	4.9	Cobble (80)	-
	Spring 2011	0.057	4.4 (1.46)	8.7 (1.39)	14.9 (7.88)	1.8	22.3	3.8	Cobble (81)	B3
	Spring 2012	0.024	2.8 (0.40)	8.4 (1.05)	23.0 (6.55)	2.8	24.6	3.8	Gravel (52)	B4
MF-1	Fall 2010	0.012	2.2 (0.38)	6.1 (0.40)	-	-	12.3	6.7	Gravel (33)	-
	Spring 2011	0.003	1.7 (0.47)	3.6 (0.48)	8.4 (0)	1.8	16.5	7.6	Gravel (40)	B4a
	Spring 2012	0.003	2.1 (0.51)	3.4 (0.31)	5.3 (0.57)	1.6	12.8	7.3	Gravel (12)	B4a
MF-2	Fall 2010	0.028	3.0 (0.72)	5.2 (0.55)	-	-	9.0	6.9	Gravel (39)	-
	Spring 2011	0.001	1.8 (0.33)	2.8 (0.51)	7.1 (0)	1.8	9.8	8.7	Cobble (100)	A3
	Spring 2012	0.002	1.1 (0.29)	2.1 (0.37)	3.5 (0.25)	1.9	11.3	7.7	Gravel (13)	A4
SF-1	Fall 2010	0.005	5.1 (0.78)	5.1 (1.76)	-	-	20.3	5.3	Gravel (34)	-
	Spring 2011	0.001	2.8 (0.86)	2.8 (0.93)	16.3 (0)	4.4	18.0	7.4	Gravel (15)	B4a
	Spring 2012	0.001	1.3 (0.29)	4.3 (0.73)	9.0 (1.87)	2.4	22.0	5.6	Gravel (17)	B4a
SF-2	Fall 2010	0.014	2.7 (0.21)	2.7 (0.42)	-	-	23.9	6.2	Gravel (26)	-
	Spring 2011	0.002	2.3 (0.33)	2.3 (0.41)	2.5 (0.20)	2.5	26.4	7.5	Gravel (52)	B4a
	Spring 2012	0.002	1.6 (0.38)	3.8 (0.55)	6.3 (0.75)	1.8	21.8	5.5	Gravel (21)	B4a

a moderate sensitivity to disturbance, excellent recovery potential, moderate sediment supply, low stream bank erosion potential, and moderate vegetation control (Rosgen 1994). Site 2 of the Middle Fork exhibited low width/depth ratios (less than 12) and gradient greater than 7%, resulting in a categorization of an A stream type. Type A streams are associated with frequently spaced pools and can be very stable if boulder or bedrock dominated (Rosgen 1994), however, this section of the Middle Fork was classified as a type A3/A4 stream which has a very high sensitivity to disturbance, very poor recovery potential, very high sediment supply, high stream bank erosion potential, and negligible vegetation control (Rosgen 1994). It is important to note the Rosgen scores reported here were based on two 100-m assessments within each tributary to the Rio Ruidoso and may be considered a coarse estimate of the Rosgen stream classification system.

The number of pools increased throughout the three year study at all sites and was likely the result of drought. While number of pools increased, the average maximum pool depth decreased by the end of the study (Table 6). The number riffles also increased by the end of the study, however, pool-riffle ratios averaged 1.2 for all sample sites reflecting more pools than riffles and runs by the end of the study, well into the drought. It is commonly believed that a pool-riffle ratio of 1.0 reflects optimum salmonid habitat by providing adequate resting and feeding areas with an adequate number of riffles to produce food and support spawning (Platts et al. 1983). In an earlier study, Platts (1974) observed the highest standing crops of salmonids in the South Fork Salmon River drainage were in stream reaches with a pool-riffle ratio of 0.4. Thus, one should interpret the pool-riffle ratio with caution. Mean residual depths varied considerably between reaches and sampling periods (Table 6), but appear sufficient in depth to support fish during periods of extreme drought as was observed in this study.

The percent fines increased for nearly all sample sites likely due to the accumulation of finer sediments from the reduced flows (Table 7). A benchmark for montane streams in New Mexico of less than 20% fine sediment was established by New Mexico Environment Department (NMED 2011). Fine sediment can interfere with biologically important habitat components such as spawning gravel and cobble surfaces by covering with fines (Chapman and McLeod 1987). Fine sediments resulted in decreased inter-gravel oxygen and reduced or eliminated quality and quantity of habitat for fish, macroinvertebrates, and algae (Lisle 1989; Waters 1995; Suttle et al. 2004). Chapman and McLeod (1987) found that bed material size is

Table 6. Mean maximum pool depth, residual pool depth (mean ± standard error), number of pools, number of riffles versus runs, and pool-riffle ratio of sites sampled fall 2010, and spring 2011 and 2012 within the Rio Ruidoso watershed. Sample sites are Main Stem (MS), North Fork site 1 (NF-1) and site 2 (NF-2), Middle Fork site 1 (MF-1) and site 2 (MF-2), and South Fork site 1 (SF-1) and site 2 (SF-2).

Site	Year	Max Pool Depth (m)	Residual Pool Depth (m)	No. Pools/100 m	No. Riffles/Runs per 100 m	Pool-riffle Ratio
MS	Fall 2010	0.5 (0.04)	0.4 (0.05)	5.5	3.6	1.2
	Spring 2011	0.4 (0.04)	0.3 (0.02)	6.4	5.5	0.4
	Spring 2012	0.3 (0.02)	0.2 (0.03)	12.7	16.4	1.0
NF-1	Fall 2010	0.7 (0.09)	0.5 (0.09)	3.0	5.0	0.5
	Spring 2011	0.5 (0.09)	0.5 (0.09)	4.0	4.0	0.5
	Spring 2012	0.4 (0.03)	0.3 (0.04)	13.0	12.0	2.4
NF-2	Fall 2010	0.6 (0.06)	0.4 (0.06)	6.0	1.7	4.7
	Spring 2011	0.5 (0.03)	0.4 (0.03)	6.0	6.8	0.4
	Spring 2012	0.4 (0.03)	0.3 (0.03)	16.2	13.6	1.5
MF-1	Fall 2010	0.4 (0.05)	0.3 (0.06)	9.7	5.8	1.6
	Spring 2011	0.4 (0.06)	0.4 (0.06)	4.9	4.9	0.3
	Spring 2012	0.3 (0.02)	0.2 (0.02)	20.4	13.6	3.4
MF-2	Fall 2010	0.5 (0.18)	0.4 (0.18)	4.1	5.1	1.6
	Spring 2011	0.4 (0.10)	0.3 (0.10)	6.1	7.1	0.3
	Spring 2012	0.3 (0.04)	0.2 (0.04)	18.3	12.2	1.1
SF-1	Fall 2010	0.5 (0.06)	0.3 (0.05)	3.8	3.8	0.3
	Spring 2011	0.4 (0.07)	0.4 (0.07)	4.8	2.9	0.5
	Spring 2012	0.3 (0.04)	0.2 (0.03)	13.4	12.4	1.0
SF-2	Fall 2010	0.6 (0.07)	0.5 (0.08)	5.9	3.4	0.9
	Spring 2011	0.5 (0.09)	0.4 (0.09)	4.2	3.4	0.4
	Spring 2012	0.3 (0.04)	0.3 (0.04)	17.7	12.6	1.7

Table 7. Number of large woody debris (LWD) observed per 100 m, percentage of fine sediments (< 2 mm), and percent overhead canopy cover (mean ± standard error) in sample sites Fall 2010, Spring 2011 and 2012 within the Rio Ruidoso. Sample sites are Main Stem (MS), North Fork site 1 (NF-1) and site 2 (NF-2), Middle Fork site 1 (MF-1) and site 2 (MF-2), and South Fork site 1 (SF-1) and site 2 (SF-2).

Site	Year	LWD pieces/100 m	Fine Sediments (%)	Canopy Cover (%)
MS	Fall 2010	19	9	30 (11.4)
	Spring 2011	24	6	21 (7.0)
	Spring 2012	19	20	28 (13.4)
NF-1	Fall 2010	18	6	55 (11.5)
	Spring 2011	18	16	43 (8.9)
	Spring 2012	20	18	44 (3.6)
NF-2	Fall 2010	29	15	39 (7.5)
	Spring 2011	31	12	30 (11.8)
	Spring 2012	12	13	31 (8.1)
MF-1	Fall 2010	46	18	34 (15.0)
	Spring 2011	18	13	34 (13.5)
	Spring 2012	24	31	40 (15.4)
MF-2	Fall 2010	32	14	16 (9.7)
	Spring 2011	15	8	16 (8.6)
	Spring 2012	10	26	20 (8.7)
SF-1	Fall 2010	27	22	24 (4.7)
	Spring 2011	4	16	32 (8.6)
	Spring 2012	13	29	31 (8.1)
SF-2	Fall 2010	21	21	8 (5.5)
	Spring 2011	14	10	2 (1.0)
	Spring 2012	14	34	7 (5.4)

related to habitat suitability for fish and macroinvertebrates and that fine sediment decreased both density and diversity of aquatic insects. Specific aspects of sediment-macroinvertebrate relationships include an abundance of invertebrate taxa correlated with substrate particle size; fine sediments will reduce the abundance of taxa intolerant to sediments by reducing interstitial habitat normally available in large-particle substrate (gravel, cobbles). Community composition will change as substrate particle size changes from large (gravel, cobbles) to small (sand, silt, clay) (Waters 1995). Excessive fines accumulated in the South and Middle Forks and were presumably from reduced flow and may be of concern during years of drought.

Mean canopy cover varied from 2 to 55% throughout the study (Table 7). This variation was due to fall and spring collections; however, no seasonal pattern in plant growth was evident in either season. Canopy cover filters and absorbs incident radiation and affects periphyton primary productivity by altering solar inputs and water temperatures (Platts and Nelson 1989). Canopy, including riparian vegetation, provide litterfall to streams forming habitat and nutrients for fish and macroinvertebrates (Platts and Nelson 1989). In addition to altering solar inputs, riparian vegetation insulates the stream and buffers it against extreme high and low temperatures (Beschta 1997). Removal of riparian canopy in cool, forested streams leads to higher incident radiation, blooms in algal and macroinvertebrate populations, and associated increases in salmonid abundance (see review by Tait et al. 1994). In warmer, more arid regions, however, too little canopy cover can result in higher stream temperatures that are unable to support salmonids. There was no evidence of logging within the riparian area throughout the watershed, thus, riparian vegetation appears sufficient to maintain suitable thermal refugia for salmonids.

Large instream woody debris varied from 4 to 46 pieces/100 m throughout the sites (Table 7). The presence of large instream woody debris affects stream salmonids positively by increasing pool frequency, depth, area, and sediment retention (e.g., Young 1996; Cederholm et al. 1997; Hilderbrand et al. 1997). The densities of large woody debris throughout all study sites were similar to those reported by Fausch and Northcote (1992) in a British Columbia stream and Roni and Quinn (2001) in numerous streams in Oregon and Washington that were representative of healthy salmonid populations. Thus, the presence of instream woody debris throughout the Rio Ruidoso supports optimal habitat which would favor resiliency of a RGCT population if repatriated to the Rio Ruidoso watershed.

Bank stability was generally good for all sites. Overall, 38-100% of all stream banks were rated as covered/stable (Table 8). Erosion indices reflected sites were ≤ 2.1, indicating stream banks were stable and little erosion was occurring (McInnis and McIver 2001). However, when comparing 2010 and 2012, erosion indices increased slightly across most of the sites. For example, the erosion index in the South Fork site 2 increased from 1.1 in fall of 2010 to 2.1 in the spring of 2012 which could mean these sites appear vulnerable to erosion due to a lack of cover or stability (McInnis and McIver 2001). No doubt, drought influenced erosion potential as well as our estimates of cover.

Four of the seven sites (57%) revealed no undercut banks and those study sites with undercut banks had very low frequencies (0-38%; Table 8). Undercut banks provides cover for salmonids as well as habitat for aquatic macroinvertebrates (Rhodes and Hubert 1991). The paucity of undercut banks throughout the Rio Ruidoso watershed was somewhat expected given the high elevation, high gradient, and large substrate characteristics of the stream systems.

Aquatic Macroinvertebrate Assemblage

A diverse assemblage of aquatic benthic macroinvertebrates totaling 30 taxa was collected throughout the study (Appendices 6-8). Summaries of the metrics used in the bioassessment of the macroinvertebrate community across the three sample dates revealed that three of the seven sites met their biological potential throughout the entire study. With the exception of the Middle Fork site 1 (MF-1) in Fall 2010 (Table 9), North Fork site 1 (NF-1) and South Fork site 1 (SF-1) in Spring 2012 (Table 11), Biological Condition of the remaining sample sites throughout were rated as *not impaired*. Species indicative of high water quality conditions were present throughout nearly all sites across the three sample dates. These species included: stoneflies *Megarcys signata, Alloperla severa, Claassenia sabulsa*; mayflies *Baetis tricaudatus*, *Drunella grandis*; caddisflies *Rhyacophila* sp., *Glossoma* sp., *Hydropsyche* sp., *Oecetis* sp., *Micrasema* sp. Although a disproportionate number of *Hexatoma* sp. (true flies) (20,227/m^2) were observed in the spring 2012 sample at South Fork site 1 (SF-1), this does not necessarily reflect significant impairment of the stream. Given sufficient stream flow and favorable temperature regimes, diversity and abundance of the benthic macroinvertebrate community should offer a sufficient food base to RGCT.

Table 8. Undercut depth (m) (mean ± standard error), prevalence (%), and percentages of stream bank classes observed for each erosion index category and associated erosion potential values of sites sampled Fall 2010, Spring 2011 and 2012 within the Rio Ruidoso. Sample sites are Main Stem (MS), North Fork site 1 (NF-1) and site 2 (NF-2), Middle Fork site 1 (MF-1) and site 2 (MF-2), and South Fork site 1 (SF-1) and site 2 (SF-2).

Site	Year	Undercut Depth (m)	Undercut Prevalence (%)	Covered/ Stable	Uncovered/ Stable	Covered/ Unstable	Uncovered/ Unstable	Erosion Potential
MS	Fall 2010	0	0	88	0	12	0	1.1
	Spring 2011	0	0	75	12	0	12	1.4
	Spring 2012	0	0	75	0.2	0	0	1.2
NF-1	Fall 2010	0	0	62	25	0	12	1.5
	Spring 2011	0	0	38	12	12	38	2.0
	Spring 2012	0	0	62	0	0.2	12	1.5
NF-2	Fall 2010	0.3 (0)	12.5	100	0	0	0	1.0
	Spring 2011	0	0	62	12	0	25	1.6
	Spring 2012	0.4 (0)	12.5	38	12	0	50	2.1
MF-1	Fall 2010	0.2 (0)	12.5	100	0	0	0	1.0
	Spring 2011	0	0	100	0	0	0	1.0
	Spring 2012	0.6 (0)	12.5	100	0	0	0	1.0
MF-2	Fall 2010	0	0	100	0	0	0	1.0
	Spring 2011	0	0	75	12	12	0	1.2
	Spring 2012	0	0	88	0	0	12	1.2
SF-1	Fall 2010	0	0	88	0	12	0	1.1
	Spring 2011	0	0	100	0	0	0	1.0
	Spring 2012	0	0	75	0	12	12	1.4
SF-2	Fall 2010	0	0	88	0	12	0	1.1
	Spring 2011	0.2 (0.06)	37.5	62	0	0	38	1.8
	Spring 2012	0	0	38	12	0	50	2.1

Table 9. Multimetric bioassessment of benthic macroinvertebrates throughout sample sites on the Rio Ruidoso fall 2010 (Plafkin et al. 1989 and modified by Jacobi et al. 1998). Sample sites are Main Stem (MS), North Fork site 1 (NF-1) and site 2 (NF-2), Middle Fork site 1 (MF-1) and site 2 (MF-2), and South Fork site 1 (SF-1) and site 2 (SF-2).

	MS (Reference)	NF-1	NF-2	MF-1	MF-2	SF-1	SF-2
Total Number/m^2	1135	1753	1527	575	1107	1570	1971
Total Number of Taxa	18	19	16	11	20	17	19
BCI (CTQd) (≤66 meeting biological potential)	52	62	54	65	57	53	62
HBI	4	3	5	5	3	4	5
EPT Index	11	9	8	7	11	9	10
EPT/EPT + Chironomidae	1.0	1.0	1.0	0.9	1.0	1.0	0.9
Community Loss	0	0.3	0.4	0.7	0.3	0.4	0.3
% Dominant Taxon	40	26	39	53	25	43	32
Diversity Index	2.7	3.2	2.6	2.4	3.4	2.7	3.1
Scrapers/Scrp+Filter Collectors	0.1	0.5	0.02	0.1	0.6	0.1	0.1
Shredders/Total	0.2	0.3	0.2	0.1	0.1	0.1	0.1
Number/m^2	6	4	6	6	6	6	4
Number of Taxa	6	6	6	4	6	6	6
BCI (CTQd)	6	4	6	4	6	6	6
HBI	6	6	4	4	6	6	4
EPT Index	6	4	2	0	6	4	6
EPT/EPT + Chironomidae	6	6	6	6	6	6	6
Community Loss	6	6	6	4	6	6	6
% Dominant Taxon	0	4	2	0	4	0	2
Diversity Index	4	6	4	4	6	4	6
Scrapers/Scrp+Filter Collectors	6	6	2	6	6	6	6
Shredders/Total	6	6	6	2	6	6	6
Biological Condition Rating (score out of 66 optimal)	58	58	50	40	64	56	58
Biological Condition Rating (%)	-	100	86	68	100	96	100
BIOLOGICAL CONDITION (NI=not impaired, SI=slightly impaired)	-	NI	NI	**SI**	NI	NI	NI

Table 10. Multimetric bioassessment of benthic macroinvertebrates throughout sample sites on the Rio Ruidoso spring 2011 (Plafkin et al. 1989 and modified by Jacobi et al. 1998). Sample sites are Main Stem (MS), North Fork site 1 (NF-1) and site 2 (NF-2), Middle Fork site 1 (MF-1) and site 2 (MF-2), and South Fork site 1 (SF-1) and site 2 (SF-2).

	MS (Reference)	NF-1	NF-2	MF-1	MF-2	SF-1	SF-2
Total Number/m^2	2573	1436	2602	2033	2377	4385	2551
Total Number of Taxa	21	16	23	21	21	26	20
BCI (CTQd) (≤66 meeting biological potential)	50	52	53	51	52	51	53
HBI	4	4	4	4	3	5	4
EPT Index	11	10	11	13	10	13	12
EPT/EPT + Chironomidae	0.9	0.9	0.9	0.8	1.0	0.6	0.9
Community Loss	0	0.6	0.4	0.2	0.4	0.3	0.4
% Dominant Taxon	53	45	40	48	36	31	56
Diversity Index	2.5	2.6	2.6	2.7	2.7	3.1	2.4
Scrapers/Scrp+Filter Collectors	0.8	0.9	0.6	0.9	1.0	0.9	0.8
Shredders/Total	0.1	0.2	0.1	0.1	0.2	0.03	0.02
Number/m^2	6	6	6	6	6	4	6
Number of Taxa	6	4	6	6	6	6	6
BCI (CTQd)	6	6	6	6	6	6	6
HBI	6	6	6	6	6	4	6
EPT Index	6	4	6	6	6	6	6
EPT/EPT + Chironomidae	6	6	6	6	6	4	6
Community Loss	6	6	6	4	6	6	6
% Dominant Taxon	0	0	0	0	2	2	0
Diversity Index	4	4	4	4	6	6	4
Scrapers/Scrp+Filter Collectors	6	6	6	6	6	6	6
Shredders/Total	6	6	6	6	6	6	2
Biological Condition Rating (score out of 66 optimal)	58	54	58	58	60	56	54
Biological Condition Rating (%)	-	93	100	68	100	96	100
BIOLOGICAL CONDITION (NI=not impaired, SI=slightly impaired)	-	NI	NI	NI	NI	NI	NI

Table 11. Multimetric bioassessment of benthic macroinvertebrates throughout sample sites on the Rio Ruidoso spring 2012 (Plafkin et al. 1989 and modified by Jacobi et al. 1998). Sample sites are Main Stem (MS), North Fork site 1 (NF-1) and site 2 (NF-2), Middle Fork site 1 (MF-1) and site 2 (MF-2), and South Fork site 1 (SF-1) and site 2 (SF-2).

	MS (Reference)	NF-1	NF-2	MF-1	MF-2	SF-1	SF-2
Number/m^2	2882	8160	3021	5394	8725	30108	6742
Number of Taxa	24	23	23	28	24	28	30
BCI (CTQd) (≤66 meeting biological potential)	57	64	56	54	50	63	60
HBI	5	6	4	2	3	3	6
EPT Index	12	14	15	15	13	13	11
EPT/EPT + Chironomidae	0.8	0.9	0.8	1.0	0.9	0.6	0.4
Community Loss	0	0.4	0.5	0.3	0.5	0.5	0.4
% Dominant Taxon	28	69	20	21	26	67	39
Diversity Index	3.6	1.9	3.3	3.6	3.0	1.9	2.9
Scrapers/Scrp+Filter Collectors	0.6	0.9	0.3	0.5	1.0	0.6	0.8
Shredders/Total	0.1	0.2	0.1	0.2	0.4	0.04	0.04
Number/m^2	6	0	6	4	0	0	2
Number of Taxa	6	6	6	6	6	6	6
BCI	6	6	6	6	6	6	6
HBI	6	4	6	6	6	6	6
EPT Index	6	6	6	6	6	6	6
EPT/EPT + Chironomidae	6	6	6	6	6	4	4
Community Loss	6	6	6	6	4	6	6
% Dominant Taxon	4	0	4	4	4	0	2
Diversity Index	6	2	6	6	6	2	4
Scrapers/Scrp+Filter Collectors	6	6	6	6	6	6	6
Shredders/Total	6	0	6	6	6	6	6
Biological Condition Rating (score out of 66 optimal)	64	42	64	62	56	48	54
Biological Condition Rating (%)	-	65	100	96	87	75	84
BIOLOGICAL CONDITION (NI=not impaired, SI=slightly impaired)	-	**SI**	NI	NI	NI	**SI**	NI

Fish Assemblage and Indices of Population Structure

Three trout species (rainbow trout, brown trout, brook trout) were collected in the Rio Ruidoso watershed. Cutthroat trout were not observed, however, several rainbow trout exhibited morphological characteristics of introgression with cutthroat trout (e.g., faint orange slashes under lower jaw). The North Fork sites consisted solely of brown trout while the main stem and South Fork consisted of both brown trout and rainbow trout. Brown trout were not captured at either site above the lower barrier on the Middle Fork. Rainbow trout was the primary species collected at Middle Fork site 1 with one brook trout captured fall 2010. Presumably, this fish dispersed downstream from above the upper barrier on the Middle Fork where surveys revealed only brook trout were present.

Fish densities were highly variable with estimates that ranged from 0.23 fish/m^2 spring 2011 (North Fork site 2) to 1.70 fish/m^2 fall 2010 (South Fork site 2) (Figure 2). The largest decrease in fish density among sample collections occurred in Middle Fork site 1 where densities declined from 1.07 fish/m^2 fall 2010 to 0.58 fish/m^2 spring 2012. The largest increase in overall fish density occurred at the South Fork site 1, where densities increased from 0.51 fish/m^2 fall 2010 to 0.90 fish/m^2 spring 2012 (Figure 2). Recruitment rates were high (0.51 fish/m^2) for rainbow trout in Middle Fork site 1 (Figure 3a). We observed few adult fish (0.02 fish/m^2) relative to age-0 fish (0.29 fish/m^2) in the main stem; however, some of the largest fish were captured in this site. While fish were not limited by food within the main stem, habitat (i.e., pools) was absent for large adult fish. Recruitment of age-0 brown trout was highest in the South Fork site 2 where densities were 0.88 fish/m^2 fall 2010 (Figure 3b). Above the protection of the barrier in site 2 of the Middle Fork, brook trout obtained relatively high densities (0.5-0.8 fish/m^2) including recruitment of age-0 fish (0.12 fish/m^2) (Figure 3c). Standing crop estimates were highly variable among sites and among sample collections (Figure 4). Estimates ranged from 94.3 kg/ha in the main stem reach fall 2010 to 443 kg/ha in the South Fork site 2 spring 2012. Standing crop decreased in the North Fork site 2 site from 263 kg/ha fall 2010 to 97 kg/ha spring 2011, but rebounded spring 2012 (216 kg/ha). Despite the variability among reaches and across seasons, drought had relatively no effect on standing crop throughout the Rio Ruidoso study sites.

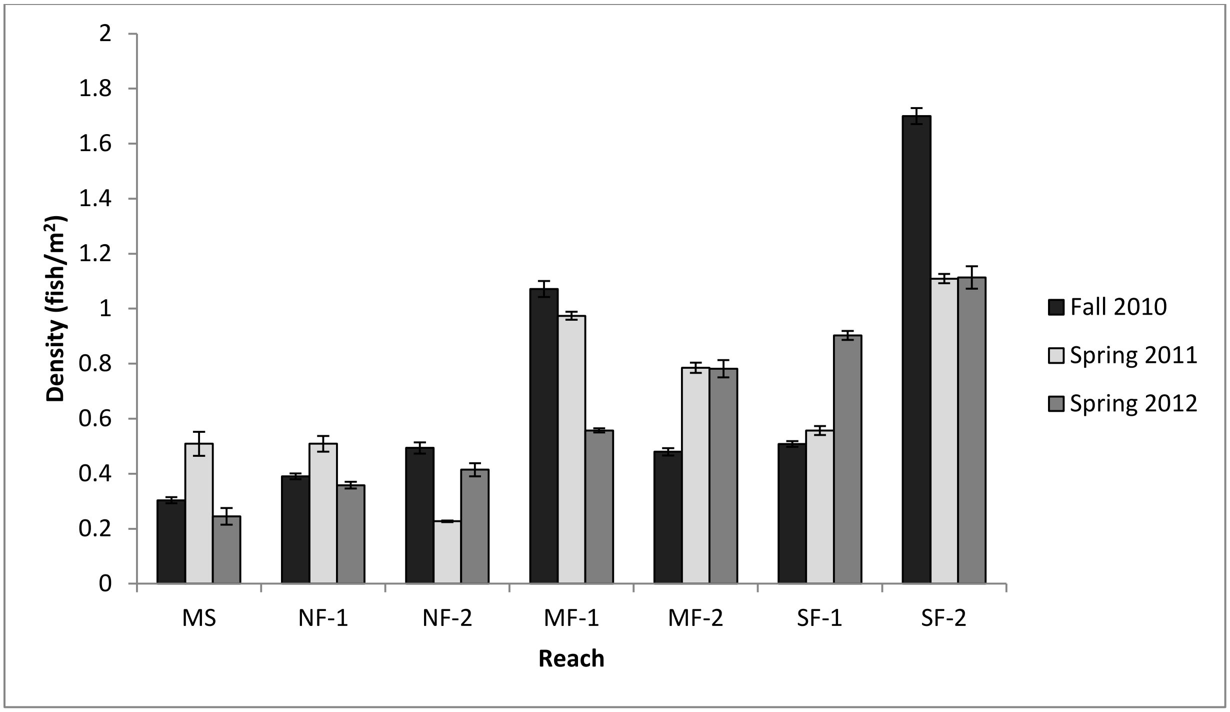

Figure 2. Fish densities (fish/m^2) of the three fish species combined for fall 2010, spring 2011, and spring 2012 from the Main Stem (MS), North Fork site 1 (NF-1) and site 2 (NF-2), Middle Fork site 1 (MF-1) and site 2 (MF-2), and South Fork site 1 (SF-1) and site 2 (SF-2) of the Rio Ruidoso. Error bars are ± 1 standard error.

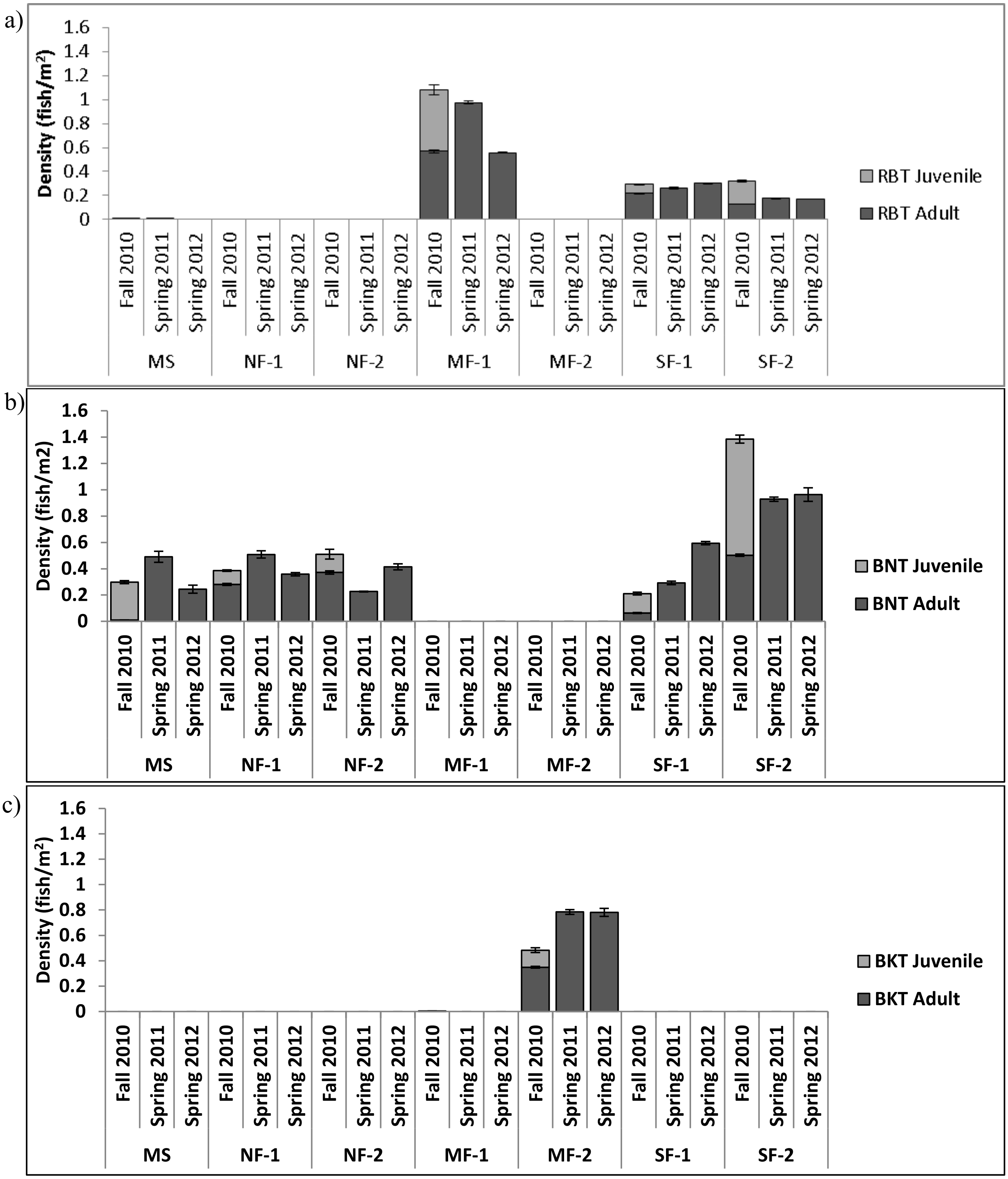

Figure 3. Average density estimates (fish/m^2, ± standard error) of both juvenile (age-0) and adult (age-1+) rainbow trout (a), brown trout (b), and brook trout (c) sampled in fall 2010, spring 2011, and spring 2012 from Main Stem (MS), North Fork site 1 (NF-1) and site 2 (NF-2), Middle Fork site 1 (MF-1) and site 2 (MF-2), and South Fork site 1 (SF-1) and site 2 (SF-2) of the Rio Ruidoso.

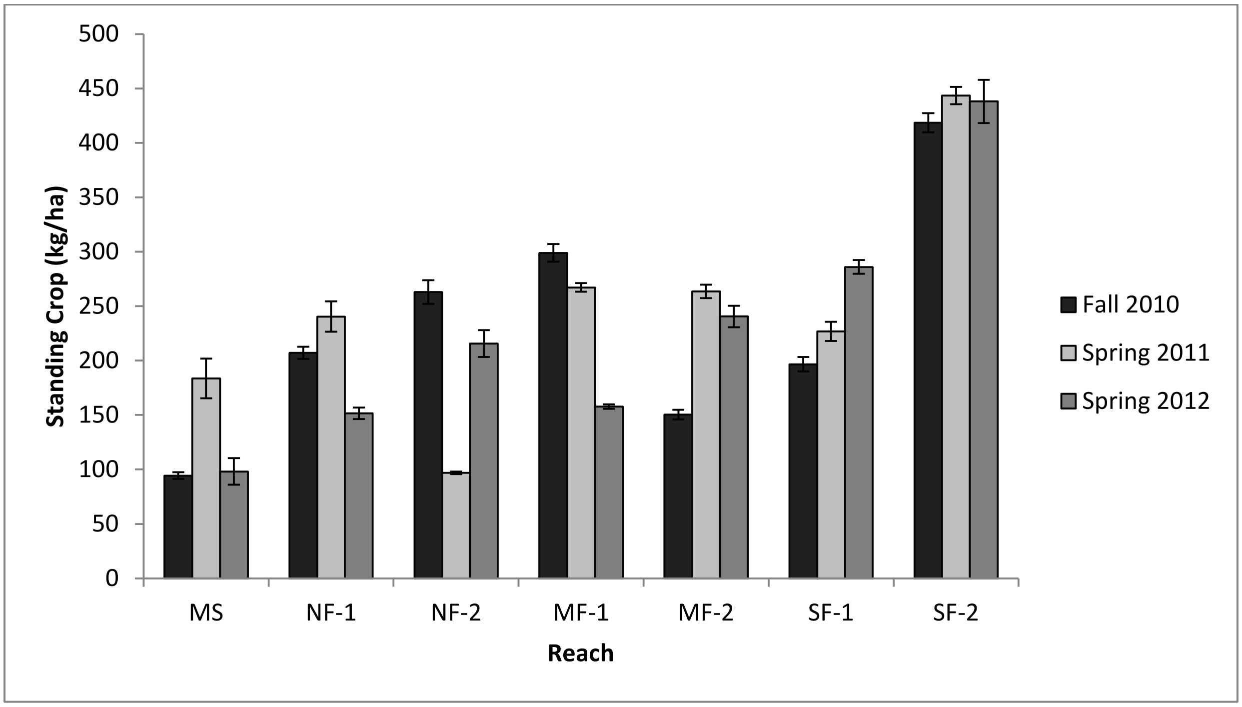

Figure 4. Standing crop (kg/ha) estimates (mean ± standard error) from the main stem (MS), North Fork site 1 (NF-1) and site 2 (NF-2), Middle Fork site 1 (MF-1) and site 2 (MF-2), and South Fork site 1 (SF-1) and site 2 (SF-2) of the Rio Ruidoso.

Mean fish densities and standing crop estimates averaged across all sites and across the fall and spring sampling periods revealed Rio Ruidoso watershed has among the highest densities (0.67 fish/m^2) and biomass (235.2 kg/ha) reported in the western United States (Platts and McHenry 1988). Less than 10% of streams have fish densities greater than that observed in the Rio Ruidoso and less than 5% of streams reported standing crop estimates greater than the Rio Ruidoso.

Prior to the drought, estimates of mean relative weight reflected fish at most sites with relative weights at or greater than 100 were in excellent condition throughout the Rio Ruidoso watershed (Figure 5). However, between fall 2010 and spring 2012 sample collections, relative weight for all three species declined at both Middle Fork and South Fork. Most notable was the decline in mean relative weight of brook trout in Middle Fork site 2 from 115 fall 2010 to 91 spring 2012. The brook trout are isolated to a small section of the Middle Fork above a barrier and thus unable to find more suitable habitat. When coupled with high density, food and optimal habitat (pools) may have been limited during the drought.

In the spring of 2011, a total of 144 fish were floy-tagged in South Fork site 1 (8 brown trout, 20 rainbow trout), South Fork site 2 (56 brown trout, 14 rainbow trout), Middle Fork site 1 (21 rainbow trout), and Middle Fork site 2 (25 brook trout) ranging in size from 146 to 376 mm TL (187 mm ± 2.84, mean ± SE). In the spring of 2012, a total of 11 fish were recaptured (7.6% of the total tagged) and all were recaptured within the same site initially tagged (Table 12). Thus, distance moved between release and capture was not calculated. Recaptured fish gained an average of 15 mm (± 2.4 mm) in length and 5.9 g (± 5.6 g) in weight over one year. Nearly half (45%) of recaptured fish lost weight, corroborating results that relative weights declined between spring 2011 and spring 2012. The low recapture was possibly due to fish moving out of the study site, tag loss, or predation. The co-author of this report observed osprey (*Pandion haliaetus*) foraging throughout the study sites at the time of the surveys and would have been able to cue in on the brightly colored tag (Personal observation, B. Kalb).

Length-frequency histograms for brown trout revealed clear breaks between age-0 fish and age-1+ fish in fall 2010 (see Appendices). Low numbers of recently emerged young-of-year brown trout were captured spring 2011; however, no subsequent analysis of age-0 densities or recruitment were performed due to the extremely low capture probabilities of these small fish. For analysis, the same cutoff point for age determination of brown trout was used for brook trout

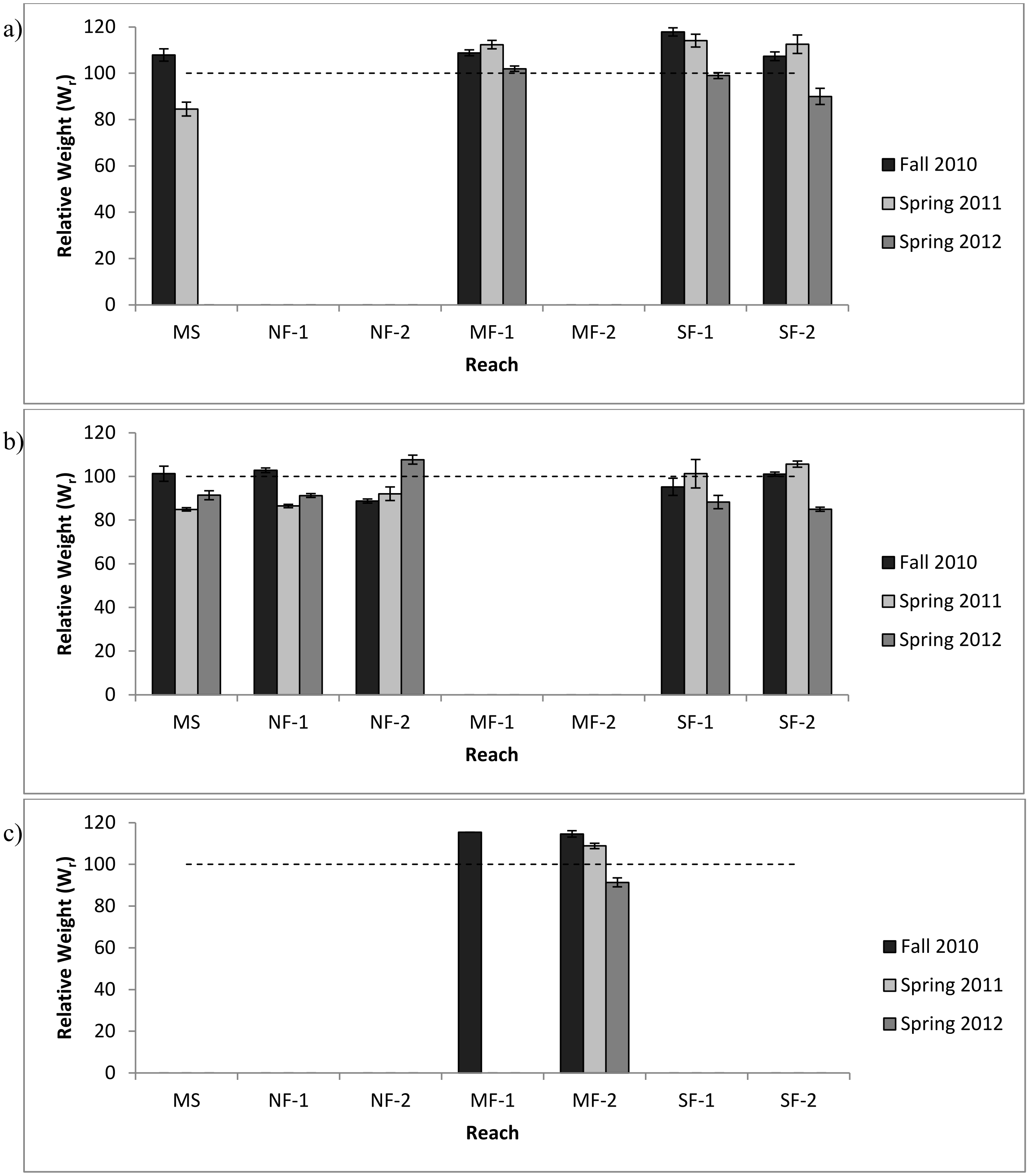

Figure 5. Mean relative weight (W_r) of rainbow trout (a), brown trout (b), and brook trout (c) captured during fall 2010, spring 2011, spring 2012 from the Main Stem (MS), North Fork site 1 (NF-1) and site 2 (NF-2), Middle Fork site 1 (MF-1) and site 2 (MF-2), and South Fork site 1 (SF-1) and site 2 (SF-2) of the Rio Ruidoso. Relative weights above dashed line (100) represent fish in excellent condition and below the dashed line represent less than optimum condition. Error bars are ± standard error.

Table 12. Mean (± standard error) change (Δ) in length (mm) and weight (g) of fish tagged spring 2011 and recaptured spring 2012 from Middle Fork site 1 (MF-1), Middle Fork site 2 (MF-2), South Fork site 1 (SF-1), and South Fork site 2 (SF-2). Changes in length and weight between tagging and recapture are provided (Δ).

Reach	Number tagged	Number recaptured	Δ Length (mm)	Δ Weight (g)
MF-1	21	4	19.0 (3.5)	23.5 (4.9)
MF-2	25	1	3.0 (0)	-9.0 (0)
SF-1	28	0	-	-
SF-2	70	6	14.3 (3.1)	-3.3 (6.4)

“-“ fish were not recaptured.

in other sites as both brook and brown trout are fall spawners and likely to be similar in length early in age. Brook trout did not provide any clear distinction between age-0 and age-1+ fish due to either variable growth rates in fish across ages and/or low water temperatures resulting in slow growth rates. Rainbow trout of age-0 were ≤ 100 mm in the fall 2010 and not captured in the spring sample collections.

Conclusions and Management Recommendations

A comprehensive and systematic survey of the Rio Ruidoso and its major tributaries (North, Middle, and South forks) within the Mescalero Apache Reservation documented sufficient habitat and prey base to support a self-sustaining RGCT population. Despite severe drought and subsequent low discharge during the study, fish density and biomass estimates were among the highest reported in the western United States (Platts and McHenry 1988). While this may suggest the Rio Ruidoso watershed has the potential for resiliency and recovery from drought conditions, an increase in drought severity as well as increase in mean annual air temperatures between 2.1 and 5.7°C are predicted to occur within this century (IPCC 2007). In areas of the Rio Ruidoso watershed, summer water temperatures exceeded thermal benchmarks identified by the New Mexico water quality standards for “high quality coldwater” habitat. Additionally, the threat of a catastrophic fire within the watershed is substantial as evidenced by the Little Bear Fire, which burned just north of the watershed and into parts of the North Fork in 2012. Wildfire and subsequent ash and sediment flows would result in long term detrimental effects on fish and macroinvertebrate communities requiring years to recover (Gresswell 1999). While these risks are considerable, the potential for successful restoration of RGCT to the Rio Ruidoso watershed may contribute to resilience and persistence of the subspecies throughout its range.

Criteria for the RGCT Strategic Plan requires optimal salmonid habitat be present that includes deep pools, cover, adequate spawning substrate, nursery areas for young fish, and thermal regimes that bracket the thermal tolerance range throughout critical life stages (Alves et al. 2008). Minimum stream length is also important and will vary with habitat quality. Hilderbrande and Kershner (2000) estimated minimum stream length required by inland cutthroat trout populations for long-term persistence. As the target population size increased from 1,000 to 5,000 individuals, stream distance increased from 5 to 25 km. This did not account for fish mortality or food and habitat quality. When a loss rate of 10% was included and food or habitat quality decreased, minimum stream lengths increased from 10 to 50 km for target population sizes of 1,000 to 5,000 individuals. While federal and state propagation and augmentation programs provide a healthy and genetically-robust fish, the habitat must be able to support the fish throughout its entire life cycle with self-sustaining populations. If the Rio Ruidoso watershed on the Reservation is sufficient in stream length and habitat is suitable to support self-sustaining RGCT populations, then this would meet the necessary criteria for establishing a metapopulation and one of the highest priorities for conservation action of a species at risk which increases the distribution, connectivity, and condition of the species' habitat. The following strategies could include:

1) *Development of a Metapopulation through Barrier Construction*

The presence of public access to the headwaters of the North Fork Rio Ruidoso near Ski Apache represents an inherent risk of reintroduction of non-native fish from the public. Due to this risk, restoration is most likely to be successful only for the South and Middle forks of the Rio Ruidoso because they have no easy public access points and are completely contained within the boundary of the Mescalero Apache Reservation. By restoring both of these segments, an RGCT metapopulation can be created within approximately 12 km of perennial stream where individuals can disperse between the two tributaries. Movement of individuals will not only provide opportunity to seek refuge in the event of a catastrophic event such as a wildfire, but facilitate gene flow and thereby reduce the threat of extirpation from stochastic processes (Hastings and Harrison 1994). The combined effect of stream length and a continuum of complex habitat will most likely support diverse life history strategies as well as maintain gene flow and genetic variation. Hilderbrand and Kershner (2000) demonstrated that a minimum of 8 km of stream is necessary if fish densities are high (greater than 0.3 fish/m^2) to support an effective cutthroat population of 500 breeding pairs.

A barrier will prevent upstream movement of non-native salmonids upstream into the reclaimed stream reaches. The proposed location of the barrier is approximately 100 m below the confluence of the Middle and South forks and would protect 12 km of perennial stream habitat for repatriation of RGCT (Figure 6). This site was selected because of a naturally

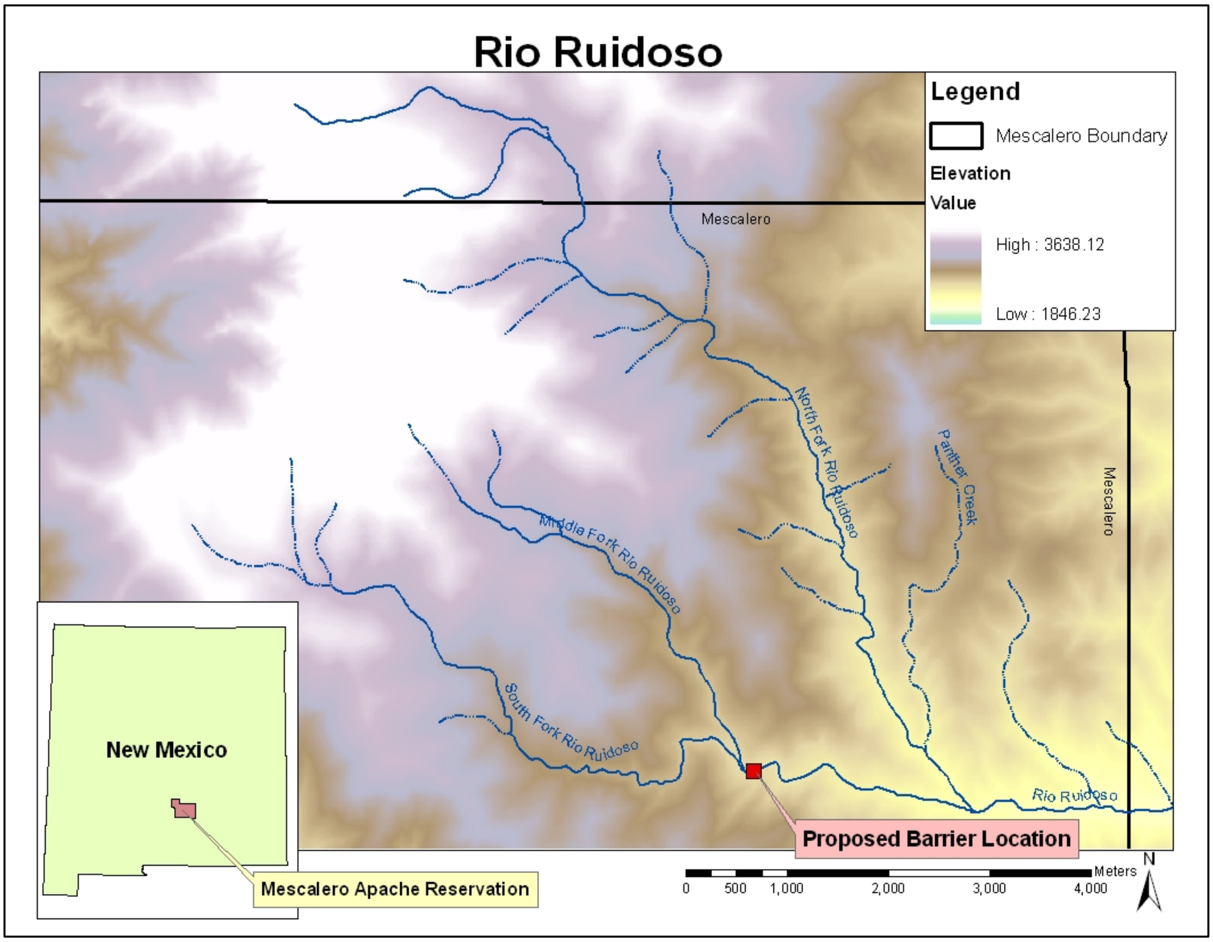

Figure 6. Headwaters of Rio Ruidoso within the Mescalero Apache Reservation showing proposed barrier location (red square).

occurring long cascade of bedrock that can be manipulated into a substantive 7-18 meter waterfall. Due to the remoteness of the proposed barrier location, construction of the barrier would involve blasting the cascade using carefully placed explosives. The resulting barrier would be of sufficient vertical height with a splash-pad made out of blasted rock to prevent fish from moving over the barrier during high flows.

2) Compliance

Prior to barrier construction and fish removal, National Environmental Policy Act (NEPA) compliance is needed. Public meetings with members of the Tribe and State and Federal biologists to discuss the transport, fate and effects of the piscicide and proximity to the Mescalero and City of Ruidoso drinking water will provide transparency. Notifications to the public would need to be published to restrict access and notify of any environmental considerations to avoid exposure to treated waters.

3) Fish Removal

CFT Legumine™ (5% rotenone) has been used extensively in fisheries management to remove unwanted fish from streams. The chemical acts at the cellular level to interrupt respiration in gill-breathing organisms (Schnick 1974) and when applied at the recommended concentrations is generally nontoxic to humans and other non-gill-breathing organisms. The presence of both spring spawning rainbow trout and fall spawning brown and brook trout will require chemical removal of fish June and October to ensure treatment targets young-of-year fish.

Prior to treatment, stream discharge and flow rates would be calculated to determine drip rates and spacing of drip stations. Sentinel fish would be placed in cages at predefined intervals to determine how far to target concentrations downstream past the barrier. Trained personnel would apply the piscicide to segments upstream of the barrier. Crews with backpack sprayers would apply the piscicide to backwaters, poorly mixed shorelines, and intermittent tributaries. Once applied, rotenone degrades naturally through photolysis and hydrolysis; however, a piscicide neutralization drip station containing potassium permanganate would be introduced to neutralize rotenone and thereby protect water quality as well as non-target aquatic biota in downstream areas.

4) Post-treatment Monitoring

Intensive monitoring one year post-treatment will be necessary during base flow conditions to ensure complete eradication of non-native salmonids. While chemical renovation is generally successful during the first treatment, there have been instances where re-treatment of the piscicide was necessary. If non-native fish are detected, then immediate action would need to be taken with the re-treatment of the piscicide and subsequent follow up one year post-treatment until non-native fish are no longer recovered.

5) 'Repatriation'

A memorandum of understanding between the Mescalero Apache Reservation and the New Mexico Department of Game and Fish would facilitate securing the Pecos linage of RGCT. Once non-native fish are removed upstream of the barrier, repatriation of RGCT (Pecos lineage) would begin with the stocking of varying year classes until monitoring reveals natural recruitment is occurring and sufficient densities are present to support a viable population long term. A long-term monitoring program to include fish surveys above and below the barrier on an annual basis would allow monitoring of RGCT as well as detect any incursion of non-native fish.

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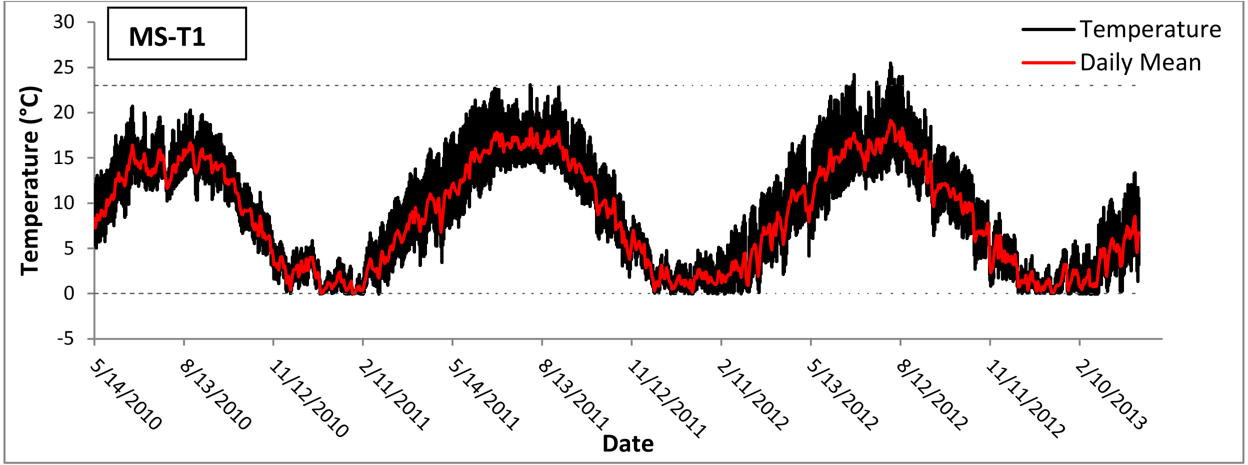
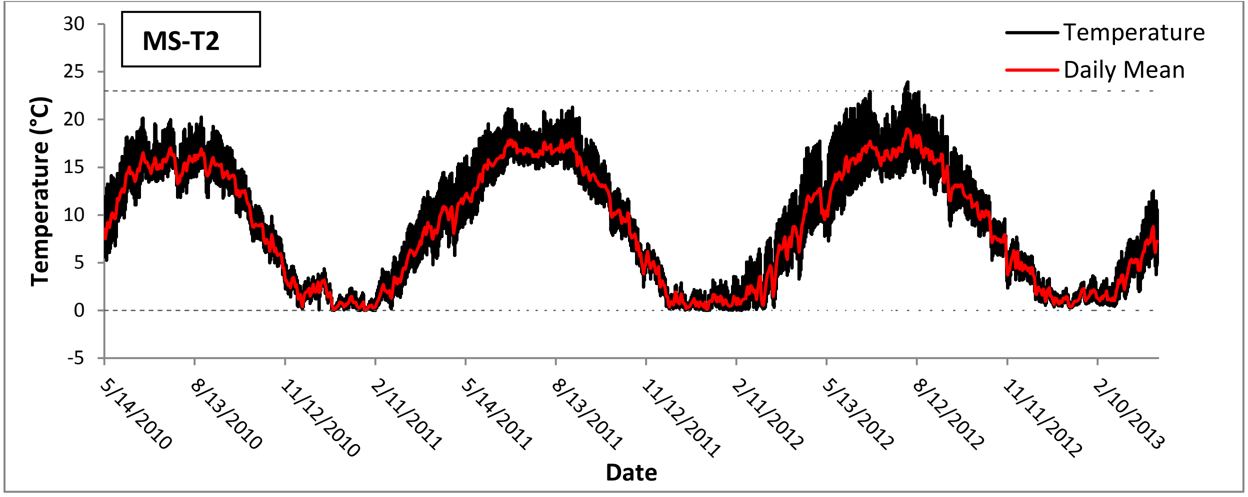
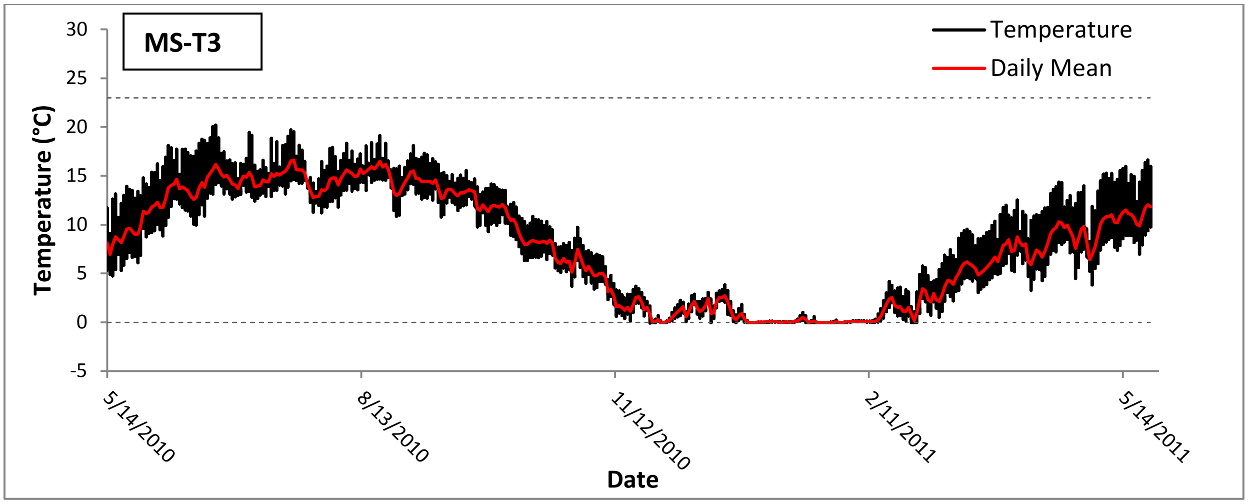
APPENDICES

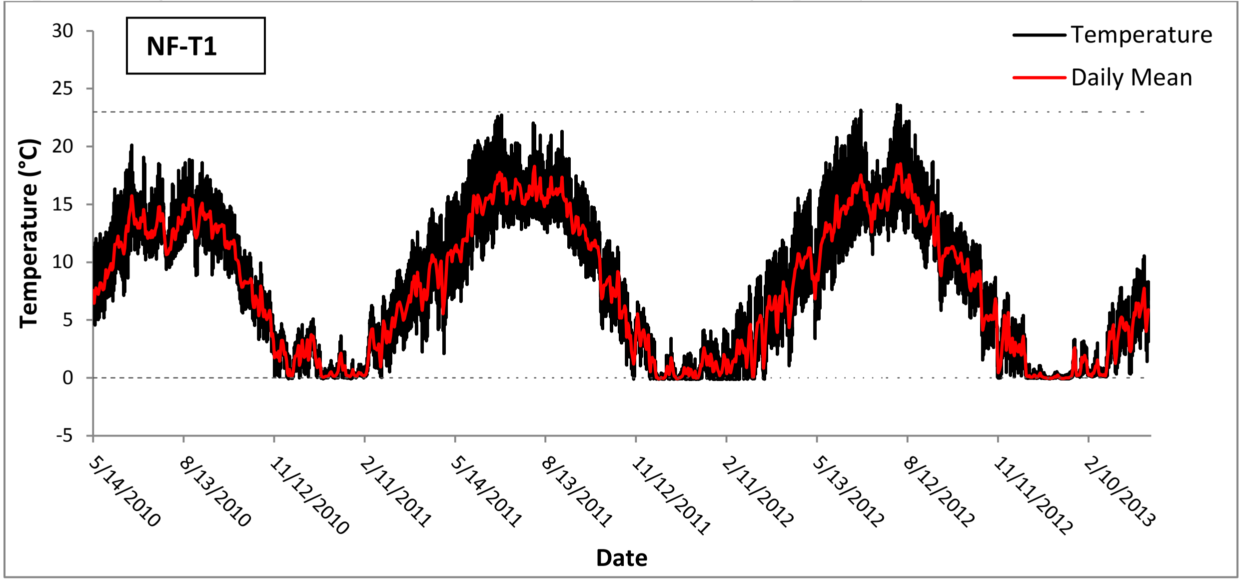
Appendix 1. Hourly stream temperatures and mean daily stream temperatures between May 14, 2010 and April 12, 2013 for temperature stations on the main stem Ruidoso (MS-T1 and MS-T2) and May 14, 2010 to May 24, 2011 on the main stem Ruidoso for the MS-T3 temperature station. Dashed lines denote 0°C (potentially supercooling water) and 23°C (NMWQCC criteria for "high quality coldwater streams").

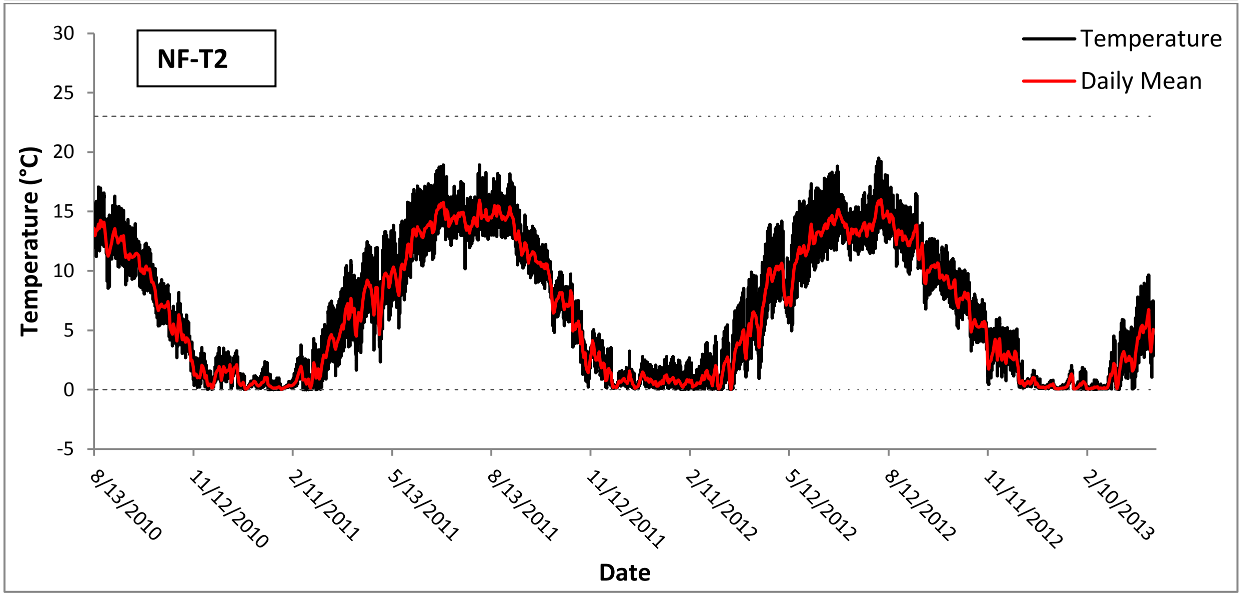




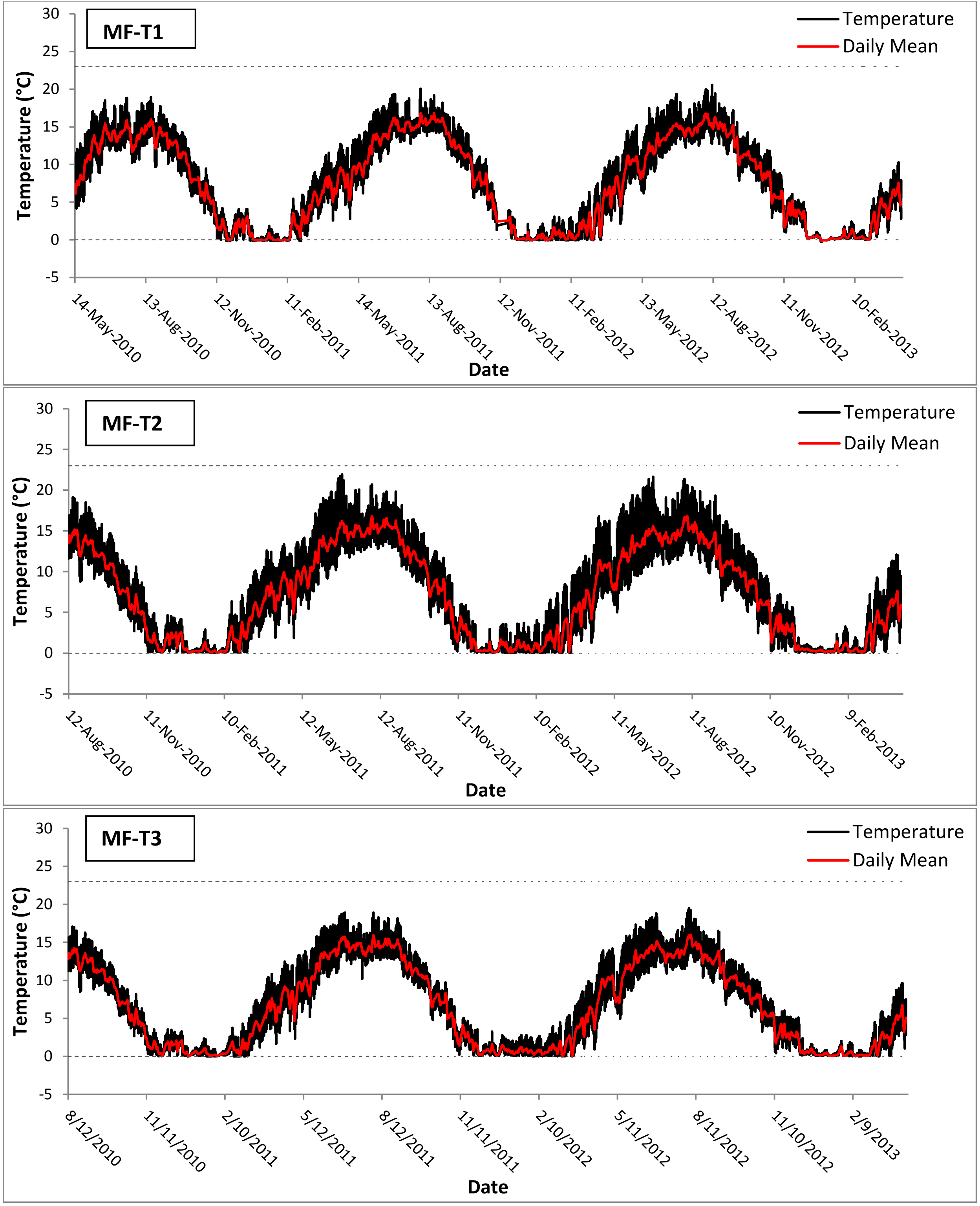


Appendix 2. Hourly stream temperatures and mean daily stream temperatures between May 14, 2010 and April 12, 2013 for temperature stations on the North Fork Rio Ruidoso (NF-T1) and between August 13, 2010 and April 12, 2013 (NF-T2). Dashed lines denote 0°C (potentially supercooling water) and 23°C (NMWQCC criteria for "high quality coldwater streams").

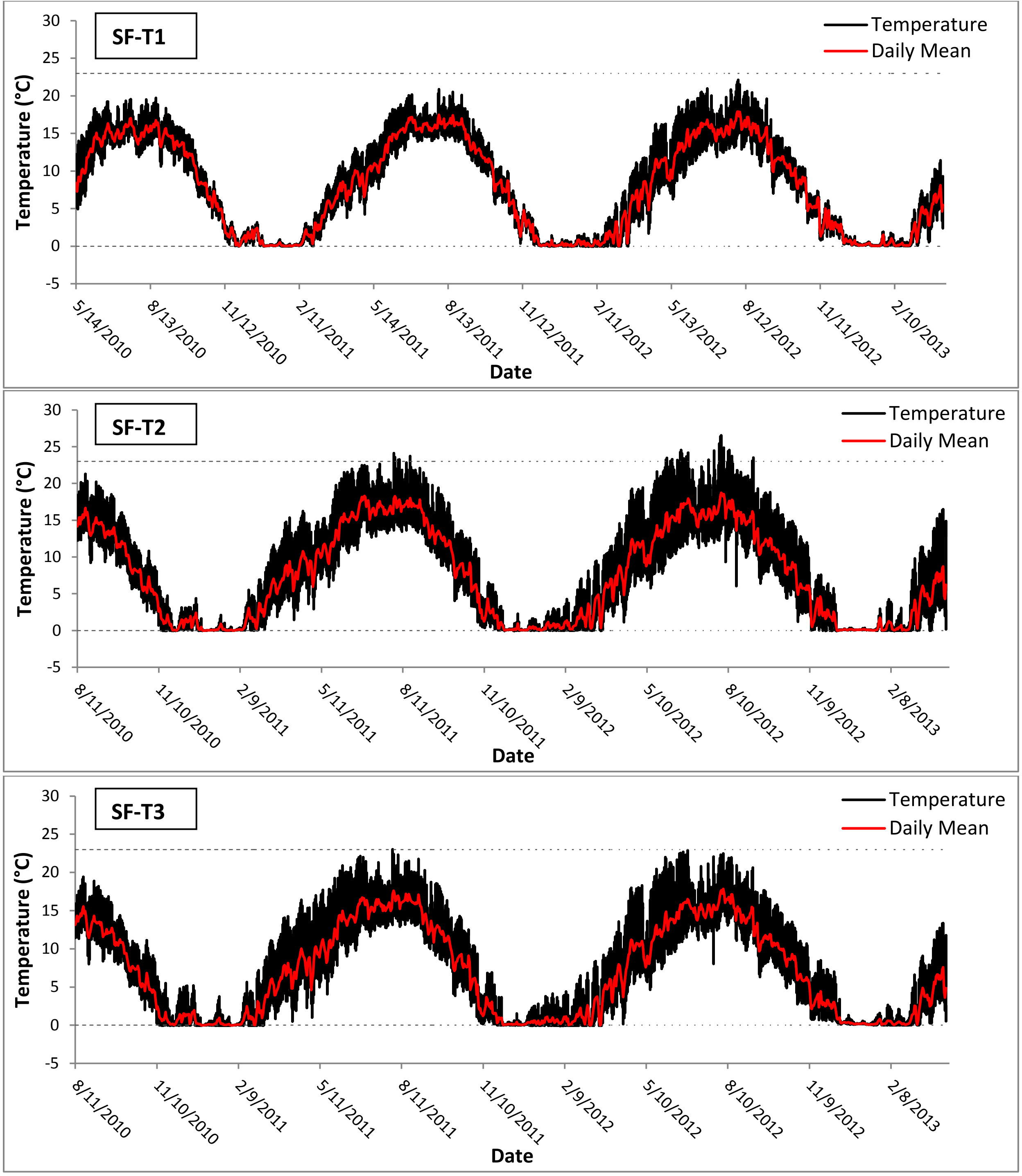




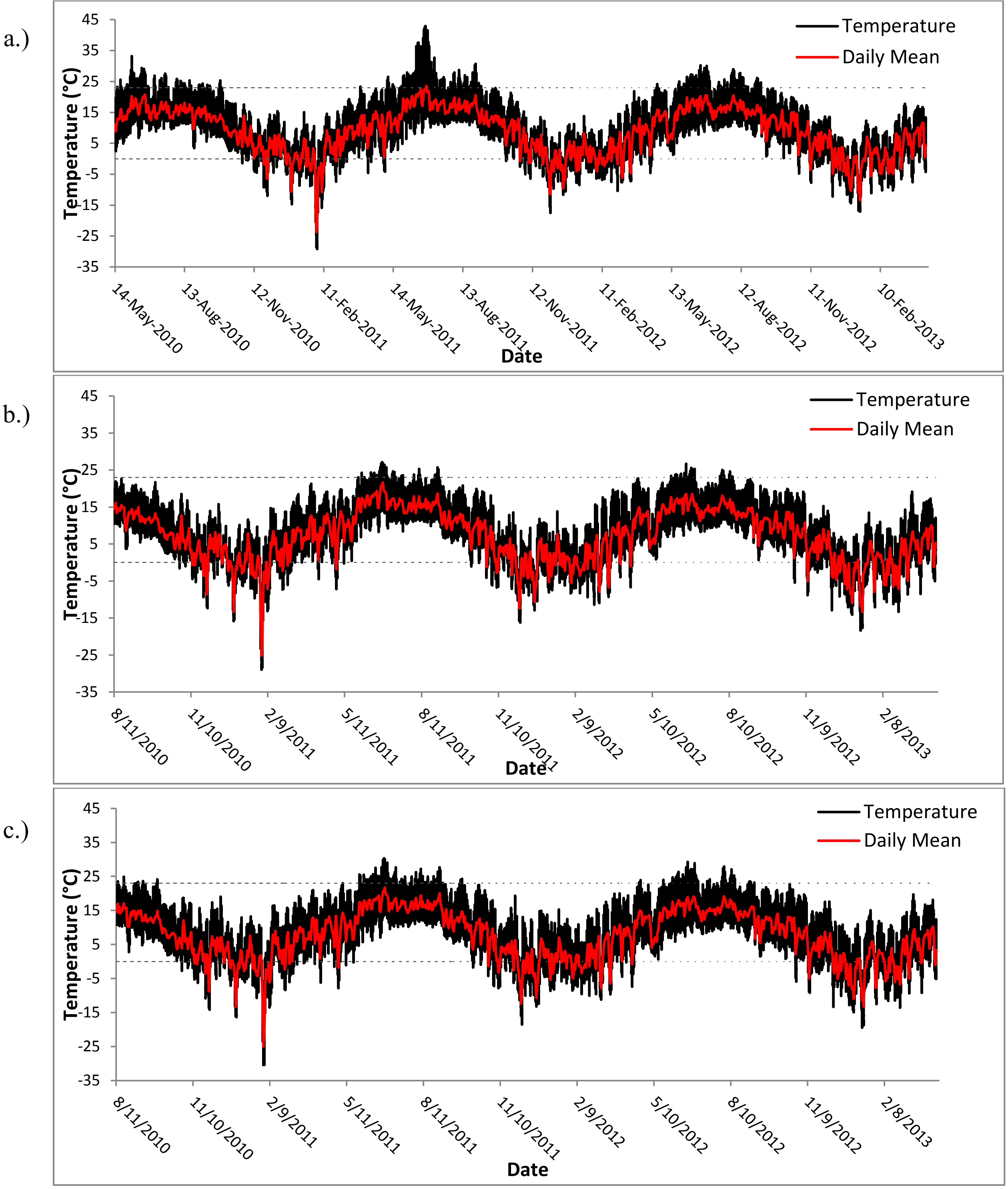
Appendix 3. Hourly stream temperatures and mean daily stream temperatures between May 14, 2010 and April 12, 2013 for temperature stations on the Middle Fork Rio Ruidoso (MF-T1) and between August 12, 2010 and April 12, 2013 (MF-T2 and MF-T3). Dashed lines denote 0°C (potentially supercooling water) and 23°C (NMWQCC criteria for "high quality coldwater streams").



Appendix 4. Hourly stream temperatures and mean daily stream temperatures between May 15, 2010 and April 12, 2013 for temperature stations on the South Fork Rio Ruidoso (SF-T1) and between August 11, 2010 and April 12, 2011 (SF-T2 and SF-T3). Dashed lines denote 0°C (potentially supercooling water) and 23°C (NMWQCC criteria for "high quality coldwater streams").



Appendix 5. Hourly air temperatures and mean daily air temperatures for an air temperature logger that was paired with instream loggers. (a) One logger was paired with both Middle Fork (MF-T1) and South Fork Rio Ruidoso (SF-T1) stream temperature loggers collected between May 14, 2010 and April 12, 2013. (b) One logger was paired with the MF-T3 logger. (c) One was paired with the SF-T3 logger between August 11, 2010 and April 12, 2013. Dashed lines denote 0°C (freezing point) and 23°C (NMWQCC criteria for "high quality coldwater streams").



Appendix 6. Benthic macroinvertebrate taxa (mean organisms/m^2) sampled fall 2010 from Rio Ruidoso main stem (MS), North Fork site 1 (NF-1) and site 2 (NF-2), Middle Fork site 1 (MF-1) and site 2 (MF-2), and South Fork site 1 (SF-1) and site 2 (SF-2).

	MS	NF-1	NF-2	MF-1	MF-2	SF-1	SF-2
Plecoptera							
Maegarcys signata	22	-	11	14	25	39	7
Alloperla severa	4	32	7	14	50	57	7
Claassenia sabulsa	11	18	-	-	-	-	-
Ephemeroptera							
Baetis tricaudatus	187	197	176	65	65	162	233
Paraleptophlebia sp.	-	4	-	-	-	-	-
Drunella grandis	4	14	14	-	14	4	18
Cinygmula sp.	-	-	-	-	75	-	-
Trichoptera							
Rhyacophila sp.	4	-	22	-	14	11	18
Glossoma sp.	32	201	-	22	144	29	39
Hydropsyche sp.	456	230	592	305	126	675	624
Hydroptila sp	-	-	-	-	22	-	50
Neothremma sp..	4	-	-	-	-	-	-
Oecetis sp.	65	205	327	54	90	29	240
Micrasema sp.	197	459	223	29	136	144	219
Diptera							
Dicranota sp.	-	-	22	-	4	-	22
Hexatoma sp.	29	57	11	14	22	43	39
Maruina sp.	-	4	-	-	4	-	-
Dixa sp.	-	4	-	-	-	7	-
Simulium sp.	-	7	-	4	-	-	7
Chironomidae	11	65	25	32	25	36	111
Diamesinae	4	14	-	-	-	-	39
Tabanus sp.	-	-	-	-	-	-	4
Ceratopogonidae	-	-	-	-	7	-	-
Hemiptera							
	-	-	-	-	-	-	-
Coleoptera							
Heterelmis corpulentus	93	223	75	22	276	301	244
Other							
Arachnida (spiders)	-	4	-	-	4	-	-
Hydraachnidia sp. (mites)	-	14	4	-	-	-	-
Tubificidae	-	-	-	-	4	-	-
Total organisms/m^2	1135	1753	1527	575	1107	1570	1971

"-" indicates that no taxa were found

Appendix 7. Benthic macroinvertebrate taxa (mean organisms/m^2) sampled spring 2011 from Rio Ruidoso main stem (MS), North Fork site 1 (NF-1) and site 2 (NF-2), Middle Fork site 1 (MF-1) and site 2 (MF-2), and South Fork site 1 (SF-1) and site 2 (SF-2).

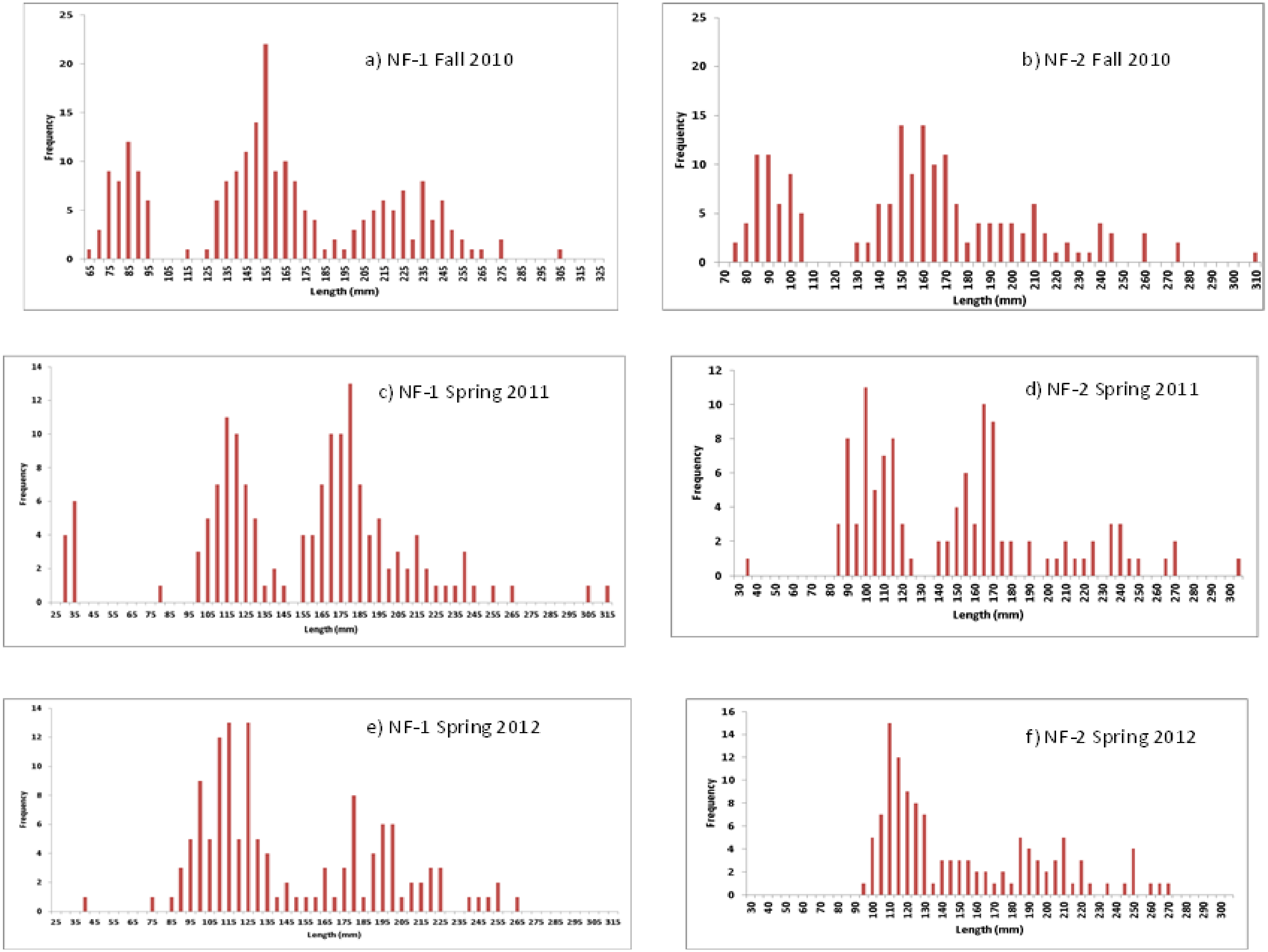
	MS	NF-1	NF-2	MF-1	MF-2	SF-1	SF-2
Plecoptera							
Maegarcys signata	43	-	11	18	4	-	47
Alloperla severa	43	83	22	194	75	341	65
Claassenia sabulsa	4	7	-	14	-	115	-
Ephemeroptera							
Baetis tricaudatus	205	54	122	36	233	244	118
Paraleptophlebia sp.	47	47	4	25	-	11	25
Drunella grandis	4	7	14	25	4	4	11
Cinygmula sp.	1357	650	1052	969	861	1227	1432
Trichoptera							
Rhyacophila sp.	4	-	39	11	7	32	4
Glossoma sp.	32	50	65	65	136	197	-
Hydropsyche sp.	345	57	628	111	14	136	291
Hydroptila sp	-	-	-	-	-	39	43
Neothremma sp.	4	-	-	4	-	14	-
Oecetis sp.	25	25	4	7	4	-	4
Micrasema sp.	154	262	255	126	592	83	25
Lepidostoma sp.	-	-	-	-	-	65	18
Diptera							
Dicranota sp.	-	-	11	-	4	11	11
Hexatoma sp.	4	11	11	4	25	11	11
Maruina sp.	4	-	-	-	4	-	-
Dixa sp.	-	-	-	-	-	7	-
Simulium sp.	-	7	7	-	-	-	-
Chironomidae	133	129	237	273	108	1353	262
Diamesinae	4	-	-	-	-	140	-
Tabanus sp.	-	-	-	-	-	4	-
Ceratopogonidae	-	-	-	18	14	18	-
Hemiptera							
	-	-	-	-	-	-	-
Coleoptera							
Heterelmis corpulentus	50	39	50	104	255	212	144
Optioservus sp.	-	-	4	-	-	-	-
Helicus striatus	-	-	4	-	-	-	-
Curculionidae	-	-	-	-	4	-	-
Other							
Arachnida (spiders)	7	4	-	4	4	-	-
Hydraachnidia sp. (mites)	4	-	4	11	7	7	11
Tubificidae	-	-	7	-	-	-	-
Collembola (springtails)	-	-	4	-	4	-	-
Total organisms/m^2	2573	1436	2602	2033	2377	4385	2551

"-" indicates that no taxa were found.

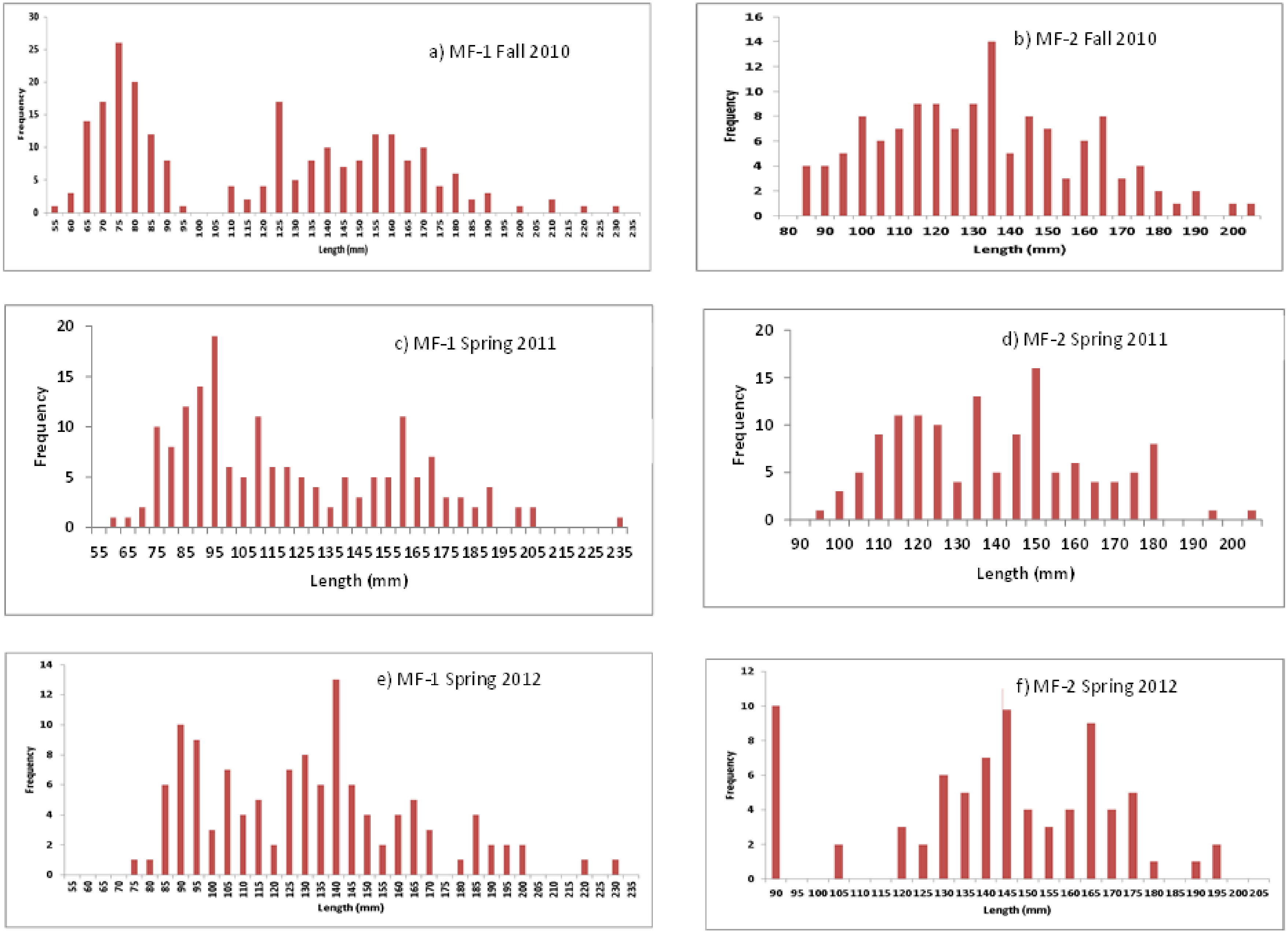
Appendix 8. Benthic macroinvertebrate taxa (mean organisms/m^2) sampled spring 2012 from Rio Ruidoso main stem (MS), North Fork site 1 (NF-1) and site 2 (NF-2), Middle Fork site 1 (MF-1) and site 2 (MF-2), and South Fork site 1 (SF-1) and site 2 (SF-2).

	MS	NF-1	NF-2	MF-1	MF-2	SF-1	SF-2
Plecoptera (stoneflies)							
Nemouridae	118	65	54	258	1,345	1,234	172
Megarcys signata	-	-	11	4	4	-	-
Alloperla severa	176	122	11	337	208	222	456
Claassenia sabulsa	14	25	11	-	-	-	-
Ephemeroptera (mayflies)							
Baetis tricaudatus	237	312	194	466	606	1,550	448
Paraleptophlebia sp.	-	179	65	441	18	22	4
Drunella grandis	-	4	0	4	-	-	-
Leptohypes sp.	-	-	-	-	-	39	-
Cinygmula sp.	65	97	65	606	308	1,033	197
Trichoptera (caddisflies)							
Rhyacophila sp.	108	7	27	140	-	86	32
Glossoma sp.	230	54	-	1,119	47	-	369
Polycentropodidae	-	5,624	5	-	-	212	-
Hydropsyche sp.	179	93	140	456	4	72	-
Cheumatopsyche sp.	201	334	371	219	83	352	126
Helicopsychidae	-	29	-	-	-	-	-
Hydroptila sp	-	-	5	29	-	115	-
Neothremma sp.	-	-	506	-	2,109	-	39
Oecetis sp.	-	7	5	-	4	100	4
Limnephilidae	-	-	-	-	-	22	-
Lepidostoma sp.	4	-	-	14	2,263	-	-
Brachycentrus sp.	7	-	-	14	-	-	-
Micrasema sp.	39	-	614	499	319	-	68
Diptera (true flies)							
Dicranota sp.	22	4	-	-	-	-	-
Hexatoma sp.	-	22	5	-	29	20,227	32
Maruina sp.	190	-	22	4	-	-	4
Dixa sp.	-	-	-	4	4	7	7
Simulium sp.	796	65	194	7	-	25	1,040
Chironomidae	280	750	619	176	653	3,673	2,647
Diamesinae	47	-	-	-	-	-	-
Ceratopogonidae	11	-	-	22	32	39	22
Aeshnidae	-	-	-	-	-	4	-
Hemiptera (true bugs)							
	-	-	-	-	-	-	-
Coleoptera (beetles)							
Heterlimnius corpulentus	111	327	59	495	430	556	911
Carabidae	0	-	-	-	-	4	-
Other							
Arachnida (spiders)	0	18	5	7	7	158	4
Hydraachnidia (mites)	0	-	-	7	4	7	-
Tubificidae	4	4	4	-	-	-	-
Total organisms/m^2	2,882	8,160	3,021	5,394	8,725	30,108	6,742

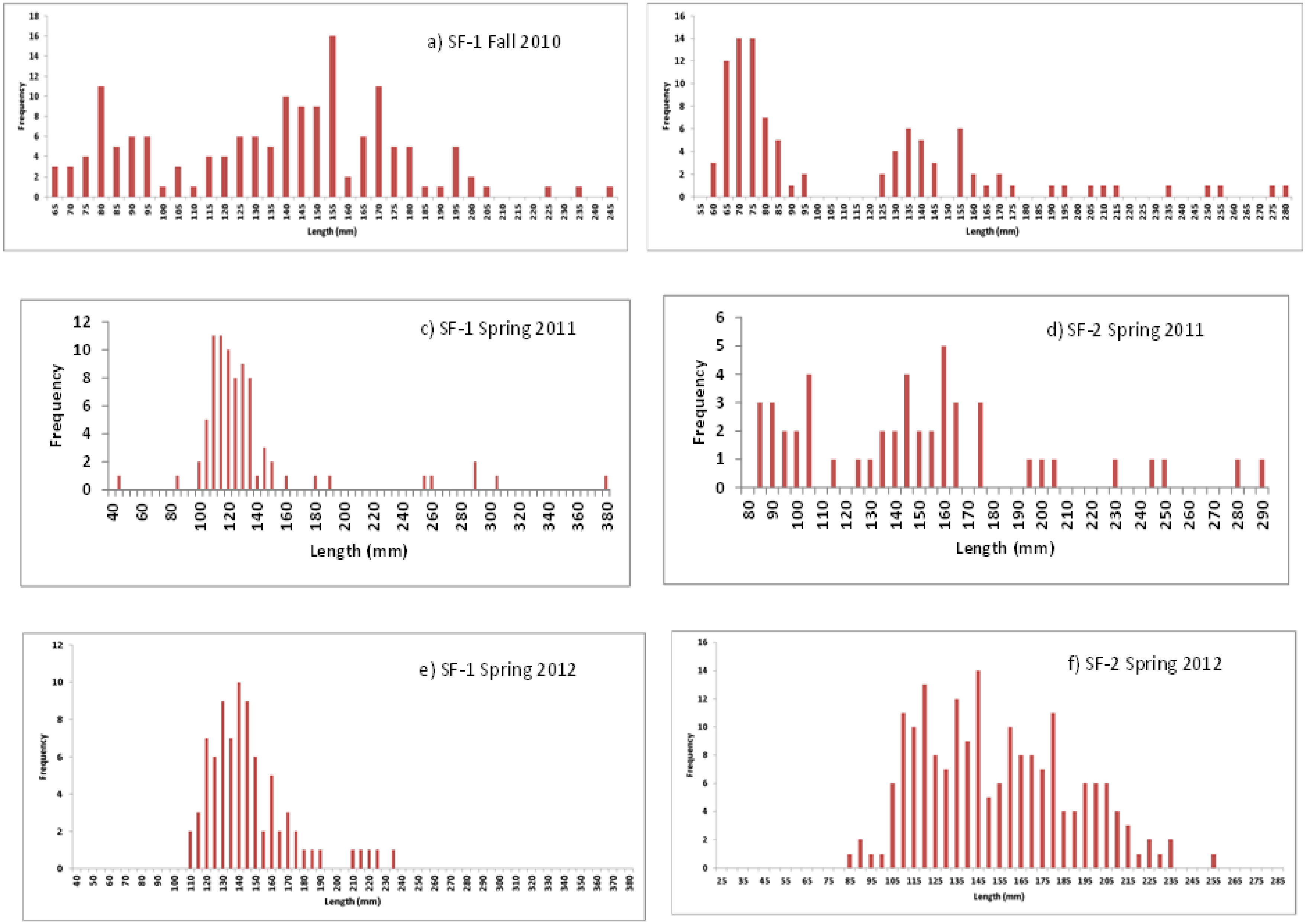
“-“ indicates no taxa were found.



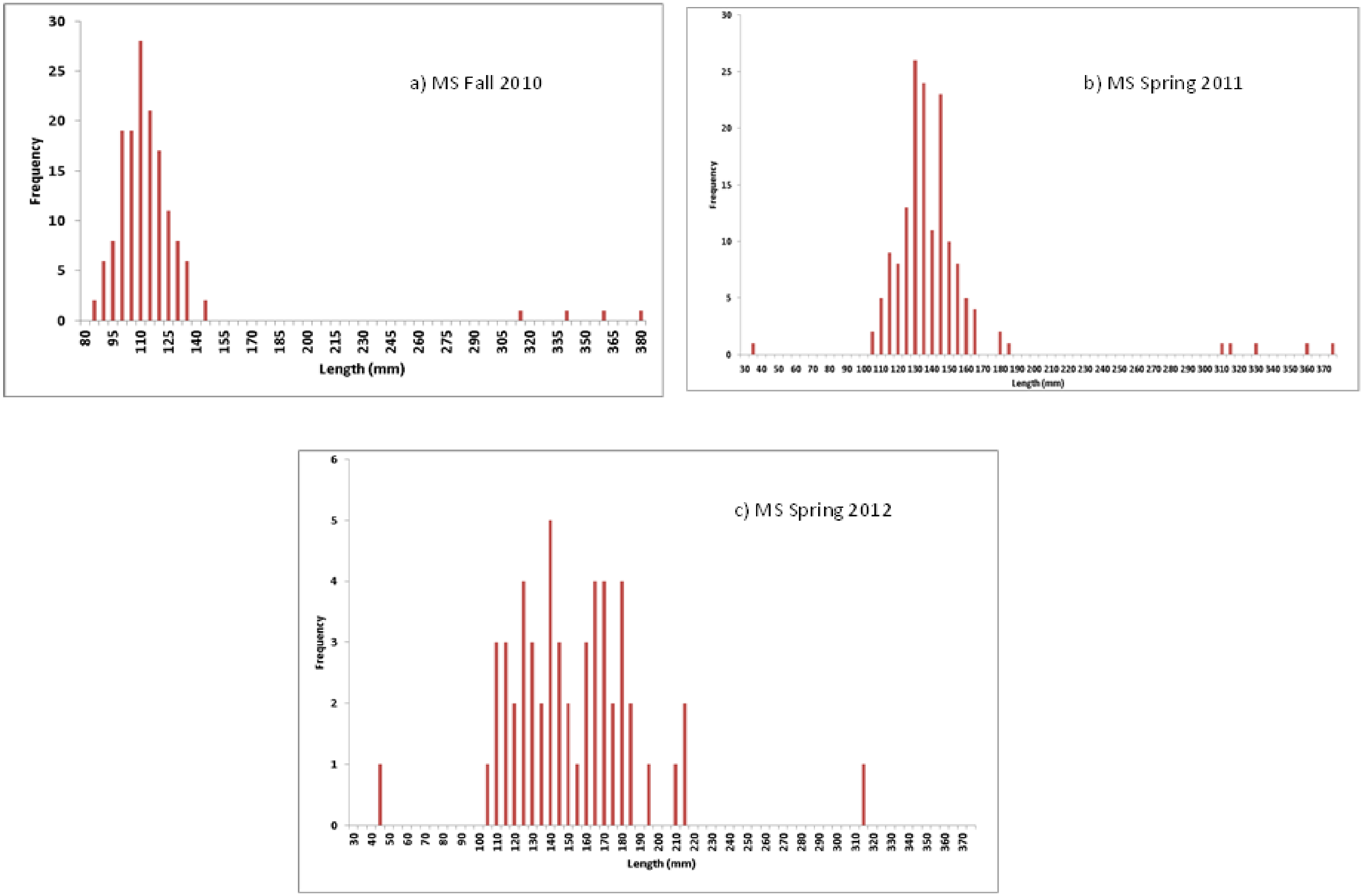
Appendix 9. Length (mm) frequency histograms of brown trout captured on the North Fork sites 1 (NF-1) and 2 (NF-2).



Appendix 10. Length (mm) frequency histograms of rainbow trout captured at Middle Fork site 1 (MF-1) and brook trout captured at Middle Fork site 2 (MF-2).



Appendix 11. Length (mm) frequency histograms of combined rainbow trout and brown trout captured on South Fork sites 1 (SF-1) and 2 (SF-2).



Appendix 12. Length (mm) frequency histograms of brown trout captured on the main stem (MS) of the Rio Ruidoso.