INTERIM ANNUAL REPORT (FY 2016)

1. ADMINISTRATIVE

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Period of Time Covered by Report: April 2015 – September 2016

Project Title: Impacts of Drought on Southwestern Cutthroat Trout: Influences of Changes in Discharge and Stream Temperature on the Persistence across a Sub-set of Rio Grande Cutthroat Trout Populations

Agreement Number: G15AC00263

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2. PURPOSE AND OBJECTIVES

The primary goal of the study is to assess the likelihood and project the impacts of drought on a subset of Rio Grande Cutthroat Trout (*Oncorhynchus clarkii virginalis*, RGCT) populations. This work will provide insight into RGCT persistence under anticipated environmental and biological pressures (*e.g.*, drought, temperature, competition). Specific study objectives will be to (1) empirically assess the effects of seasonal stream temperature and discharge on vital rates: apparent survival, growth, recruitment; and (2) model drought effects on the persistence of RGCT populations. The second objective includes two sub-objectives: a) model stream discharge, intermittency, and temperature in occupied RGCT streams under projected drought conditions and b) evaluate how drought conditions will alter population vital rates and persistence of these populations.

Tasks associated with the first objective began shortly after the arrival of Dr. Huntsman at New Mexico State University (February 2016). Dr. Huntsman noted that Objective 1 described the selection of only three RGCT populations. His recommendation was to increase the number of populations from three to at least eight populations to appropriately model vital rates (see Table 1). These eight populations should encompass a combination of environmental and biological pressures. Although newly developed models can identify a subset of important vital rates via count data through advancements in modeling software and computing power, these models lack predictive power when compared to empirical data made available via capture-mark-recapture methodologies. This equates to a complete block design in an analysis of variance framework (Table 1). For example, three factors that influence RGCT vital rates would require at least eight populations to capture all combinations of these factors (assuming only two fates of each factor: drought vs. no drought). In addition, a much more robust sampling effort would be needed to predict vital rates throughout the RGCT range. However, acquiring the needed capture-mark-recapture data would be logistically impossible. This problem can be ameliorated by incorporating an integrated population model that combines capture-mark-recapture data with count data to estimate vital rates across sampling locations. For the capture-mark-recapture component of the study, site selection is imperative. In addition, these locations must also support a robust RGCT population to result in a reasonable number of recaptures each sampling period (three seasons per year for three years).

A meeting with state biologists of the New Mexico Department of Game and Fish (NMDGF) resulted in recommendations and eventual approval of the State Collection Permit (authorization # 3033, 4/5/2016) of RGCT populations of importance. In addition, approval was granted to obtain access to the RGCT database (not publically available) which identifies core RGCT populations, known RGCT distributions throughout New Mexico and Colorado, genetic structure, estimated population sizes, potential barrier locations, and presence of invasive trout.

3. ORGANIZATION AND APPROACH

Study Stream Selection and Sample Collection: Study streams were chosen based on three criteria: (1) risk of the maximum weekly average temperature (MWAT) exceeding the 30-day ultimate upper incipient lethal temperature for juvenile RGCT (21.7ºC, Ziegler et al. 2013), (2) presence or absence of invasive trout in the drainage, and (3) history of intermittency (see Table 1). All sample reaches were established above fish barriers to insure sufficient numbers of RGCT were encountered for mark-recapture analysis. Therefore, invasive trout were not anticipated to be encountered, however, brown trout are common above the barrier of one of the study streams (Columbine Creek). Rio Grande Cutthroat Trout were sampled from all eight study streams in the spring (5/4/2016-6/14/2016), summer (7/24/2016-8/10/2016), and fall (9/30/2016-10/9/2016) (Figure 1, Table 2).

During each sampling period, RGCT were captured via triple pass depletion sampling with a backpack electrofishing unit, although equipment failure resulted in 1 or 2 passes at a subset of study streams during the summer (n = 4) and fall (n = 1) collections. During each survey, block nets were anchored to the upper and lower ends of a 300 m segment of stream for depletion surveys. Additionally, six 50m reaches within each 300 m study stream were delineated so fish could be processed and released near their point of capture. This also allowed for tracking potential fish movement at a spatial resolution of approximately 50 m. Upon capture, all fish were measured for length (fork and total lengths, ±1 mm) and weight (±0.1 g). Additionally, fish greater than 80 mm total length (TL) were implanted with a passive integrated transponder (PIT) tag if they did not already possess a tag (Table 3). Lastly, diets from five large (≥115 mm TL) and five small (<115 mm TL) RGCT size-classes were collected using gastric lavage for diet identification. Unfortunately, no information exists on size-at-maturity for RGCT. Information on size-at-maturity for Yellowstone Cutthroat Trout (*O. c. bouvieri*) does exist, where Yellowstone Cutthroat Trout mature at approximately 2-3 years at 100-150mm total length (Meyer et al. 2003). Therefore, the two size-classes defined here were based on RGCT von Bertalanffy longevity models developed from otoliths collected by NMDGF, with a size cutoff at an age of 2.5 years.

Water Quality: Water samples were collected from each study stream to characterize total alkalinity and total hardness (mg/L as $CaCO_3$). Water quality was collected using a HACH meter to obtain instantaneous water temperature (^{o}C), dissolved oxygen concentration (mg/L), conductivity (µS/cm), and pH. Lastly, stream discharge was estimated at each study site using the area-velocity approach (HACH digital flow meter; ft^3/sec).

To monitor stream temperature and intermittency, two ProV2 temperature loggers as well as two intermittency loggers were deployed in two separate pools and riffles within each study stream. The intermittency loggers are a modified Hobo Pendant data logger (ONSET, Inc) that enables simultaneous collection of high-resolution water temperature and electrical resistance (Chapin et al. 2014). This single, multi-functional sensor can reliably collect both the temperature and flow within a stream from which one can infer wet versus dry conditions.

Drift and Benthic Macroinvertebrates: Prior to electrofishing, macroinvertebrate drift and benthic samples were collected within each study stream. While not a part of the original scope of work, aquatic invertebrates provide the needed insight to characterize energetics and trophic basis of production in response to temperature challenges and intermittency. Drift macroinvertebrates were collected mid-day between 9:00 and 14:00 (Grant and Noakes 1987). Three replicate drift samples were collected with drift nets (width = 44 cm, depth = 27 cm; 250 µm mesh) deployed at three independent riffles (separated by a non-riffle channel unit). Benthic macroinvertebrates were similarly collected from three independent pools and three independent riffles using a benthic Hess sampler (diameter = 33 cm; 250 µm mesh). All samples were returned to the laboratory where they will be processed by splitting into 1 mm and 250 µm fractions (for large samples). All macroinvertebrates from the coarse fraction (>1 mm) will be separated from organic and inorganic material and identified to the lowest taxonomic unit possible (typically *genus*). The fine fraction (1 mm-250 µm) will be split to a $1/8^{th}$ fraction using a Folsom plankton splitter, and all macroinvertebrates will be identified. For small samples, the entire sample will be identified.

Fish Habitat: In the summer (July 6-9), habitat was classified within each 50 m segment of each study stream using a thalweg profile (Petty et al. 2003, 2005). Every three meters for the entire 300 m study reach, a habitat measurement was taken within the thalweg. Measurements taken at each point along the thalweg included 60% velocity, substrate size (mm), depth (cm), distance to fish cover (cm), and fish cover type (e.g., rock, woody debris, undercut). All substrate was grouped into substrate categories based on the Wolman pebble count methodologies. Additionally, wetted width (m) and canopy cover (via a densiometer) was recorded at every 5^{th} measurement. Lastly, channel units (*i.e.*, pool, riffle, run, glide, and cascade) were identified and the slope (%) of the channel unit was measured with a clinometer.

Preliminary Analysis- A principal component analysis (PCA) was used to summarize habitat characteristics for each 50 m segment within each study stream. Summarized habitat data based on a PCA, temperature (°C), and discharge (ft^3/sec) were then used within a hierarchical N-mixture modelling framework (Royle 2004) to explain RGCT abundance at a 50 m scale. Counts of RGCT were modeled for each segment and season as a function of the second and third principal component (PC) axes and average maximum daily temperature ($Temp$). The first PC axis was removed from analysis due to high correlation with the stream temperature metric. Detection efficiency was similarly modeled as a function of stream discharge (Q). Lastly, each study stream was included as a random effect on both abundance and detection models to account for lack of independence due to multiple stream segments being located within the same study stream. The true counts (latent state, $N_{i,t}$) at segment *i* on season *t* with the binomial N-mixture model were modeled according to the following equations:

Eqn. 1:

$$N_{i,t} \sim Poisson(\lambda_{i,t})$$

Eqn. 2:

$$y_{i,t} | N_{i,t} \sim binomial(N_{i,t}, pi_{Stream_i,t})$$

Eqn. 3:

$$pi_{Stream_i,t,j} = p_{Stream_i,t} * (1 - p_{Stream_i,t})^{j-1}$$

Eqn. 4:

$$logit(p_{Stream_i,t}) = \varepsilon_{Stream_i} + \beta_Q * Q_{Stream_i,t}$$

Eqn. 5:

$$\varepsilon_{Stream_i} \sim N(\mu_{Stream}, \sigma^2{}_{Stream})$$

Eqn. 6:

$$\log(\lambda_{i,t}) = \alpha_{Stream_i} + \beta_{Temp} * Temp_{Stream_i,t} + \beta_{PC\,2} * PC\,2_i + \beta_{PC\,3} * PC\,3_i + offset_i$$

Eqn. 7:

$$\alpha_{Stream_i} \sim N(\mu_{Stream}, \sigma^2{}_{Stream})$$

Where detection efficiency (p) was estimated for each stream (*stream$_i$*), electrofishing pass (1, 2, or 3) represented by $_j$, and season *t* as a function of discharge Q. Stream was also modelled as a random effect on both detection efficiency (ε_{Stream_i}) as well as RGCT counts (α_{Stream}). We included an offset (log of segment length) when modeling RGCT counts to account for unequal length of some stream segments.
A Bayesian approach with Markov chain Monte Carlo (MCMC) methods in JAGS (Plummer 2013) was used within the R programing language (R Development Core Team 2015) with the "jagsUI" package (Kellner 2015) to construct the N-mixture model. The Bayesian analysis was run with three chains, a chain length of 100,000 burn-in of 50,000, and a thinning value of 100. Model convergence was confirmed by Gelman and Rubin convergence diagnostics ($\hat{R}$ < 1.1, Gelman and Rubin 1992). Minimally informative priors were used for all regression coefficients, $\beta \sim N(0,1)$.

Growth rates were estimated for RGCT as the difference in log transformed total lengths (TL) between initial capture and recapture divided by the number of days between captures ([log(TL recapture) – log(TL initial capture)]/days). Total lengths were transformed for growth data because fish growth is typically non-linear. Growth rates were estimated for the two size-classes and during the summer and fall intervals, since fish were first captured in the spring.

4. RESULTS (PRELIMINARY)

Stream Temperature and Fish Habitat: Stream temperature loggers identified thermal profiles in four of the eight study streams exceeded the ultimate upper incipient lethal temperature of 21.7ºC for juvenile RGCT (Ziegler et al. 2013; Figure 2). The warmest streams on average were the two grassland streams (Comanche and Vidal), with Cañones and El Rito being the next warmest. The remaining four streams (Vidal, Alamitos, Jacks, and Powderhouse) never exceeded the upper incipient temperature. Interestingly, the four streams that exceeded this upper stressful thermal limit also contained fish with fungal infections (Figure 3). While anecdotal, these observations suggest these populations were immunocompromised likely due to stressful thermal limits and warrants further investigations (Table 3).

The first three components of the PCA accounted for 55% of the variation in the habitat variables. The first principal component axis (PC 1) separated sites by a stream velocity gradient, where streams with greatest flows loaded strongly on the negative side of this axis (Figure 4, Table 4). Columbine and Alamitos loaded strongly on the high velocity side of this axis, while the two low gradient grassland streams (Vidal and Comanche) loaded strongest on the positive side of PC 1. In contrast, PC 2 reflected a fish cover gradient, where streams with greater distances between objects that could conceal RGCT loaded strongest on the positive side of this axis. El Rito, Cañones, and Vidal had greater distances between fish cover objects compared to Columbine, Powderhouse, Jacks, and Comanche. A third PC axis identified a stream depth gradient, where the deepest sites with dominant substrates of silt and boulder loaded strongest in the negative direction (Figure 4).

Fish Sampling, Movement, N-mixture Model, and Growth Rates: A total of 1,762 RGCT were captured across the three sample collection dates. Of this total, 1,201 were tagged and 515 recaptures were encountered (Table 3). The highest number of RGCT captured was 541 from Jacks, followed by 410 in Alamitos, and 298 in Powderhouse. The fewest number of fish encountered was from Columbine (the only RGCT population sympatric with brown trout) followed by 56 RGCT encountered in both grassland streams (Vidal and Comanche). The highest number of recaptured fish were from Jacks, where 52% of the fish tagged in the spring were recaptured in the summer. The stream with the fewest recaptures was Comanche, where only 19% of the fish tagged in the spring were recaptured in the summer. Compared to other mark-recapture studies of cutthroat trout subspecies, the reported recapture rates for RGCT were relatively high (Uthe et al. 2016; 975 fish marked and 148 recaptured = 15% recapture).

Greater than 50% of all recaptured fish were captured within the 50 m stream segment from which they were previously encountered (Table 3). Rio Grande cutthroat trout moved least in Powderhouse, where 80% of recaptured fish were found within the same stream segment. The greatest movement of RGCT occurred in Jacks, where 46% of recaptured fish were found within the same stream 50 m stream segment. For those fish that moved, most moved upstream between capture events. This however, could be due to fish being pushed upstream during electrofishing, where fidelity within a 50 m stream segment may actually be much higher than reported.

Results from the N-mixture model indicated that, as expected, detection efficiency decreased with increasing flows (Figure 5). After accounting for imperfect detection, abundances were found to be highest in the deepest stream segments (Figure 6). Additionally, abundances were inversely related to stream temperature, where the highest number of RGCT were found in colder streams.

Growth rates for large (≥ 115 mm TL) and small (< 115 mm TL) RGCT were similar across sites (Figure 7), although daily growth rates for large RGCT was highest in Jacks for both summer and fall. Few RGCT in the small size-class were encountered in Cañones, Columbine, Comanche, or Vidal (one recapture across both growth intervals). The fastest growth occurred in Powderhouse, although one fall recapture from Columbine exhibited the highest growth of all small RGCT (0.0032 mm/day, Figure 7).

Table 1: Nested design for study site selection based on history of thermal regimes, presence of invasive trout within the drainage, and intermittency. A “Y” (yes) indicates the stream meets the specified criterion and “N” (no) indicates the stream did not meet the criterion.

Watershed	Stream Name	Temperature (MWAT>21.7ºC)	Invasive Trout within the Drainage	Intermittent
Rio Chama	Cañones	Y	Y	Y
Rio Chama	El Rito	Y	Y	N
Upper Rio Grande	Comanche	Y	N	Y
Upper Rio Grande	Vidal	Y	N	N
Upper Rio Grande	Alamitos	N	N	N
Pecos	Jacks	N	N	Y
Upper Rio Grande	Columbine	N	Y	N
Upper Rio Grande	Powderhouse	N	Y	Y

Table 2: Location of the eight study streams that contain Rio Grande Cutthroat trout (Stream Name) in New Mexico within the Upper Rio Grande, Rio Chama, and Pecos Headwaters. Hydrologic Unit Codes (HUC), site identification within each HUC, elevation (meters), and coordinates for the upstream and downstream ends of each study reach (300 m) are provided as UTMs.

Watershed (Hydrologic Unit Code)	Stream Name	Site ID	Elevation (m)	Upstream		Downstream	
Upper Rio Grande (13020101)				UTM E	UTM N	UTM E	UTM N
	Alamitos	20101AC101W	3087	13S 0455910	3989502	13S 0456120	3989606
	Columbine	20101CB101W	2538	13S 0453721	4057006	13S 0453724	4057144
	Comanche	20101CM104W	2849	13S 0475811	4067694	13S 0475931	4067888
	Powderhouse	20101PH101W	2985	13S 0476108	4079633	13S 0476062	4079686
	Vidal	20101VD101W	2608	13S 0476345	4067979	13S 0475988	4067943
Rio Chama (13020102)							
	Cañones	20102CA101W	2489	13S 0364760	3996208	13S 0364902	3996403
	El Rito	20102ER101W	2752	13S 0385871	4044380	13S 0385850	4044057
Pecos Headwaters (13060001)							
	Jacks	60001JC101W	2593	13S 0440301	3965734	13S 0440418	3965486

Table 3: Summary of the number of Rio Grande Cutthroat trout (RGCT) captured, tagged, and recaptured in spring, summer, and fall of 2016 for each of the eight study streams. The number of fish with evidence of fungus and hemorrhaging are also provided for each population. No movement indicates a recaptured fish was found in the same stream segment it was previous captured.

	Alamitos	Cañones	Columbine	Comanche	El Rito	Jacks	Powderhouse	Vidal
Tagged								
Spring	72	61	8	16	63	187	65	16
Summer	101	34	13	24	16	75	71	16
Fall	119	33	4	1	21	109	109	3
Total	292	128	25	41	100	371	245	35
Total Recaptured	85	56	11	14	41	132	50	16
Total Encountered								
Spring	76	61	9	16	63	187	65	16
Summer	142	58	17	25	36	156	85	23
Fall	192	85	13	15	59	198	148	17
Fish with Fungus	0	1	0	7	2	0	0	6
Movement								
No Movement	0.66	0.59	0.60	0.69	0.57	0.56	0.80	0.58
Movement	0.34	0.41	0.40	0.31	0.43	0.44	0.20	0.42

Table 4: Principal component analysis factor loadings for each habitat variable.

Variable	Variable Definition	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8
AVGvel	Average velocity (ft/s)	-0.331					0.113		
CVvel	C.V. velocity (ft/s)	0.284	-0.132	-0.139					-0.201
MINvel	Minimum velocity (ft/s)	-0.249				0.103	0.430		
MAXvel	Maximum velocity (ft/s)	-0.303							-0.138
AVGdep	Average depth (cm)	-0.202	-0.175	-0.361	0.216				
CVdep	C.V. depth (cm)	0.248	-0.100	-0.125		0.185	-0.125		0.117
MINdep	Minimum depth (cm)	-0.304		-0.155	0.123				
MAXdep	Maximum depth (cm)		-0.217	-0.433	0.166	0.111	-0.116		
AVGdfc	Average distance to cover (m)	0.196	0.349		0.110	-0.158	0.151		0.116
CVdfc	C.V. distance to cover (m)	-0.110	-0.319	0.167	-0.162	0.136	0.105		0.301
MINdfc	Minimum distance to cover (m)	0.110	0.285	-0.157		-0.422		-0.205	-0.163
MAXdfc	Maximum distance to cover (m)	0.189	0.307			-0.164	0.203	0.110	0.223
BOULDER	Fish cover: % Boulder	0.110	0.122	-0.264	-0.423			-0.313	0.148
LWD	Fish cover: % Large woody debris	-0.154			-0.403	-0.135	0.257	0.153	-0.156
ROOTS	Fish cover: % Roots	-0.124	0.228	0.126	0.311	0.218	-0.310	-0.164	-0.197
UB	Fish cover: % Undercut bank	0.159	-0.199		0.393	-0.114	0.195	0.231	0.124
VEG	Fish cover: % Vegetation	-0.103	-0.129	-0.106		-0.262	-0.492	0.229	0.306
% BD	% Bedrock			-0.219	-0.177	-0.559	-0.137		
% BOULDER	% Boulder	-0.195		-0.319	-0.119		0.251	-0.180	0.205
% CL	% Clay			0.146	0.163			-0.701	
% COBBLE	% Cobble		0.410			0.175	-0.177	0.241	
% GR	% Gravel	0.122	-0.226	0.307	0.175	-0.284			0.204
% SA	% Sand	0.206	-0.192		-0.112		0.106	0.136	-0.505
% SI	% Silt	0.181	-0.118	-0.300		0.197			-0.318

Table 4: Principal component analysis factor loadings for each habitat variable (continued).

Variable	Variable Definition	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8
CANOPY	% Canopy cover	0.189	0.100	-0.269	0.234		0.205		0.143
GRADIENT	% Gradient	-0.143	-0.109		0.264	-0.227	0.233	-0.186	-0.245
WW	Wetted width (m)	-0.271	0.227						
	Standard Deviation	2.88	1.96	1.69	1.39	1.25	1.20	1.10	1.01
	Cumulative Proportion	0.31	0.45	0.55	0.63	0.68	0.74	0.78	0.82

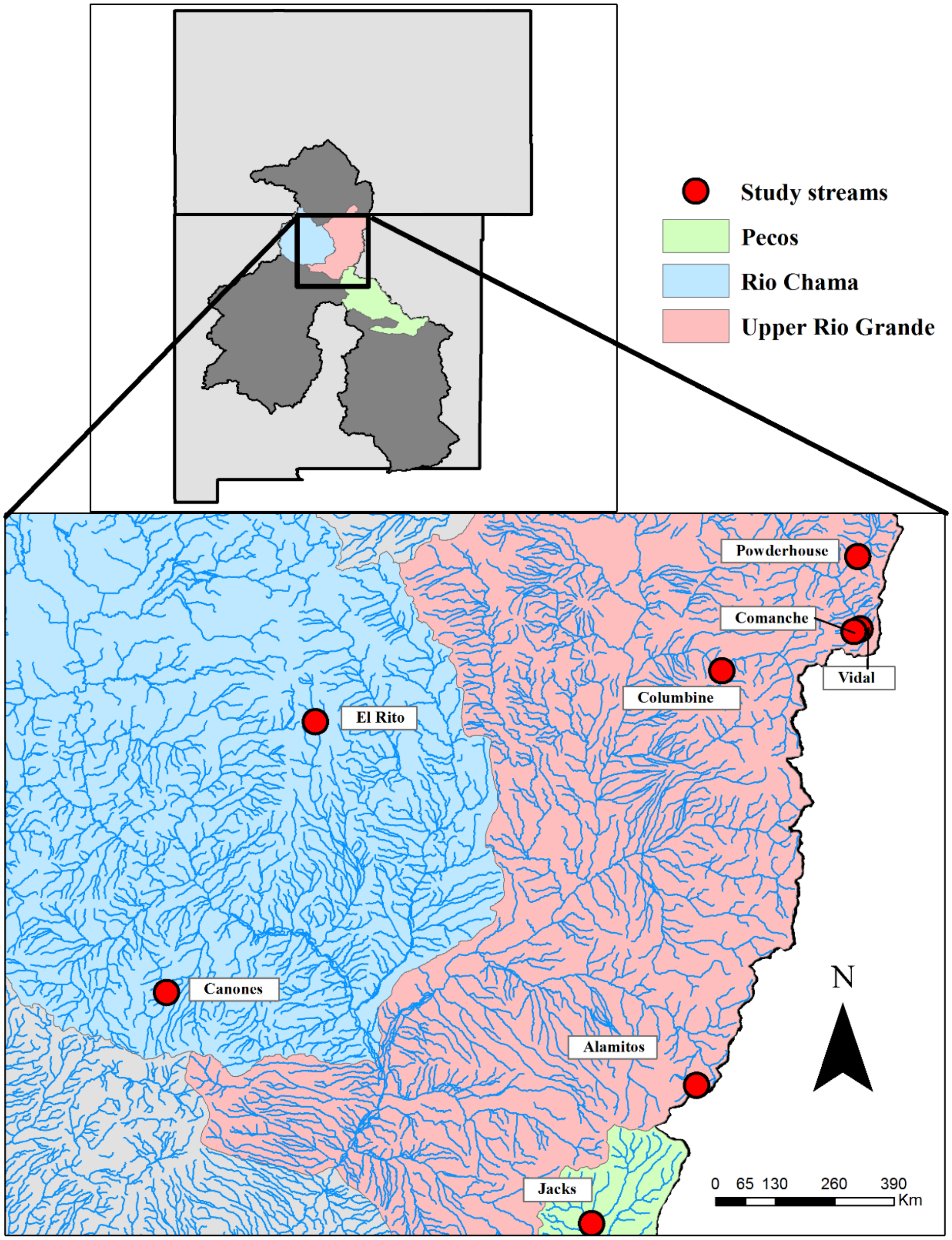

Figure 1: Location of the eight Rio Grande Cutthroat Trout study streams within New Mexico. Streams are located within the three watersheds (Pecos, Rio Chama, and Upper Rio Grande).

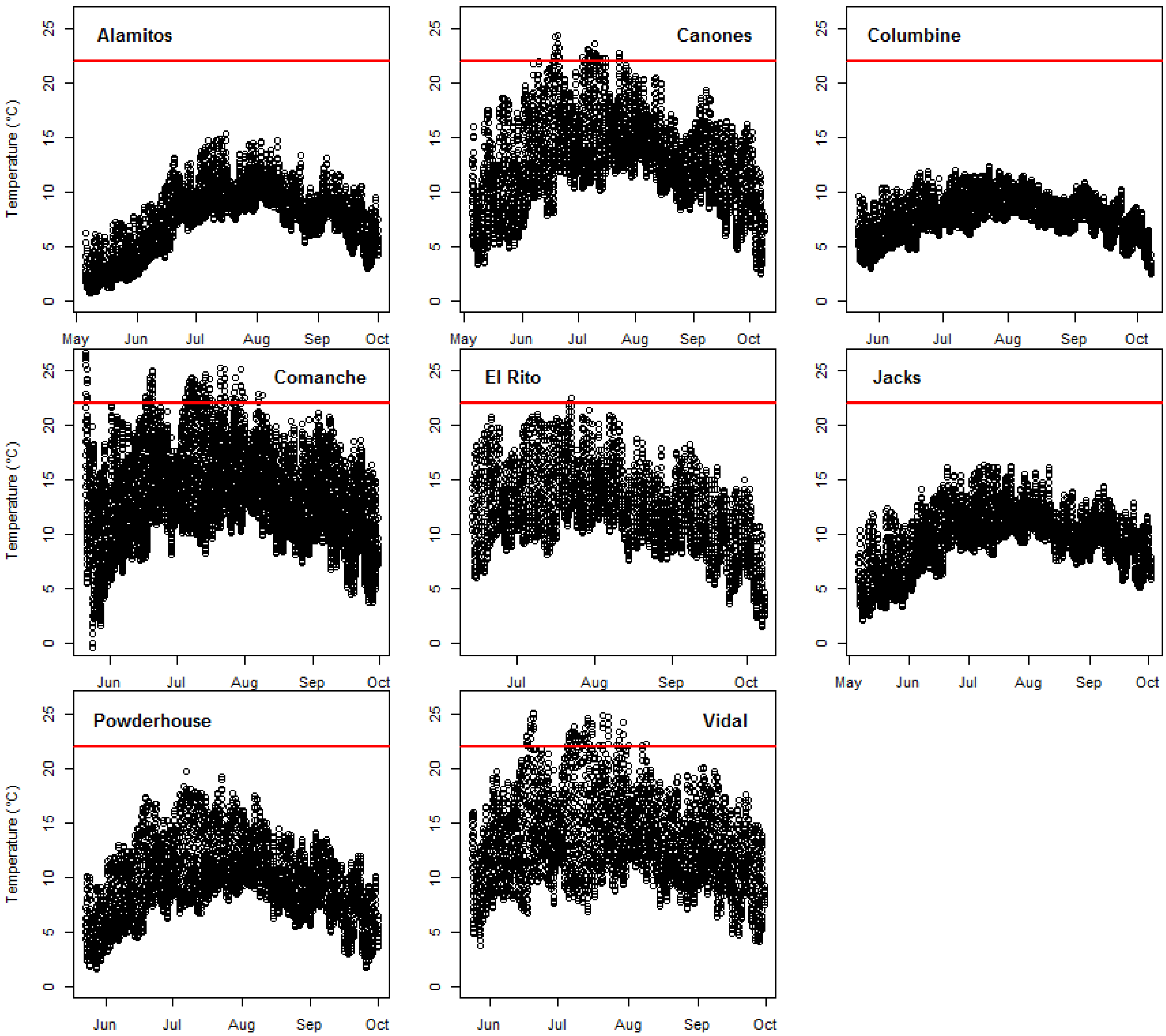

Figure 2: Hourly stream temperature (ºC) for the eight Rio Grande Cutthroat Trout study streams from spring through fall of 2016. Horizontal red lines represent the 30-day ultimate upper incipient lethal temperature for juvenile Rio Grande Cutthroat Trout (21.7ºC, Ziegler et al. 2013).

Figure 3: Evidence of fungus (circled in yellow) and petechial hemorrhaging (circled in red) in Rio Grande Cutthroat Trout from Vidal Creek in Costilla, New Mexico. Photo by B. Huntsman, 8/10/2016.

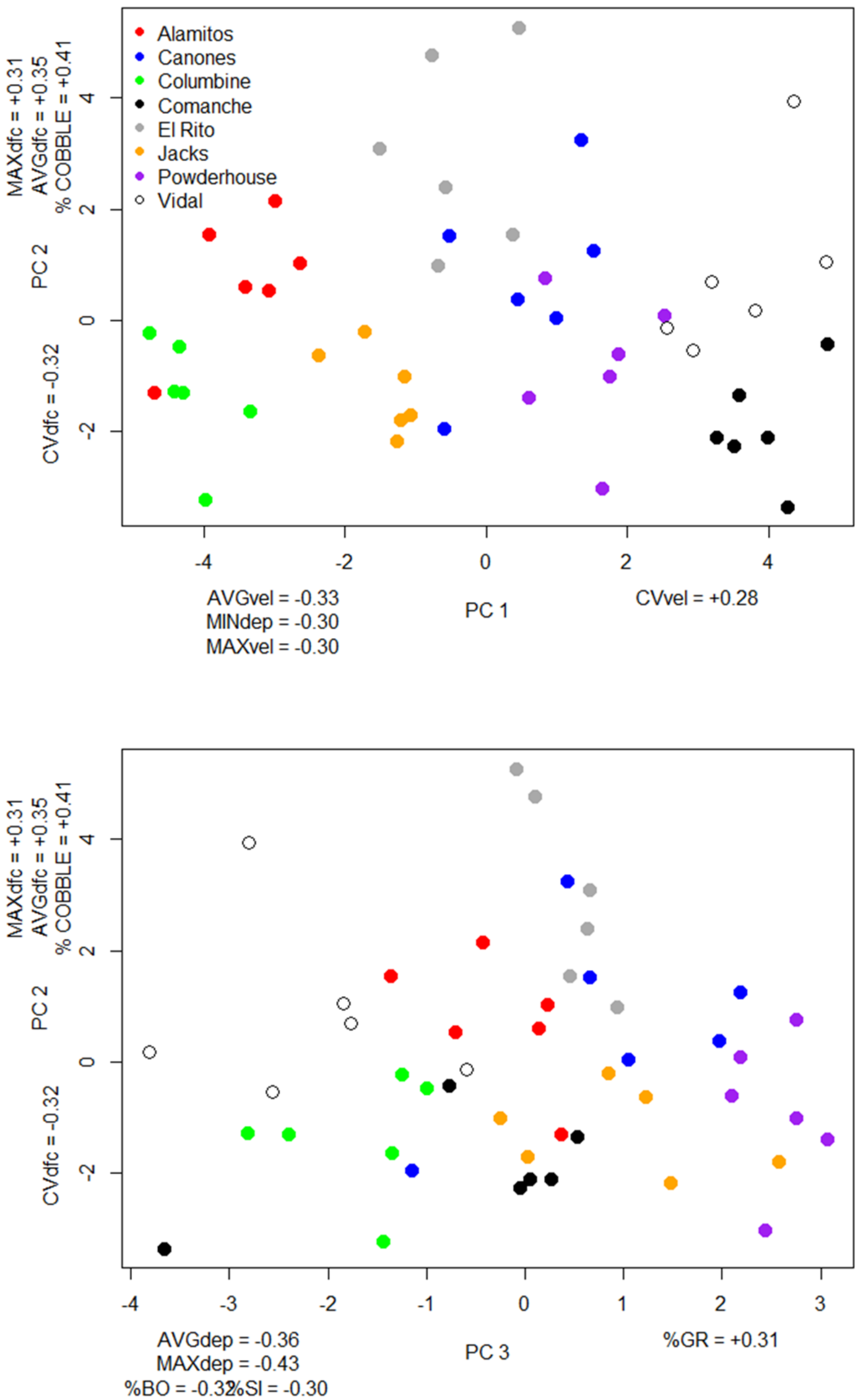

Figure 4: Principal component analysis (PCA) for each of the six 50 m reaches sampled within each of the eight Rio Grande Cutthroat Trout study streams.

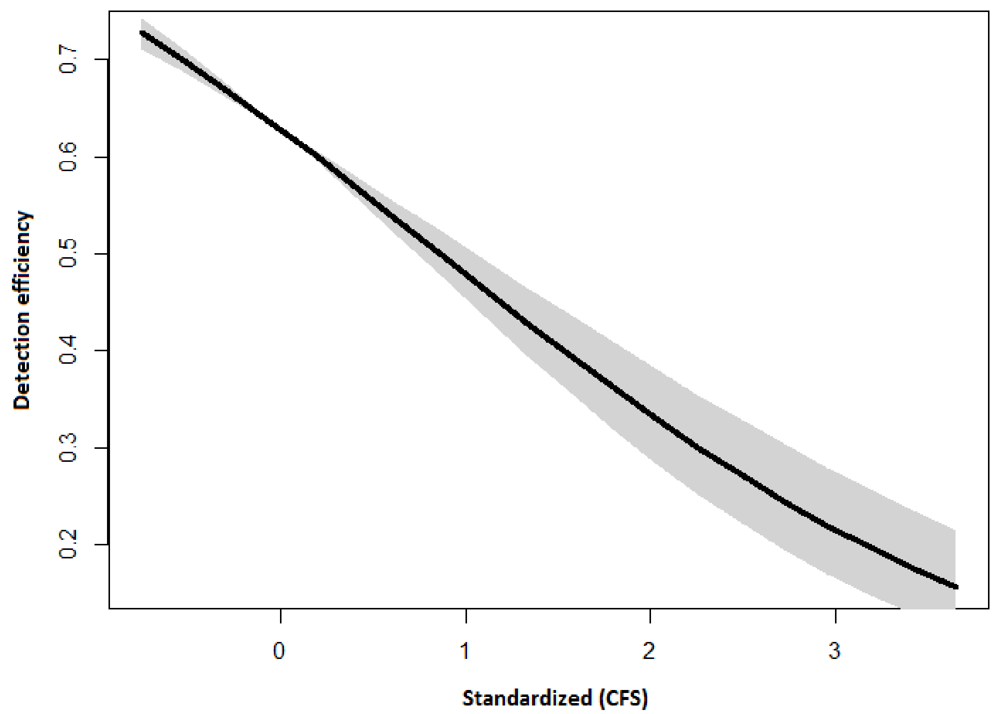

Figure 5: Detection efficiency modeled across all eight study streams that contain Rio Grande Cutthroat Trout populations in the spring, summer, and fall of 2016. Detection efficiency was modelled as a function of stream discharge as cubic feet per second (CFS) standardized for Bayesian analysis. The black line represents the mean and the grey polygons are 95% credible intervals. The 5, 25, 50, 75, and 95% quantiles for discharge measurements were 0.02, 0.25, 2.92, 5.27, 15.04 CFS, respectively.

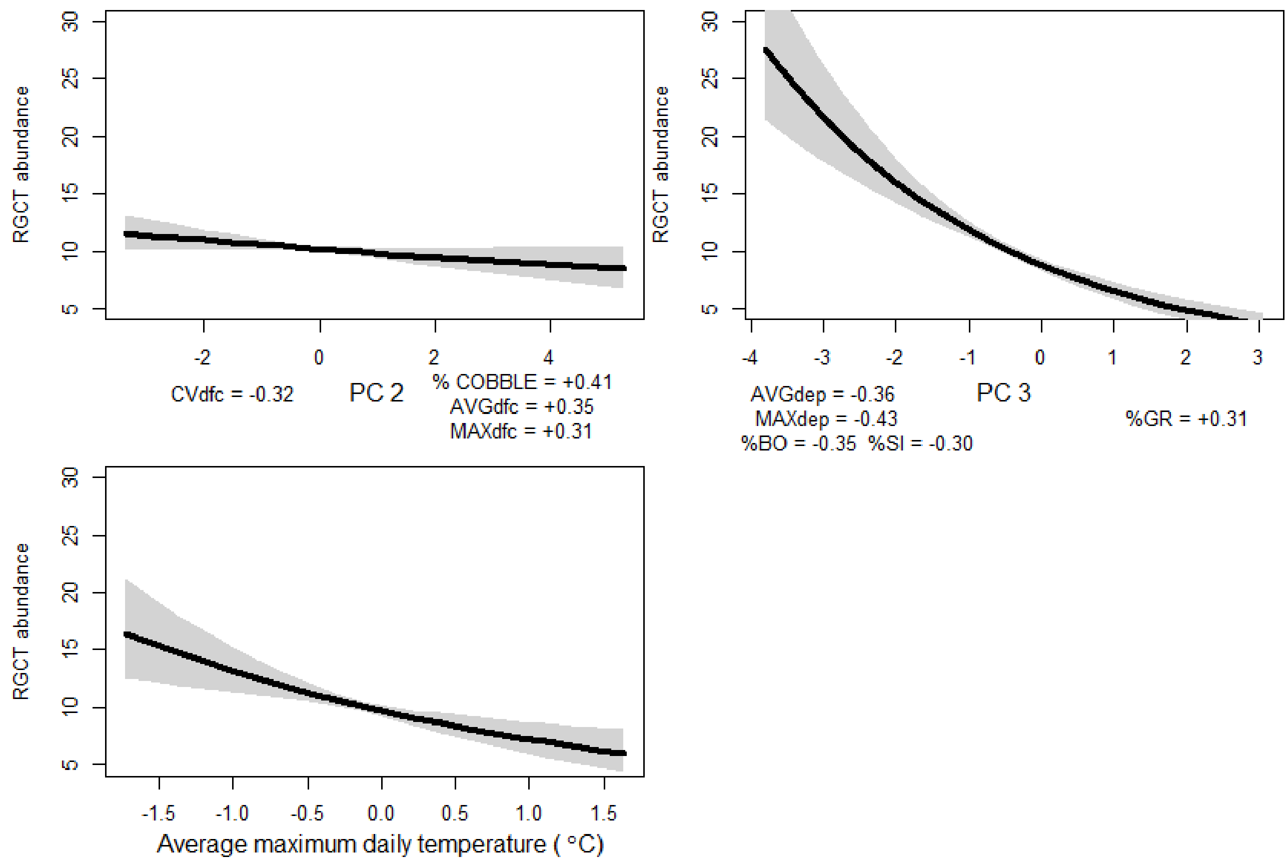

Figure 6: Results for closed N-mixture model predicting Rio Grande Cutthroat Trout abundance as a function of principal component (PC) axes and average maximum daily stream temperature (^oC). Spring temperature was estimated as temperature collected before July 1, summer from July 1 to August 31, and fall from September 1 to when fall sampling occurred (early October). Average maximum daily temperature was standardized for Bayesian analysis. Black lines represent the mean and the grey polygons are 95% credible intervals.

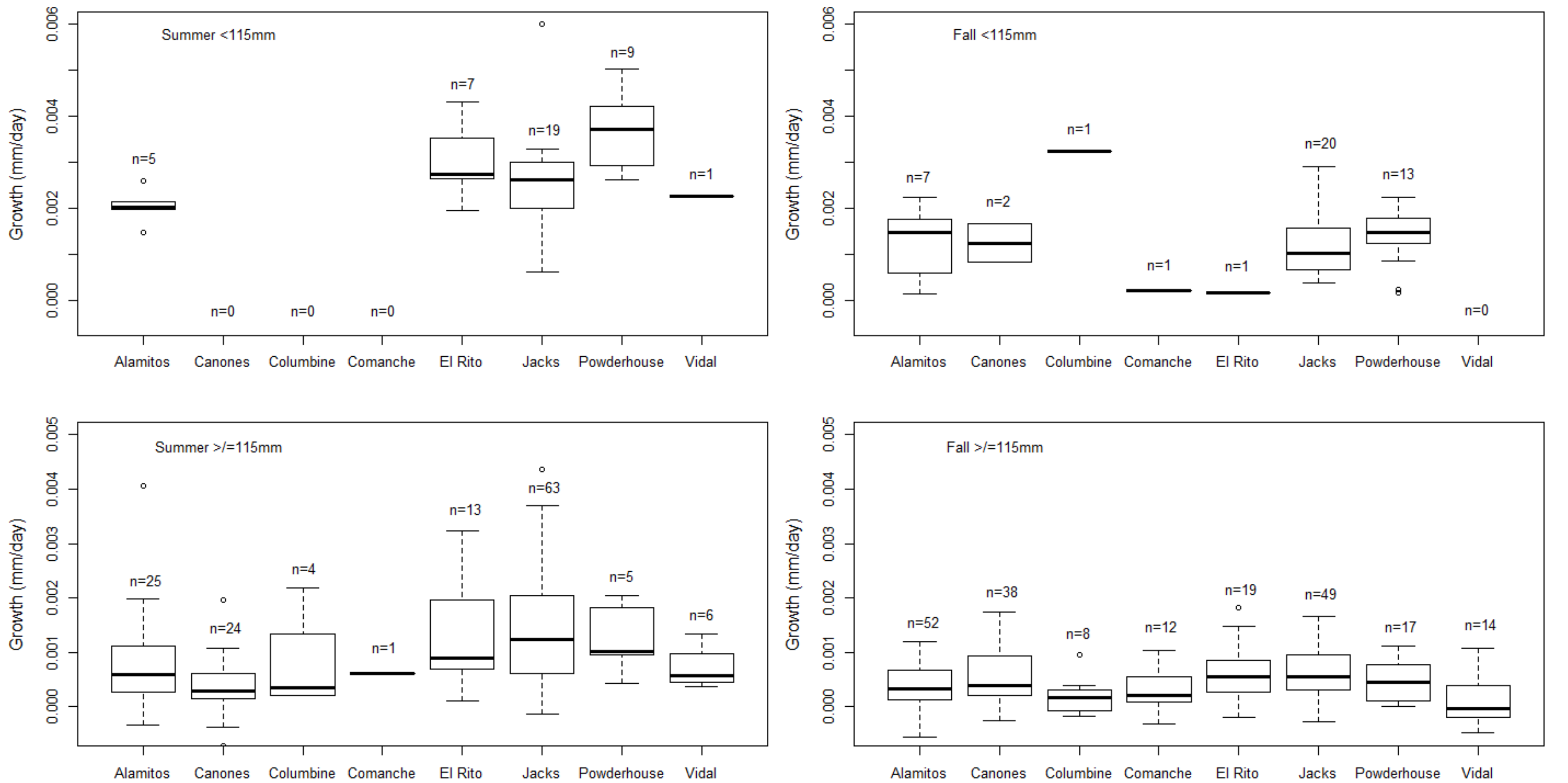

Figure 7: Growth (mm/day) for Rio Grande Cutthroat Trout by size-class (small ≤ 115 mm and large <115 mm) and season (summer and fall) for each study stream. Data is presented in whisker box plots with 5, 25, 75, and 95% quantiles represented by the box and whiskers. The dark horizontal line is the median with open circles representing outliers.

Interesting Patterns and Interpretation: Our preliminary analyses indicate that habitat and temperature play an important role in RGCT population dynamics. Populations within the two grassland study streams (Comanche and Vidal) and the Cañones experienced thermal regimes in excess of the published critical upper limit (~21.7ºC) and supported fewer fish than cooler streams. We caution that with only one year of monitoring it is difficult to attribute lower abundance to temperature related mortality as opposed to RGCT seeking thermal refugia, a common behavior in salmonids. However, limited movement observed in this study and the presence of immunocompromised fish in streams where temperatures exceed upper lethal limits suggest temperatures are likely negatively impacting vital rates and warrant further study (*i.e.*, survival).

Another interesting pattern observed from this preliminary analysis was that Columbine supported the fewest RGCT. This is surprising since temperature regimes (Figure 2) and habitat (Figure 3) within Columbine suggest population size should be relatively large based on favorable conditions predicted from the N-mixture model. Specifically, temperature is well below upper lethal limits and stream depth is among the deepest among study sites (PC 3). However, RGCT counts in Columbine were consistently lower than all other study streams and small RGCT were consistently absent from collections. Interestingly, this was the only stream in the study that contained sympatric non-native trout (Brown Trout *Salmo trutta*). Although surveys below barriers at these sites have not been conducted, it could provide a unique "experimental manipulation" to tease out the impacts of invasive trout on RGCT population dynamics.

A final interesting pattern from these preliminary analyses is that little separation in instantaneous growth rates were observed across all sites. This was surprising given that the populations experienced a range of stream temperatures and fish densities. However, the greatest variability in growth among the populations occurred with the smaller size-class. This would be expected since small salmonids are less likely to successfully compete for resources (*e.g.*, foraging positions) compared to large salmonids. Unfortunately, few small fish were consistently found in all streams limiting our sample size. The importance of density-dependence and environmental factors (*e.g.* temperature) will be further explored with regression models as well as investigating trophic basis of production, to determine the importance of such factors on RGCT productivity.

5. NEXT STEPS

Timeline (April 2015-September 2019; no cost time extension) 3.5 years

Objective 1; Objective 2a; Objective 2b

Apr-2015	Establish cooperative agreement with New Mexico Cooperative Fish and Wildlife Research Unit; begin project development through teleconferences. Recommend site visits occur for all investigators.
Jan-2016	Hired post-doctoral research associate (Dr. Brock Huntsman) to oversee the project.

Mar-Apr 2016	Establish study stream reaches, deploy ProV2, STICs, and water level loggers. Conduct Spring population surveys and PIT tag all fishes. Complete physical habitat attributes within each population.
May-Oct 2016	Conduct Summer and Fall population surveys and PIT tag all fishes. Enter data and begin building models to characterize growth, recruitment, and apparent survival for the populations. Retrieve data from ProV2, STICs, and water level loggers. Re-deploy loggers.
Nov-2016 to Mar-2017	Enter data from Spring, Summer, and Fall collections. Sort and identify to lowest taxa both drift and benthic macroinvertebrate samples. Begin data collection of stream discharge model. Present study update at each of the annual range-wide and state species status meetings held in January 2017 (Range-wide) and February 2017 (New Mexico). Interim report submitted to NCCWSC and NMDGF.
Apr-Oct 2017	Conduct Spring, Summer, and Fall population surveys and PIT tag all fishes. Enter data and continue building models to characterize growth, recruitment, and apparent survival for the populations. Retrieve data from ProV2, STICs, and water level loggers. Re-deploy loggers.
Nov-2017 to Mar-2018	Enter data from Spring, Summer, and Fall field collections. Continue with development of stream discharge model. Present study update at each of the annual range-wide and State species status meetings held in January 2018 (Range-wide) and February 2018 (New Mexico). Present study results at the Joint Annual Meeting of the Arizona-New Mexico Chapter of the American Fisheries Society (February 2018). Interim report submitted to NCCWSC and NMDGF.
Apr-Oct 2018	Conduct Spring, Summer, and Fall population surveys and PIT tag all fishes. Enter data and begin building models to characterize growth, recruitment, and apparent survival for the populations. Retrieve data from ProV2, STICs, and water level loggers. Re-deploy loggers.
Nov-2018 to Mar-2019	Enter data from Spring, Summer, and Fall field collections. Continue with development of stream discharge model. Present study update at each of the annual range-wide and State species status meetings held in January 2019 (Range-wide) and February 2019 (New Mexico). Present study results at the Joint Annual Meeting of the Arizona-New Mexico Chapter of the American Fisheries Society (February 2019). Interim report submitted to NCCWSC and NMDGF.
Apr-Aug 2019	Finish building models to characterize growth, recruitment, and apparent survival for the populations. Analyze data from ProV2, STICs, and water level loggers. Build deterministic population matrix models and analyze effects of drought on population persistence. Present study update at each of the status meetings. Annual range-wide status assessment is held in January 2019 and New Mexico species status assessment is held in February 2019. Present study results at the Joint Annual Meeting of the Arizona-New

Mexico Chapter of the American Fisheries Society (February 2019). Present results to date at the XII Wild Trout Symposium, West Yellowstone, Montana (July).

Sep-2019 Complete File Report. Complete and submit manuscript on the effects of drought on population vital rates and persistence of Rio Grande cutthroat trout population persistence.

6. OUTREACH

a. No articles or reports have been developed at this time; however, an RGCT otolith manuscript is currently being developed with NMDGF.
b. No project-related presentations, seminars, or webinars have been developed at this time; however, a presentation is planned for the 50th Joint Annual Meeting of the AZ/NM American Fisheries Society and the New Mexico and Arizona Wildlife Societies (February 2017).
c. This project is conducted through the partnership of New Mexico Department of Game and Fish, U.S. Forest Service (Carson and Santa Fe National Forests), and local and national interest groups such as Trout Unlimited (National Trout Unlimited and local chapters such as the Gila/Rio Grande Chapter).
d. No websites have been created for data sharing at this time.
e. No other products such as databases, audio/video productions, or fact sheets has been developed at this time.

7. PROFESSIONAL DEVELOPEMENT

a. A workshop on integrated population models was attended at Patuxent Wildlife Research Center by Dr. Brock Huntsman (Aug. 1-5, 2016).
b. Educational outreach in the form of hiring graduate and undergraduate students to assist with the project: Recruitment of Lauren Flynn to pursue her graduate research (M.S. degree at NMSU) with the PIs of the project. Ms. Flynn will contribute towards the project by way of addressing the effects that temperature and intermittency will have on the energetics and secondary production of RGCT. Mr. Quintin Dean, undergraduate senior in the Department of Fish, Wildlife and Conservation Ecology at NMSU, was hired to participate in the project by assisting Dr. Huntsman with sorting and identifying drift and benthic macroinvertebrates. The majority of Mr. Dean's wages will be paid by an NMSU scholarship.

8. BUDGET

As of 17 October 2016, project balance: $172,038 (total funding $257,878). The agreement was modified 8/8/2016 to add $20,700 for Ms. Lauren Flynn, graduate research assistant, to assist with the project and to pursue her MS degree. Expenditures from inception of project are the following (do not include 15% indirect costs): Payroll (includes 32% fringe) $37,575.94; Travel $3,487.91; Materials and Supplies $9,413.04.

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