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Final Technical Research Report for 2015

A Study of Trout Movements on the Rio San Antonio and East Fork Streams on the Valles Caldera National Preserve

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Executive Summary

This project came about in response to the Conchas fire in 2011, which burned significant portions of the upper and middle watersheds for both streams on the preserve; the East Fork (EF) and the Rio San Antonio (RSA). Rains following the blaze induced heavy, ash-laden runoffs that greatly reduced trout populations overall. Some stretches of the streams that had previously hosted healthy populations of trout were rendered essentially devoid of them. However, other stretches that had previously hosted high density populations of trout, were either unaffected or, in some cases, suspected of population density increases.

Since trout sport fishing is a major attraction on the preserve and an important source of revenue, the preserve managers considered ways to rehabilitate the populations of trout in the devastated areas of the streams. One idea was to extract trout from the high population areas and to reintroduce them into lower population areas. However, questions arose as to the veracity of such an effort with some suggesting that the relocated trout would simply migrate back to the extraction areas, thus defeating the intended purpose of the effort. Trout, like their famous cousins the Northwest Salmon, are suspected of migrating to the waters in which they were born in order to spawn.

I developed this controlled experiment to answer the question of whether relocated trout would remain in the relocation area or migrate away. A second objective was to understand the direction and distance of any migrating trout, with special emphasis on whether some tagged trout returned to the extraction areas.

Using a team of volunteers from NM Trout, Trout Unlimited\(^2\) and others, we electroshocked and extracted trout from high population areas of both streams. Each extracted trout was tagged and relocated to a lower population area of the same stream. The tagging was performed by a retired veterinarian using Floy tags, each of which is a tiny spear with a unique identifying number printed on its shank. The tags were harmlessly inserted into the fleshy portions of each trout.

We completed the tagging and relocation effort in the fall of 2013. Seventy two trout were tagged and relocated on the EF. The same was done to 85 trout on the RSA. We recorded detailed information about each tagged trout, including species, length and weight.

The extraction area on the EF was in the headwater area, about a third of a kilometer east of the Lightning Shack. The relocation area was about three kilometers west of the Lightning Shack.\(^3\)

On the RSA, the extraction area was near the upper end of old fishing reach 2 and the reintroduction area was directly south of the cabin.

In the spring of 2014, my team of volunteers electroshocked the relocation areas on both streams. No trout was recovered from the EF relocation area but five were recovered from the RSA relocation zone.

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\(^2\) NM Trout and Trout Unlimited are local trout clubs. Trout Unlimited is nationally affiliated.

\(^3\) These measures refer to distances along the bank of the stream, not point to point distances.
We also electroshocked the extraction areas on both streams, but no trout was recovered from either one.

Anglers reported recoveries of 10 tagged trout, five on each stream. Angler reports flowed to me throughout the warm season. Some angler reports were very detailed, including precise measures of trout lengths and GPS latitude and longitude locations of the recoveries. Others were more anecdotal.

In total, the data show that most of the tagged trout migrated away from the relocation areas, with some traveling as far as 11 kilometers. The recovery sample from the RSA showed that trout migrated about equally upstream and downstream from the relocation area near the cabin. There are no data suggesting that the trout migrated back to their extraction areas.

All of the recovered trout had gained weight and length from the time they were tagged to the time of their recovery. Based on the recovery sample, the trout gained around 20% in weight and around 8% in length, but there is a large variance in the sample. Based on the sample, there is no statistically significant difference between growth rates of trout in the two streams.

An ancillary investigation into trout movements, which was not directly related to the tagging effort but related to the principal question about trout movements, focused on investigating the possible migration of 900 Triploid Rainbow trout that were stocked into the EF at the VC01 bridge in the spring of 2012. Anglers and staff had noted that the trout disappeared quickly from the stocking site and that they appeared to have migrated about nine kilometers to the headwaters of the EF.

My analysis of high quality fish survey data that Bob Parmenter’s science team regularly collects on the upper EF showed convincingly that the Triploids had indeed migrated to the headwaters but then quickly disappeared, leaving little sign as to the cause of their disappearance.

I also reviewed a five year history of the water quality data that Bob Parmenter’s science team collects on the lower EF and RSA. The data, which are reasonably good quality, showed that water quality in the streams was not significantly affected by the fire and does not appear to be related to trout movements.

During 2015, the last year of the study, I continued to monitor trout recoveries by anglers. The VCNP staff continued to hand out to all anglers a pamphlet that discussed the study and asking that they report any tagged trout that they recovered. In addition, with permission of the US Forest Service, I placed notices at all of the campgrounds outside of the preserve along the East Fork, Rio San Antonio and Jemez Rivers down to near the Jemez Pueblo. But no tagged trout was recovered.

The study is thus terminated. Based on the findings in this study, it appears that from a fisheries management perspective it is unproductive to attempt to relocate trout from higher density areas to lower density areas. The relocated trout—whether they are stocked Triploid Rainbows or stream born wild Browns/Rainbows—largely did not remain in the relocation areas.

A final conclusion is that the data collected by Bob Parmenter’s science teams are of very good quality and contain a great deal of information that can be drawn out with proper analysis. I urge
other researchers to use this rich data resource to address questions of interest about trout behavior.
Introduction, Background and Report Organization

Brief Purpose and Benefits of the Experiment: The report covers work done in three years of a three year experiment.

The purpose of this experiment is to gain an improved understanding of trout movements in the two major streams flowing in the Valles Caldera National Preserve. The principal focus of the investigation is to record how trout move after they have been relocated from high population density areas to lower density areas.

The scientific hypothesis was that the relocated tagged trout would remain in the reintroduction area. The hypothesis was deliberately structured as such because it is easy to test. That is, the hypothesis can be rejected by simply sampling the reintroduction areas at a later time and finding few or no trout.

Information from this experiment will not only add to the body of scientific knowledge about trout behavior but will aid the preserve’s managers in directing the rehabilitation of the trout resource. More details about the experimental effort in year one can be found in my 2013 progress report.4

Approach: My general approach was to extract up to 100 trout on each stream, tag them and relocate them on their stream of origin. At a later date I planned to use electroshocking and anglers to recover the tagged trout from the streams. I planned to use the tag-associated data to glean information about the movements of the tagged trout.

Since the scientific hypothesis under test in this experiment was that the tagged trout would not move after relocation, the relocation areas would be priority locations in the recovery effort. The extraction zones would be the next highest priority because it is commonly believed that trout have a homing instinct similar to their famous Northwest Pacific Salmon cousins. I expected, however, that tagged trout might be found anywhere on the two streams of the preserve.

As I discussed in my 2013 report, trout have been known to migrate many dozens of miles. Thus, if there were a significant migration away from the relocation site, there would be reasonable probability that some might be recovered in the public waters outside the preserve’s boundaries. I planned to ask the NM Department of Game & Fish (NMDG&F) to place a notice on their website that would describe the study and instruct the anglers about how to record and report vital information about a recovery.

In addition to the direct effort involved with the trout, I also planned to examine the water quality records on the preserve. Since the Conchas fire in June of 2011, there had been conjecture that the water quality might have changed and those changes might be contributing to the apparent redistribution and movement of trout on the streams.

Additionally, as in any study I planned to remain vigilant for any other opportunities to learn about trout movements. As will discuss later in this report, I had such an opportunity.

**Funding:** I had no formal funding for any part of the experiment. I supplied gratis all labor for all phases of the effort, including experimental design, organization, implementation, data analysis and reporting. I supplied funds from personal resources whenever they were needed.

The VCNP purchased the Floy fish tagging system. They also provided a vehicle and a driver, including a whole day of labor, to support the tagging and reintroduction effort. Additionally, the preserve provided the electroshocking equipment and data, including a copy of the fish survey database for both streams and water quality data, both of which are collected by Bob Parmenter’s scientific teams. The VCNP Visitor Center staff was also helpful and quite instrumental in the effort, as I will describe later.

Volunteers, comprising mainly anglers from NM Trout and Trout Unlimited, did much of the physical labor in the field—the tagging and recovery efforts.

**Synopsis of work in 2013:** As noted above, I have written a comprehensive report of the research completed in 2013. However, I present a brief synopsis of the 2013 efforts below for the convenience of the reader.

In the spring of 2013, I conducted a preliminary survey of the streams to determine the optimal extraction and relocation areas. In the fall of 2013, our team extracted, tagged and relocated a total of 157 trout from both streams in the preserve (85 on the RSA and 72 on the EF).

The exact extraction and relocation areas are presented in the table below.

Summary statistics for all of the tagged trout are presented in the table at left along with a picture of a tagged trout (see photo below).

It is noteworthy that although the goal was to extract trout from both the upper and lower reaches of the San Antonio and to relocate them near the cabin, the research team was able to extract only three trout from the lower reach due to

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5 Floy tags are used to tag fish with a unique identifier. The tagging system is manufactured by Floy Tag and Manufacturing, Inc. in Seattle, WA. Each tag contains a unique number printed on its shank.
low population densities. Therefore, most of the tagged trout on the San Antonio were extracted from the upper reaches.

The pair of histograms below shows the distribution of both size and weight of the trout that were tagged and relocated. More details are contained in the Excel spreadsheet (Combined raw tag data.xls), which is available upon request.

As can be seen, both distributions show a skew toward lower values, suggesting that there are more small trout in the sample than large ones. The skew is particularly evident in the weights, which suggests that many of the longer trout were less robust than might be expected.

![Histograms of Trout Size and Weight](image)

**How the remainder of this report is organized**

The primary effort in 2014 and 2015 focused on the recovery of tagged trout. A second effort involved a cursory analysis of the history of water quality on the streams on the preserve. As far as I could determine, no previous analysis of these water quality data had been published.

A third activity involved the study of the movements of Triploid Rainbow trout that were stocked on the East Fork in the summer of 2012 and which were suspected of migrating about nine kilometers (5.5 miles) to the headwaters of the stream. The Triploid study was not part of the original planned research. It was added into the effort in 2014 because it provided an opportunity to learn more about Rainbow trout movements, which is consistent with the central objective of this research.

I present the results of the three efforts in separate parts, with the Part 1 discussing the recovery of the tagged trout, Part 2 presenting the information on water quality and Part 3 covering the analysis of the Triploids. The final technical section presents conclusions, recommendations and lessons learned.

Appendix 1 contains Google maps showing the extraction and reintroduction areas for both streams. Bob Parameter’s permanent fish survey locations are also noted on these maps. Other maps show the locations of the trout recoveries on both streams. Each recovery is noted on the maps with a code that identifies the trout by tag number so that the reader can find related information about that trout in the tables and discussion in the text. The roads along with other common landmarks are marked for reference and a ruler scale is found in the lower left hand corner of each map.

Appendix 2 contains a discussion about statistical fundamentals.

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6 In 2015 the only activity was to monitor for tagged trout recoveries. But there was none.
7 A Triploid is a sterile Rainbow trout that is used by the NMDG&F for stocking streams.
Part 1. Recovery of Tagged Trout and Associated Analysis

Recovery plans. The recovery effort is an essential activity in the experiment and my plan called for three types of activities:

1. Apply electroshocking to selected areas of the streams. In the spring of 2014 I planned to electroshock a 300-meter stretch of stream centered on the reintroduction areas as well as similar stretches centered on the extraction areas. I had planned a second electroshocking of the same areas in the fall of 2014.

Bob’s fish survey team biannually applies three pass depletion electroshocking to three locations on both the EF and the RSA. Stunned trout are removed, measured and released back into the stream. The data are carefully recorded. These regular surveys were considered part of the overall recovery effort.

2. In spring of 2014 I would employ a program of intense fishing for all areas of the Rio San Antonio and the upper areas of the East Fork, all geared to recover tagged trout. By “intense fishing” I mean that expert anglers would fish specific, contiguously linked beats and each would be instructed about how to record critical information about each recovery—its length and the exact GPS location.

3. Throughout the summer of 2014 I planned to solicit regular anglers to report any tagged trout that they recovered. I intended to ask the VCNP visitor staff to inform anglers about the experiment and encourage them to report any tagged trout that was taken. I planned to prepare a pamphlet that the staff would give to each angler that would describe the project and provide instructions on how to identify the tag number, measure the trout and record the location of the recovery.

4. During 2015, the last year of the study, I continued to monitor trout recoveries by anglers. The VCNP staff continued to hand out to all anglers a pamphlet that discussed the study and asking that they report any tagged trout that they recovered. In addition, with permission of the US Forest Service, I placed notices at all of the campgrounds outside of the preserve along the East Fork, Rio San Antonio and Jemez Rivers down to near the Jemez Pueblo.

As I noted in my 2013 technical report, I expected to recover about 10% of the tagged trout, or about seven on the EF and nine on the RSA. The results of these efforts are found below.

Results of the electroshocking recovery efforts. In spring of 2014 I had arranged a team of volunteers to conduct the electroshocking recovery effort on the two streams. I originally estimated that two days were needed to electroshock all of the extraction and reintroduction areas on the RSA and one day to do the same on the EF for a total of three days of labor.

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8 Three pass depletion electroshock survey methods involve the following steps: 1. Isolate a section of stream to be surveyed by placing nets in the stream at the beginning and ending of each section. 2. Starting at the lower screened end and working to the upper screened end, apply electroshocking and net the stunned fish. 3. Remove the stunned fish and measure them, sequestering them until the survey of the section is complete. 4. Repeat the above process twice more. 5. Remove the screens and return all sequestered fish to the stream.
Unfortunately, I had sufficient manpower resources for only two days of effort. As a result, I scaled back the electroshocking effort to include one day to electroshock two areas on the RSA and a second day to do the same on the EF.

Since there were four sites involved on the RSA, I had to select the best two sites in which to apply the available resources. Since the hypothesis under test was that the trout would not migrate away from the reintroduction area, those areas—one on each stream—became the highest priority for electroshocking.

I chose the RSA upper site 2 as the second electroshocking site on that stream because it is the area where the majority of the tagged trout were extracted. Thus, electroshocking that upper area produced the highest probability of recovering a trout that had migrated back to its home waters. The electroshocking of the two locations on the RSA was conducted on 11 May 2014.

There was only one extraction site on the EF, and it and the reintroduction site were electroshocked on 6 Jun 2014.

In all cases, manpower limitations constrained the electroshocking to a single pass depletion method applied to a 300 meter stretch of stream centered on the application site. I chose the 300 meter shocking zone length based on an assumption that even if the tagged trout remained in the area, they would not stay flocked at the specific spot of reintroduction, which was about a 10 meter stretch of stream. Thus, electroshocking the longest zone possible would improve the chances of a recovery. Three hundred meters was the maximum length that could be electroshocked with the available manpower resources. Single pass depletion electroshocking will typically extract around a third of the fish in the shocked stretch of stream.

For clarity regarding the 300 meter shocking zones, consider the electroshocking zone at the RSA reintroduction site (the cabin). The electroshocking zone began about 150 meters of stream distance downstream from the point where the trout were reintroduced (i.e., at about the cabin) and ended 300 meters upstream from that starting point. Similarly, the 300 meter stretches were straddled about the centers of the other three electroshocked stretches. Stream distance is the distance along the stream.

Unfortunately, I could not electroshock the streams in the fall of 2014 because of a personal illness and several family deaths, both of which occupied all of my time and did not allow me to work in the field. I could find nobody to take over the effort while I was down.

_no tagged trout was recovered by electroshocking on either of the two East Fork sites_ (i.e., the extraction area and the reintroduction area).

_no tagged trout was recovered at the RSA upper extraction site_.

However, _five tagged trout were recovered at the RSA reintroduction site_ at the cabin. The table below (with title: “...Tagged trout recovered by electroshocking”) summarizes the results. Most of the columns have obvious meanings. Weights and lengths are noted in English and

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9 Single pass depletion electroshocking is identical to three pass depletion electroshocking except that only one pass of electroshocking is applied.

10 Based on records from Bob Parmenter’s fish surveys on the EF and RSA.
International units. Columns 12 and 13 require additional explanation. In the column labeled “Tagging location” are found the codes I assigned to the extraction locations and are the same as those used throughout the Excel workbooks containing the recovery data. 11 A key is provided at the bottom of the table for the reader’s convenience. The “ID name on map” is the code for the particular tagged trout as it appears on the Google maps in Appendix 1, which show all of the tagged trout recoveries. For example, the first recovered trout is coded “Recovered by Shocking in the 1st area shocked (i.e., on RSA at the cabin site); with tag #030.

The location of each recovery taken from the RSA reintroduction shocking zone was noted and recorded, but the GPS coordinates are not shown in the table because they are all in close proximity of one another. However, their locations are found on large scale maps presented in Appendix 1. Note that the trout with tag 144 is presented in a red color on the map because it was recovered twice, once by electroshocking and again by an angler. More information about this trout follows in the discussion below.

There are some noteworthy observations from the electroshocking effort on both streams. Eighty five tagged trout were reintroduced at the cabin site on the RSA and 72 were reintroduced on the EF. However, only five tagged trout were recovered at the RSA reintroduction site at the cabin and none was recovered from the EF’s reintroduction site. Obviously, many of the tagged trout in both streams had either perished or migrated away from the reintroduction areas over the winter of 2013/2014.

11 The data are available upon request.
The tagged trout that were recovered in the RSA reintroduction area had grown over their eight month stay in the area. On average, the five trout increased in length by nearly 10% and had commensurate weight gains of around 22% (see columns 8 and 11).

There is considerable variance in the samples, but the data are consistent with expected trends, which add to their credibility. For example, trout may lose weight over time, but none is likely to lose length. All of the recovered trout were both longer and heavier than at the time of tagging, indicating both consistent and believable data as well as a healthy trout environment in the reintroduction area.

No tagged trout was recovered by Bob’s survey teams when they conducted their regular fish surveys on the RSA and EF in the spring and fall of 2014 or 2015. These survey locations can be found on maps presented in Appendix 1.

**Results of the intensive fishing recovery efforts.** A team of expert anglers from NM Trout and Trout Unlimited volunteered to intensely fish the entire length of the RSA (from the western boundary of the preserve to the headwaters on the east) and the upper portions of the EF (from as far west along the stream as could be traversed to the headwaters on the east). Each angler was assigned to fish a specific beat of about 1.5 miles in length and given a whole day for the task. Each was instructed to carefully record the tag number, length and location of each tagged trout that was taken.

One tagged trout was recovered in this effort on the East Fork (trout #173). Information on this trout is included in a summary table presented in the next subsection.

**Results of the regular angler recovery efforts.** Regular anglers frequent both of the preserve’s streams throughout the warm seasons in 2014 and 2015\(^\text{12}\), although the upper half of the RSA is favored by anglers due to its areas of high trout densities and ease of access.\(^\text{13}\) Anglers rarely fish the lower reaches of the EF due to low trout populations, and the middle reaches of the stream are not traversable due to quicksand.

Each angler checks into the preserve for a briefing prior to heading out for a day of fishing.

As part of the normal briefing, the visitor center representative gave each angler a small pamphlet that described the project, how to identify a tagged trout and instructions on reporting length and the approximate location where it was taken. A pencil was provided along with the pamphlet. This pamphlet is reproduced above.

\(^{12}\) No tagged trout were recovered in 2015.

\(^{13}\) Anglers can drive along roads that flow east-west along the north side of the RSA. However, to reach fishable areas of the EF requires about a three mile hike, which eliminates all but the hardiest of anglers.
This angler-based recovery effort was productive, posting recoveries of five tagged trout on each stream. The *angler recovery table* below summarizes the results from both the intense fishing as well as from regular anglers who fished over the summer and fall.

Columns two through five contain basic information; the type of fishing, date of the recovery, the angler’s name and species of trout. Column six contains the tag number. Columns seven through 11 contain the trout lengths at both the time of recovery and tagging, and the percentage length increase from tagging to recovery. Columns 12 and 13 contain the location of the recovery; its latitude and longitude.

A tagged-trout identifying code can be found in column 14. This code is used on the maps. As an example of how to decode the information, consider the identifier “Rc A EF 173,” 1st row of data in column 14. This is decoded thusly: “Recovery by an Angler on the *EF* with tag #173.

The 15th and 16th columns indicate the direction of migration from the trout’s reintroduction area to its recovery site and the stream distance travelled. The stream distance is the distance along the stream, not the line of sight distance between the points.

The code for the extraction area for each trout is noted in column 17. It is the same code used throughout the Excel spreadsheets that house the data. A key to these codes is provided at the bottom of the table for the reader’s convenience. Notes are presented in the last column. Quotes are the verbatim remarks from the angler about the recovery. ND means no data.

### New Mexico Department of Game & Fish involvement.

The EF and RSA originate on the preserve and both flow west. The streams revert to standard public waters after they cross the preserve’s western boundary. Previous published work reported that trout could migrate tens of miles after a relocation, such as stockings. Therefore, I expected that if the tagged trout did migrate, some might move into the public waters. The NMDG&F manages the trout in the public waters.

In order to maximize the probability of recovering as many tagged trout as possible, I wanted to alert anglers fishing the public waters about the experiment and provide guidance on how to

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### Table: Angler Recovery Table

<table>
<thead>
<tr>
<th>Num</th>
<th>Fishing type</th>
<th>Date</th>
<th>Angler</th>
<th>Species</th>
<th>Tag #</th>
<th>Recovery Length (in)</th>
<th>Recovery Length (mm)</th>
<th>Tagged Length (in)</th>
<th>Tagged Length (mm)</th>
<th>% Length change</th>
<th>Longitude</th>
<th>Latitude</th>
<th>ID name on map</th>
<th>Stream migration dist. (km)</th>
<th>Direction of migration</th>
<th>Extraction area***</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Intense fishing</td>
<td>26-Apr-14</td>
<td>Talso</td>
<td>Rainbow</td>
<td>173</td>
<td>9.4</td>
<td>238</td>
<td>9.0</td>
<td>229</td>
<td>4.2%</td>
<td>35.8688</td>
<td>106.45109</td>
<td>Rc A EF 173</td>
<td>0.1 Upstream EFUP 1</td>
<td>“Near the broken building” (presumed L shave)</td>
<td>Coords provided</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Regular fishing</td>
<td>8-May-14</td>
<td>Turky huntr</td>
<td>ND</td>
<td>071</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>35.8702</td>
<td>106.49494</td>
<td>Rc A EF 071</td>
<td>0.8 Upstream EFUP 1</td>
<td>“Near the lightning shack”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Regular fishing</td>
<td>8-May-14</td>
<td>Angler</td>
<td>ND</td>
<td>081</td>
<td>8.5</td>
<td>216</td>
<td>8.3</td>
<td>211</td>
<td>2.4%</td>
<td>35.8702</td>
<td>106.49497</td>
<td>Rc A EF 081</td>
<td>0.8 Upstream EFUP 1</td>
<td>“Near the lightning shack”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Regular fishing</td>
<td>1-Aug-14</td>
<td>Angler</td>
<td>Brown</td>
<td>086</td>
<td>11.8</td>
<td>298</td>
<td>11.0</td>
<td>279</td>
<td>6.8%</td>
<td>35.8705</td>
<td>106.49494</td>
<td>Rc A EF 086</td>
<td>0.9 Upstream EFUP 1</td>
<td>East of broken shack (presumed L shack)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Regular fishing</td>
<td>1-Aug-14</td>
<td>Angler</td>
<td>Brown</td>
<td>086</td>
<td>13.5</td>
<td>343</td>
<td>12.8</td>
<td>325</td>
<td>5.5%</td>
<td>35.871</td>
<td>106.49491</td>
<td>Rc A EF 086</td>
<td>1.0 Upstream EFUP 1</td>
<td>Coords provided</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.7%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Regular fishing</td>
<td>30-May-14</td>
<td>Brown</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>35.9724</td>
<td>106.59861</td>
<td>Rc A SA ND1</td>
<td>11.0 Downstream ND</td>
<td>Noted “beau 4”, presumed Reach 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Regular fishing</td>
<td>2-Jun-14</td>
<td>Brown</td>
<td>ND</td>
<td>109</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>35.9716</td>
<td>106.52611</td>
<td>Rc A SA 109</td>
<td>6.4 Upstream RSAUP 2</td>
<td>Mailed 14 June, “Bridge @ road 2”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Regular fishing</td>
<td>29-Jun-14</td>
<td>J. Beacon</td>
<td>Brown</td>
<td>130</td>
<td>9.0</td>
<td>229</td>
<td>8.8</td>
<td>224</td>
<td>2.3%</td>
<td>35.9714</td>
<td>106.57468</td>
<td>Rc A SA 130</td>
<td>2.7 Downstream RSAUP 2</td>
<td>Called from field by a lab researcher with info</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Regular fishing</td>
<td>1-Jul-14</td>
<td>Angler</td>
<td>Brown</td>
<td>144</td>
<td>9.0</td>
<td>229</td>
<td>7.7</td>
<td>196</td>
<td>16.9%</td>
<td>35.9709</td>
<td>106.53881</td>
<td>Rc A SA 144</td>
<td>0.3 Upstream RSAUP 2</td>
<td>East of cabin 1.2 stream miles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Regular fishing</td>
<td>12-Sep-14</td>
<td>Angler</td>
<td>Brown</td>
<td>042</td>
<td>9.5</td>
<td>241</td>
<td>8.5</td>
<td>216</td>
<td>11.8%</td>
<td>35.9673</td>
<td>106.54688</td>
<td>Rc A SA 042</td>
<td>2.5 Upstream RSAUP 1</td>
<td>East of cabin 1.2 stream miles</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10.3%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Notes

- ND=no data
- *Intense fishing:* Expert anglers assigned to a section of each stream to fish intensely for a day. All areas of RS A fished. Only upper areas of EF fished
- **This trout was also recovered during the electroshocking. See worksheet “Shock tag RSA, EF”**
- ***EFUP 1 (EF upper extraction site); RSAUP 2 (RSA upper extraction site 2; RSAUP 1 (RSA upper extractin site 1)

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14 Both streams converge at Battleship Rock, just south of La Cueva. The confluence of those streams creates the Jemez River that eventually dumps into the Rio Grande north of Bernalillo.
collect and record recovery information. I contacted the NMDG&F several times to discuss the possibility of posting a notice about the project on their website. Unfortunately, for various reasons, nothing was posted.

**Statistical analysis of trout growth rates.** As was the case with the electroshocking, each recovered trout was found to have grown in length after it was tagged. It is problematic to compare the increased lengths of the trout recovered in the spring electroshocking with those recovered by anglers. The five electroshocking recoveries all occurred on the same day whereas those recovered by anglers occurred over five months, and growth is directly related to time.

However, this bias can be eliminated by computing the growth rates in units of mm/day, which eliminates time as a biasing factor (assuming that growth rate is constant with respect to time). The tables below show the growth rates for all of the recovered trout in mm/day and inches/month. The leftmost column refers to the row number for each tagged trout in the electroshocking and angler recovery tables. They are listed in these tables for the reader’s convenience. The tag numbers are listed in the adjacent column.

The data of interest are in the column labeled “Growth rate ...,” which lists the growth rates per day from the times of tagging to the recoveries. Note that tagged trout #144 was recovered twice and is only included in the angler’s table (below, left, bottom half), so that it would not be double counted.

<table>
<thead>
<tr>
<th>Growth rates for trout recovered by ANGLERS</th>
<th>Growth rates for trout recovered by ELECTROSHOCKING on RSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>EF Table row #</td>
<td>Tag number</td>
</tr>
<tr>
<td>1</td>
<td>173</td>
</tr>
<tr>
<td>3</td>
<td>081</td>
</tr>
<tr>
<td>4</td>
<td>066</td>
</tr>
<tr>
<td>5</td>
<td>086</td>
</tr>
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<td></td>
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<tr>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

An inspection of the growth rates of trout on each stream reveals some interesting trends. The mean growth rates in mm/day for the two samples of trout recovered on the RSA are 0.0681 mm/day for the angler recoveries (table at left, bottom half) and 0.0829 mm/day for the electroshocking recoveries on the RSA (table directly above). Both of these means appear to be significantly larger than the growth rates for the trout recovered by anglers on the EF, with a mean growth rate of 0.0438 mm/day (table at left, upper half).

The samples are small and the resulting variances are large, due in part to measurement error but possibly also related to natural variation of growth rates in a trout population.

I believed the sample to be of sufficient size to accommodate a statistical T test of the difference between the growth rates for trout in the two streams. Such a test would assess whether the

15 Electroshocking produced no recoveries on the EF.
difference between the growth rates for trout recovered on the RSA versus those recovered on the EF is statistically significant, meaning that the difference is likely real and not a mere statistical aberration.

To prepare for the test I assembled one independent sample that consisted of the four growth rate measures for the trout recovered on the EF by anglers, listed as trout tag #s 173, 081, 066 and 086 taken from the table above left, upper half.

For the other independent sample, I concatenated the sample of three trout recovered by the anglers on the RSA (trout #s 130, 144 and 042 taken from the table above left, lower half) and four that were recovered during the electroshocking near the cabin (030, 139, 126, and 035, taken from table above, right), producing a single sample of seven recovered trout from the RSA. As noted above, although trout #144 was recovered twice, it was included only once in the concatenated sample to prevent double counting it.

The table at left shows the final two samples that were used in the T test. The left half presents the growth rates for all the EF recoveries and the right half shows those for the RSA. Associated summary statistics are also included. As can be seen, the difference in the means appears to be significant (0.0438 vs. 0.0766 mm/day).

The hypothesis under test is that both samples originate from the same basic population of trout, and they all grow at basically the same rates regardless of the stream in which they reside.

I applied the T test to the two samples and the results showed that the difference between the two samples was not significant at the 5% level of significance. Thus, I could not reject the hypothesis that the samples come from the same populations of trout. In simpler terms, based on these limited data and this T test, it is probable that trout grow at the same rate in both streams.

For readers not familiar with the terms used in the discussion about statistical analysis and testing, see Appendix 2 for more information presented in a less arcane discourse.

I was curious whether the growth rate might be a function of the size of the trout, with smaller trout gaining length at a faster rate than larger ones. The graph at right plots trout growth rates versus their lengths at the time of tagging. Clearly, there is no relationship between the two.

**Discussion about migration distances.** The migration distance varied greatly from one recovered trout to another and I was tempted to parse the data further in an attempt to elicit more
information about their movements relative to distance and direction. However, the samples are already at the lower limits of size for meaningful statistical testing and further subdivisions of the sample would have produced subsamples so small—some with only one value—that any further statistical tests would have been useless. Therefore, I conducted no further statistical analysis but present the following observations.

All of the recovered trout on the EF were found to have migrated upstream. But anglers could not fish downstream from the reintroduction site, so the sample is highly biased.

There is similar bias in the angler-based RSA recovery sample because many more anglers fish upstream from the reintroduction site than below it because fishing is better in the eastern half of the stream.

An examination of the data in column 15 in the EF angler recovery table on page 13 suggests that there is a positive relationship between migration distances and time, which is logical.

On the RSA, however, the trend appears to be the opposite. The longest migration, which was the first recovery in May, was 11 kilometers downstream, recovered by an angler on the RSA (but without a tag number). The second recovery in early June was also the second longest migration, this one upstream, 6.4 km. One recovered in September migrated the second shortest distance upstream, 2.5 km. After that, two recovered in early summer migrated 2.5 km and 0.3 km.

In total, there is no distinct pattern of movement that emerges from the data.

**Chronology of trout recoveries.** For completeness and edification of the reader, the plot below shows each of the angler-based recoveries positioned on a timeline. Each recovery is identified on the line by the code that I described above. The distance of migration of each recovered trout is noted in parentheses.

No remarkable patterns emerge from the plot except that recoveries streamed in steadily throughout the fishing season.

**Implications of measurement error and sample size.** Measurement error is a bigger factor for the angler recoveries than for those recovered by electroshocking. Trained scientists oversaw the measurements and recording of data during all electroshocking efforts. Scientists are schooled in the techniques of proper data generation and handling. Thus, these data are very accurate, with a
random error on the lengths probably to within a couple of millimeters +/- . By random I mean that sometimes the measurement is too long and sometimes too short, both errors occurring about equally.

However, the other field measures of trout lengths were completed by anglers, each of whom possessed varying scientific skills and none of whom were specifically trained for the recovery task. However, measuring the length of a trout is a simple process using common tools, such as a measuring tape. Most anglers carry a tape because they often enjoy knowing the size of their takes for bragging purposes. The measurement error for this process cannot be precisely known, but it is certainly several times larger than for those recorded during the electroshocking. I assumed that the error in both types of recovery processes is random and cannot it be corrected. However, I don’t believe the error is significant nor do I believe that it affects the quality of the analysis or the conclusions.

The migration distances taken from anglers contain much larger errors. In a few cases I was given precise coordinates for the recovery location. By inputting these specific coordinates into Google Earth while it was displaying a recent satellite photo of the area and by applying Google’s Path application, I estimated a precise migration distance for each trout. However, in most cases I was provided only a verbal description of the recovery location. I then estimated the location and subsequently estimated the migration distance. I roughly estimate the error to be typically a few hundred meters +/- but in some cases up to a half a kilometer +/- . However, the exact distance is not critical in the analysis. Thus, the error does not adversely affect the results.

The sample size is an issue, though. The samples are quite small and the variances are large, as expressed by the fairly significant standard deviations for the samples.\(^{16}\) Therefore, when all is considered, it is possible that a larger sample might produce different results.

**Detailed discussion about each trout recovered by anglers.** A discussion of each recovered trout on the East Fork is presented below. All migration distances are in terms of the stream distance along the bank of the stream, not point-to-point distances. Please refer to the angler recovery table above for all the data associated with each trout that is discussed below.

- Tag 173, A Rainbow trout taken by intense fishing angler Dan Talso on the East Fork on 26 Apr, and was located only 1/10\(^{th}\) of a kilometer (about 109 yards) east of the reintroduction area. The exact coordinates for the recovery location were provided along with the exact length. The trout had grown in length from 229mm to 238mm (9” to 9.4”), a 4.2% increase. Dan also reported seeing a tagged trout near the recovery zone, but the information, while interesting, was not a recovery and is not included in the recovery database.

- Tag 071 was on a trout taken by a turkey hunter who was fishing on 8 May after taking his turkey early in the hunt. No other information was provided except that the trout was recovered near the Lightning Shack. The recorded location is an approximation.

\(^{16}\) For a sample with a normal distribution, approximately 68% of all of the values would be contained within the range defined as the mean \(-1sd\) on the lower end and the mean \(+1sd\) on the upper end.
species is unknown because the species was not recorded for this trout at the time of tagging and the angler did not report it.

- Tagged trout 081 was taken by a regular angler on 1 Aug. The location is approximated based on the verbal description related to the Lightning Shack. Again, the species is unknown because it was not recorded at the time of tagging. However, the length was provided. It had grown in length from 211mm to 216mm (8.3” to 8.5”), an increase of about 2.4% and it traveled about 0.8 km upstream.

- Tag 066 was on a Brown trout taken by a regular angler on 10 Aug. The location is again approximated based on a verbal description relative to the Lightning Shack. The trout’s length was provided. It had grown from 279mm to 298mm (11” to 11.8”), an increase of about 6.8%, and it had migrated about 0.9 kilometers upstream.

- Tagged trout 086 was recovered by a regular angler on 29 Aug. The exact location of the take and its length were provided. The trout had grown from 325mm to 343mm (12.8” to 13.5”), about a 5.5% increase, and had migrated one kilometer upstream.

A discussion of each tagged trout recovered on the Rio San Antonio is presented below.

- A tagged Brown trout was taken by a regular angler on the lower reach of the stream. The tag number was not provided. The location is approximated and the length was provided. It had migrated about 11 km, the longest migration of all trout in the samples.

- Tag 109 was on a Brown trout taken near the intersection of the RSA and VC02, about 6.4 stream kilometers east (upstream) from the reintroduction point. The length was not provided.

- Tag 130 was on a Brown trout taken by J. Beacon on 29 June. Beacon is a National Lab researcher who called me from the field with information about the recovery. The exact location and length of the trout were provided. The trout had increased in length from 224mm to 229mm (8.8” to 9”), about a 2.3% increase. It had migrated downstream about 2.7 kilometers from the reintroduction site at the cabin.

- A Brown trout with Tag 144 was taken by an angler on 1 Jul. The exact location of the take and its length were noted on the pamphlet that was mailed to me. It had increased in length from 196mm to 229mm (7.7” to 9”), about a 16.9% increase from time of tagging. Interestingly, this trout was also recovered by electroshocking the cabin reintroduction area on 11 May. From the time of the tagging on 28 Sep 2013 to the time of electroshocking recovery on 11 May 2014, 225 days, this trout had increased in length from 196 mm to 220 mm, a 12.5% increase or about 0.107 mm/day.

From the time of the electroshocking recovery on 11 May to the 1 Jul angler recovery, about 51 days, the trout had increased in length from 220mm to 229mm, about 3.4% or about 0.17 mm/day. This trout was obviously healthy and flourishing in the reintroduction area.

- Tag 042 was on a Brown trout taken by an angler on 12 Sep. The exact location of the take and the length were provided. The trout had migrated 2.5 kilometers upstream and had increased in length from 216mm to 241mm (8.5” to 9.5”), an 11.8% increase.
Maps in Appendix 1 show the recovery of trout from both the electroshocking as well as the angler reports.

No tagged trout were recovered in 2015.

The 2011 Conchas wildfire impacted the two streams on the preserve.\textsuperscript{17} The fire mainly affected the eastern half of the preserve, including the upper and middle watersheds for both streams. As a result, the summer monsoon downpours in the months following the blaze produced extraordinary runoffs that carried large amounts of earthen materials downstream, much of which was deposited along the banks in the middle and lower reaches of the streams.

The EF was particularly affected by the runoff events. The middle reaches of the stream—from about the confluence of the Jaramillo to about three kilometers west of the headwaters area—have always been marshy and difficult to traverse. But after the summer of 2011, the area became a quicksand zone, unapproachable on foot or vehicle. With a few exceptions, the area remains as such today.

The fisheries in both streams were also affected by rains. The extremely heavy runoff following the fire was laden with very high levels of ammonia accumulated from the burned vegetation in the watersheds. Many trout in both streams perished in those high-ammonia runoff events, leaving devoid long stretches of the stream that at one time contained healthy populations of trout.

Whenever the preserve’s trout fisheries are discussed, questions frequently surface about how the stream’s water quality might have changed as a result of the fires and if so, how those changes might have affected the trout populations. Those questions have been raised within this research effort as well. For example, some have suggested that the migration of the stocked Triploid Rainbow trout, which is discussed in Part 3 of this report, might have been influenced in some way by changes in water quality.

As a result, I believed that an examination of the available water quality data would be appropriate. Specifically, I wanted to investigate the question of whether the Conchas fire had altered the water quality in the streams, especially any permanent alteration.

Bob Parmenter manages a team of scientists that regularly measures and records the water quality at permanent sites on both streams, with each site located close to the western boundaries of the preserve. Each monitoring station measures six water quality parameters at 15-min intervals during the warm half of the year. These include the following: temperature, specific conductance, dissolved oxygen levels, pH, and turbidity. Ammonia level is not measured.

Bob supplied to me the records of water quality measures for both streams from years 2010 through 2014. The files were very large and difficult to manipulate in Excel. And although the data were generally of reasonably good quality, there were a number of problems that needed correction before I could analyze them. There is one file per year and there were some inconsistencies between the header formats from year to year. There were also a few obviously

\textsuperscript{17} A second fire, the Thompson Ridge fire in June of 2013, had marginal impact on the streams because it burned mainly western areas of the preserve. The fire was not as devastating as the Conchas fire and did not affect the upper or middle watersheds for two streams.
incorrect values, such as negative turbidities, which I replaced with blank records.\textsuperscript{18} There were also some gaps in the record, but overall the data appeared to be reasonably complete. I spent about a half day organizing the data and correcting problems prior to analysis.

I used Excel to produce plots of each of the six water quality parameters that were recorded on each stream. I have presented in matrix form a group of bar graphs of the measures of three quality conditions that are most likely to affect trout. Each column of plots represents a time

\begin{itemize}
  \item Temperature
  \item Dissolved oxygen
  \item Turbidity
\end{itemize}

history each of the following parameters: temperature, dissolved oxygen and turbidity.

There is one plot per year with the oldest ones at the top and a chronological advancement down the page to the most recent ones at the bottom. All of the Y-axis scales for each parameter are

\textsuperscript{18} In Excel, a blank cell is ignored in any statistical computation. Thus, a blank field is interpreted as a missing value.
fixed to facilitate comparisons that might reveal changes in the magnitude over time. The X-axis labels are not fixed, but are approximately equal, thus allowing different time periods to be easily compared from year to year. Note that most of the dates begin in May and end in November. The date of the Conchas fire is noted on the 2011 plots with tiny flame icons. The turbidity is plotted on a log scale to accommodate the very large range of values that are experienced in the streams.

The table matrix of graphs for the RSA is presented in the figure above and the one for the EF is presented below. Note that the 2014 EF dataset contains many missing values.

The following are my observations. First, the temperatures profiles are consistent from year to year.
Second, dissolved oxygen appears to be affected by high turbidity. A good example is the dissolved oxygen plot for the EF in 2012 (found in the matrix directly above). When it is compared to the EF 2012 turbidity plot, a large spike in turbidity around July 31st appears to coincide in time with the noticeable dip in dissolved oxygen. It is sensible to believe that a large wash from a thunderstorm would introduce organic matter to the stream, attracting microbes that consume it. The microbes’ consumption activity would use oxygen.

The inverse relationship between oxygen levels and turbidity appears to hold for all years except 2010 on both streams and 2013 on the EF, which shows a dramatic overall reduction in turbidity as compared to other years. The corresponding oxygen plots for the EF in 2013 suggest a number of large runoff events that reduced oxygen levels and should have caused corresponding spikes in the turbidity, but none is seen.

I did not have resources to investigate these discrepancies. However, in the absence of another explanation, the evidence suggests that there are perhaps quality issues with the turbidity measures for both streams in the 2010 databases and for the EF in the 2013 database.

Finally, the impact of the Conchas fire on water quality is not evident in any of the plotted data. Furthermore, nothing in the data suggests that water quality is related to trout movements.
Part 3. Analysis of the Movements of Stocked Triploid Rainbow Trout on the East Fork

Trout populations in both VCNP streams (East Fork and Rio San Antonio) were roiled by heavy runoff from the rains that followed the Conchas wildfire in June, 2011. Large stretches of the streams that, prior to the fire had hosted healthy populations of Brown and/or Rainbow trout, became apparently devoid of trout. Other short and isolated stretches of the streams showed indications that their trout population densities had actually increased. In general, angler reports, observations of trout in the stream, and the fish population data routinely collected by Bob Parmenter’s scientific team showed that the overall populations of trout in both streams were greatly reduced in the aftermath of the fire.

By the spring of 2011, this situation became worrisome to the managers of the preserve, especially those involved in the recreational programs. A considerable portion of the summer recreational activity is related to sport fly fishing and it produces significant monetary benefits to the preserve. As a consequence, Dennis Trujillo, then the preserve’s executive director, in consultation with various groups and individuals, as well as the NM Dept. of Game and Fish (NMDG&F), ordered Rainbow trout to be stocked in the East Fork.

(Only the East Fork was stocked because the stream has native populations of Brown and Rainbow trout. The Rio San Antonio that flows within the preserve contains only Brown trout.19 The NMDG&F will only stock a stream with a species of the same types that currently populate the stream. The NMDG&F had only Triploids Rainbow available for stocking.)

The NMDG&F delivered around 900 Triploid Rainbow trout20 in batches of 300 each and introduced them into the East Fork (EF) stream at its crossing with VC01, which is the main road into the preserve off of NM Highway 4. VC01 is located in the middle of the Valle Grande, a huge grassy valley that encompasses nearly the entire southeast corner of the property. All of the Triploid stockings occurred in the spring of 2012, but the exact dates are unknown. According to the NMDG&F the average length of these trout was around 250mm (about 10”), ranging from about 230 mm (about 8”) to about 300 mm (about 12”).21

Observations and Questions. Almost immediately following the stockings, the VCNP staff observed that the trout apparently moved quickly away from the waters near the bridge where they were placed.

The waters near the bridge are sufficiently clear to allow trout to be readily observed. Feeding activity is another sign of trout.

19 Rainbows and Browns can be found on the lower reaches of the San Antonio, several miles outside of the preserve’s western boundary.
20 Triploid Rainbow trout are sterile versions of Rainbow trout and unable to reproduce. They are used for stocking because they cannot introduce offspring with genetic backgrounds that differ from those of the native populations, thus preventing a contamination of the streams’ trout population with foreign genetic traits and characteristics. Additionally, Triploids grow faster than normal trout, thus providing the sport angler with greater opportunity to snag a trophy trout.
21 Based on personal conversations between D Menicucci and NMDG&F personnel, June, 2014.
When many trout are present, the trout feed on insects that land on the surface of the water, creating a panoply of interacting ripples.

Within a week of each stocking event, the staff noted that the trout activity and sightings quickly dwindled to almost none. Angler reports of poor fishing conditions in that area confirmed the conclusions by the staff.

Francis Peter, a fly fishing expert from NM Trout, a local fly fishing club, had been conducting children’s fly fishing clinics on the East Fork for many years and he did so again in 2011 and 2012. The clinics were conducted on the upper reaches of the East Fork, near the site of the historic Lightning Shack. The Shack is located about 0.75 kilometers of stream distance west of the array of springs that provide the source water for the stream and about nine kilometers (about 5.6 miles) of stream distance east of the VC01 bridge, the site of the stockings. The Google map presented in Appendix 1 shows the sites that are discussed above.

Due to his experience with the clinics, Francis had come to know the trout populations in the EF headwaters area well. In May 2012 he observed that the trout population in that area comprised mostly Brown trout in the range of about 203mm (about 8”) to 300mm (about 12”).

However, by August 2012, he observed changes—well more than half of all trout were Rainbows and they ranged from about 230 mm (9”) to about 300 mm (12”), about the same size range for stocked Triploids.

In June of 2013 he observed another change; he estimated that only about 40% of the trout were Rainbows, and most were much smaller than he had observed the previous fall; in the range of 75 mm (about 3”) to 101 mm (4”). The Brown population appeared not to have changed significantly.

Francis postulated that the Triploid trout had migrated from the bridge to the headwaters over the summer of 2012. He did not see them in the headwaters in early May 2012 because they had apparently not completed their migration, but by August they were in the headwaters area in force. By the following June, he conjectured that they had departed the area.

The situation spurred some interesting questions: Are there data to corroborate the migration of the Triploids from the stocking location to the headwaters? Why did the Triploids migrate so quickly from the VC01 bridge area to the headwaters? Why did they depart the headwaters area almost immediately following their migration, and where did they go? How many perished in their migrations? Did they grow during their experience in the EF and if so, by how much?

I set out to address these questions and the results of my investigation can be found below.

*Trout survey database:* Bob Parmenter, Director of Scientific Services for the preserve, employs a team of scientists that regularly monitors fish on both streams on the preserve. Three permanent 100 meter reaches along both streams are surveyed by applying electroshocking methods twice per year, once in the spring and again in the fall.

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22 The lightning shack has been removed, but the place where it existed is distinctive in itself and retains the name “Lightning Shack.”

23 Stream distance is the distance measured as running along the stream as opposed to a line of sight measure.
Bob’s survey team employs a three-pass depletion method for sampling a 100 meter reach of stream at each sampling location. Each sampled reach is screened at both ends to prevent fish from leaving or entering the sampling area. An electroshocking machine and a team of people with nets begin shocking at the lower part of the reach. As they move upstream, fish are harmlessly stunned, allowing the team to capture them in nets. Immediately after being captured the fish are removed from the stream for measurements and are sequestered until the sampling is complete.

Three passes of the electroshocker are applied in each sampling reach. After the last pass, the screens are removed and the sequestered fish are returned to the stream. This method of sampling removes a high percentage of fish from the sampled reach, perhaps 90%. The data collected from the surveys are quality assured and placed in an Excel database.

The survey database contains over a dozen years of high-quality fish measurement data for three sites on the EF. One site is in the headwaters area, also known as the upper site, located near the Lightning Shack. A second is in the middle area of the EF, just east of the confluence with the Jaramillo. A third is located in the lower reaches of the EF, about 2.5 kilometers (1.5 miles) of stream distance west of the VC01 bridge. The middle site has been inaccessible for measurements since the summer of 2011 due to quicksand conditions caused by the runoff following the Conchas fire.

A Google Earth map in Appendix 1 shows the stocking location, the lightning shack and the survey locations on the EF.

Data analysis: I set out to verify Francis’ hypotheses by analyzing the data in Bob’s survey database, which Bob supplied to me.

Since I was interested in the movement of the stocked Triploids only, I first sorted the file into two worksheets; one with only Browns and the other with only Rainbows. I then culled from both worksheets only those trout that were in the range of the stocked Triploids, those greater than 150 mm (6 in). By removing smaller fish that are not of interest, it more easily allows trends to be noticed in the populations that are of interest in the study. It is, in effect, a pass filter that prevents the convolution of an unnecessary and unneeded signal into the signal of interest.

While the primary focus was on the Triploid Rainbows, I intended to use the data for the Brown trout as a control. By studying the Browns alongside the Rainbows I would be able to determine with more accuracy whether changes that I observed in the Rainbow population were due to the introduction of the Triploids as opposed to a natural process that affected both species. It is a way of mitigating a potential uncertainty.

I hypothesized that if the Triploids had indeed migrated from the bridge to the EF headwaters, their presence should be evident in the data recorded at the upper site. First, I expected the total

24 Bacon, P. and Younson, A. “The application of electro-fishing to produce census estimates of juvenile salmonid populations within defined areas: taking stock of the options,” Scottish Fisheries Research Report, Scotland, #67, 2007
25 The database contains similar information for the Rio San Antonio.
26 Convolution is a mathematical term that describes a situation where two signals are integrated together, producing a third signal that is typically viewed as a modified version of one of the original signals.
number of Rainbows at Bob’s upper EF site would show a population increase. Second, the ratio of Rainbows to Browns should also change rather dramatically in that time period. Third, the size distributions of Rainbow trout should reflect a dramatic change, while the distributions of the Browns would be relatively unaffected.

Of course, a large influx of Rainbows into the headwater area might displace some of the Browns, which could affect the distributions of Browns. But I believed that the effects of the influx of Rainbows to the area would be obvious and measurable before any disruption of the Brown populations could take place.

I computed histograms for Brown and Rainbow populations from fish survey samples for two years before and after the stocking event. A histogram is a plot that displays the number of times that a sample measure falls into a certain range, which is referred to as a bin. Bin ranges are contiguous and are arranged in either increasing or decreasing order on the plot. For example, on a histogram plot the x-axis typically contains the bin ranges. Above the range is a bar that reflects how many samples had measured values that fell within that range. When the bins encompass the entire range of the measured values in the data, the resulting plot can indicate the population size along with the characteristics of the distribution; whether it is a normal one shaped like a bell curve, or one that is skewed toward higher or lower values.

The figure on the following page presents a matrix of histogram plots for both Rainbow and Brown trout for the period 7 Oct 2010 to 22 May 2014. Again, the histograms were computed from the database for the Upper EF sampling site.

The oldest samplings are at the top of the matrix and are ordered chronologically down the page to the ones that were completed in May, 2014 located at the bottom. The plots reflect only trout that are greater than 150 mm (6 in.). To insure a clear understanding, consider the histogram for 7 Oct 10 (upper right in the matrix). It shows that there are approximately 30 Brown trout in the sample with a length between 200 mm and 220 mm.

All of the plots use the same bin range and Y-axis scale to facilitate easy comparisons between them. Thus, by scanning down from the top to the bottom, an analyst can quickly assess over time not only changes in the shape of the distributions of each species, but changes in the overall magnitude of the populations as well.

There are two important events that are noted on the left side of the matrix, and they are placed in the approximate time location relative to the chronology of histogram plots. The first is the Conchas fire that occurred in June, 2011. The other is the stocking event, which occurred in the spring of 2012.

There are some noticeable characteristics in the series of plots. First, in the years before the fire, the Browns greatly outnumbered the Rainbows. In those pre-fire years, Brown population exhibited a slight skew toward lower values. That is, in general there were more smaller trout than larger ones. This is as expected in a vibrant population.

The distribution of the Rainbows in this period show a slight skew toward larger values, indicating that there were more larger trout than smaller ones.
Second, the histograms for samples taken after the Conchas fire tell of devastated populations of all trout. Since then, the populations of the Brown trout have been increasing steadily, but the populations remain small relative to the pre-fire times.

Third, and most important, there is a significant spike in the population of Rainbow trout at the upper site in October, 2012, about five months following the spring stocking. Not only did the populations increase, but the range of sizes of Rainbows in that sample is approximately equal to the range of sizes in the batch of stocked Triploid Rainbow. Furthermore, the most popular length for the Rainbows in the October sample was between 260 mm and 280 mm (10 in to 11 in.). This is strong evidence that these changes to the distribution of Rainbow trout resulted from an influx of Triploid Rainbows that had migrated to the EF headwaters from their stocking location, about nine kilometers of stream miles to the west.

Remarkably, by the next survey period in May, 2013, the distribution of Rainbows again changes dramatically, this time indicating that few of those Triploid Rainbows remained in the area. For example, on 10 Oct 2012 there were about 20 Rainbows in the size range of 260mm to 280 mm, but on 18 May 2013 there were but a few in the same range. A large number of stocker-sized Rainbows had disappeared as quickly as they appeared and there was no indication of where they went.

Three plots corroborate what was gleaned from the histograms. The first, presented at left, shows the history of the number of Rainbow trout (those >150 mm) from the semi-annual survey at the upper site. It shows a large spike in the trout population in the fall of 2012, following the stocking event earlier in the spring. There was over a 40 fold increase in Rainbow population from 11 May 2012 to 10 October 2012 (i.e., from 2 to 87), the largest increase in the history of the surveys.

The second plot, presented at right, shows the median length of Rainbows (those > 150 mm) at the upper site. I used the median instead of the mean because it is a non-parametric estimator (i.e., the middle value) and is usually better than the parametrically computed mean for indicating average conditions in skewed or smaller distributions. As can be seen, the median value for Rainbows over 150 mm in the 10 Oct 2012 survey is about 250 mm, around 10 inches, very near the average size of stocked Triploids.

Finally, the plot presented directly left shows a history of the ratio of Rainbows to Browns (both from the population of trout > 150 mm). Historically, Browns typically outnumbered Rainbows (shown with ratios of < 1.0).
In October, 2012, the Rainbows showed their strongest historical presence relative to the Browns, where there were nearly four Rainbows for every one Brown. Clearly a large number of Rainbow trout had found their way to the EF headwaters area at that time.

**Conclusions:** The observations of the VCNP staff, as well as those of Francis Peter’s, appear to be confirmed by data measured in the regular surveys at the upper EF site. The quantitative evidence suggests that the Triploids migrated nine kilometers of stream distance from their stocking location to the headwaters area and dispersed from there quickly thereafter.

However, it is still unknown why they migrated from the VC01 bridge and why they migrated upstream. It is possible that the water temperature could be a factor because the water is cooler in the upper reaches of the EF and trout generally prefer cooler waters to warmer ones, especially during summer.

Certainly, the geomorphology of the stream and oxygen levels could also be a factor. In the upper reaches of the EF the structure of the streambed coupled with a greater rate of stream-elevation descent produces more swiftly moving waters with more riffles than are found below. These conditions likely produce higher dissolved oxygen levels in the water than might be expected near the bridge. Trout prefer higher oxygenated waters to those with lower levels.

The exact disposition of the Triploids after their brief stay in the headwaters area is unknown. Some may have perished. It is possible that the larger Browns in the headwaters area attacked the Rainbows, killing or scattering them. Another possibility is that the Rainbows may have migrated as a group to different areas of the stream, perhaps to the middle reaches where less competition might exist.

The plot below suggests that at no time did the Triploids likely migrate downstream. As can be seen, the population of Brown trout at the lower site has been very low for the entire period of record. It is possible that they could have migrated downstream quickly, bypassing the lower site before they could be counted. But it is unlikely because the population of Rainbows is so low that even a few straggling Triploids in that area would be noticeable. But the data bear not even the slightest indication of migrating Triploids ever being present.

The data were insufficient to address the question of whether and how much the Triploids might have grown during their time in the EF. While Bob’s database presents very precise measures of trout, commensurate measures for the stocked Triploids were not available.

**Additional Research Encouraged.** As is typical with an investigation such as this one, the results generated more new questions than old ones answered. Thus, there remains much research that might be conducted.

The fish survey data collected by Bob’s team is very high quality and rich with information, which can be drawn out with statistical methods as I demonstrate above. I encourage additional
analysis of these data to address questions of interest to both the scientific and angler communities.
Conclusions, Recommendations and Lessons Learned

**Discussion of results and conclusions.** The following is a summary of significant findings.

- In 2013 157 trout were extracted from the RSA and EF streams. They were tagged and reintroduced in different parts of the stream. In 2014 fifteen tagged trout were recovered, ten on the RSA and five on the EF. The overall recovery rate was near the expected rate of around 10%. Seven percent were recovered on the EF and 12% were recovered on the RSA.

- The recovery of tagged trout is an extremely difficult process. Three methods were successfully used in the recovery efforts, including intense fishing, electroshocking, and angler reports.

- The electroshocking produced the most critical information relative to the experimental hypothesis. Of the 85 tagged trout that were placed at the RSA reintroduction area in the fall of 2013 only five were recovered in the area with one-pass depletion electroshocking in May of 2014. None was recovered in the EF reintroduction area the following month using the same methods. In general, the electroshocking trout recoveries on both streams suggest that the tagged trout did not remain in their reintroduction areas. Thus, these results support the rejection of the experimental hypothesis.

Furthermore, no trout was recovered in the extraction areas, which does not support the hypothesis that trout return to their spawning grounds after relocation. However, the sample is very small and this conclusion is not well founded at this point.

- Cooperative anglers proved to be a very effective method to recover tagged trout along the stream, producing ten recoveries. Anglers reported regularly throughout the summer season and the information derived from these recoveries produced interesting and useful information about the migratory movements of the trout that departed from the reintroduction areas.

The angler reporting system is not without some statistical bias. For example, anglers prefer to fish the upper half of the RSA, which is rich in high-density trout populations, as opposed to the lower half, which is much more challenging due to generally lower trout population density and more turbid water. Thus, there are more potential recovery efforts on the upper half of the stream than the lower one. In spite of this bias, most of the angler-based recoveries occurred on the lower half of the RSA.

Furthermore, the electroshocking of the upper extraction area on the RSA along with Bob’s surveys in the upper half of the stream discovered no tagged trout. In total, the evidence suggest that there are perhaps more tagged trout scattered in the lower half of the RSA than the upper half, which is sensible because the reintroduction area is located in the lower half of the stream.

- Based on the limited data, it appears that relocated tagged trout on the RSA migrated both upstream and downstream in equal numbers, but the sample is too small to test this
hypothesis. The evidence further implies that the tagged trout scattered widely, and some have probably migrated beyond the preserve boundaries into public waters.

Unfortunately, I was unable to complete and agreement with the NMDG&F to place a notice about the project at their website so that anglers who recover a tagged trout in the public waters might know how to record and report vital information.

• Both electroshocking and angler reporting produced different but complementary information. Electroshocking is very laborious and involves the use of specialized and expensive equipment. It produces very precise data for a small area.

Angler reports, on the other hand, produce less precise data for a larger geographical area and at a very low cost. Both methods played important roles in producing data that are leading to a better understanding of the movements of relocated trout.

• Only limited information can be derived from the experience on the EF except that the tagged trout clearly did not remain in their relocation area. No inferences can be made about the direction of migration on the EF because anglers could not access the stream below the reintroduction point, thus creating a strong bias in the upstream direction.

• It is unknown why the tagged trout dispersed from their reintroduction areas and how and why they chose to move either upstream or downstream. It is possible that variations in water quality could be a factor in the changes in the trout populations along the streams and specifically the movement of the tagged trout and the Triploid Rainbows.

An analysis of the five most recent years of water quality data taken from a permanent downstream measuring location on each stream revealed nothing remarkable to explain the movements of the tagged trout or the Triploid migration. In fact, the signature of the Conchas fire in 2011 is barely noticeable in the water quality measures that have been recorded.

No data exist that reflect the variations of water quality along the stream, if such variations even exist.

Variations in stream morphology might also be a factor in driving migrations but no data exist to test this hypothesis.

• The recoveries on both streams produced interesting and potentially useful information about trout growth rates. Tagged trout in the samples were found to have grown at a rate of between about 0.04 mm/day on the EF to about 0.07 mm/day on the RSA. However, a statistical test of the samples suggests that the difference in these growth rates is not significant. The conclusion, therefore, is that based on these samples, trout grow at the same rates in both streams.

• During the effort to recover tagged trout, a unique opportunity arose to study trout movements. In the spring of 2012, 900 Triploid Rainbow trout were stocked in the lower EF near the bridge on VC01, the main road into the preserve. These Triploids were suspected of using the summer months of 2012 to migrate upstream about nine kilometers (about 5.5 miles) to the headwaters.
A statistical analysis of fish survey data taken from Bob Parmenter’s permanent fish monitoring site in the upper reaches of the EF provides convincing corroborating evidence of the Triploid migration to the headwaters as well as their rapid departure from there. Unfortunately, the analysis was not able to discern the drivers for the migration nor could it explain why and how the Triploids departed the headwaters over the subsequent winter.

- The fish survey data assembled by Bob Parmenter’s scientific teams are very high quality. The database is clean, free of missing and erroneous values. The data are stored in an Excel database that is easy to access and use. These data harbor much information that can be drawn out with statistical analysis. The data are in the public domain and I encourage other researchers to use them to address questions that are of interest to the angling and scientific communities.

Bob’s database of water quality is also valuable, but its quality is not as high as for those from the fish surveys. The water quality database is extremely large, taxing Excel’s ability to handle it. There are some inconsistent formats and some missing values, sometimes resulting in gaps that are weeks or months in duration. Occasionally, some obviously erroneous values are listed, such as negative turbidity values. However, this is not unusual for a database that has not been used in an analysis and I was able to easily correct the problems.

In general, the data are of generally good quality and I encourage other researchers to use them as part of scientific studies and analyses. I will make my corrected versions of the data available to Bob Parmenter so that he may review them for possible release to the scientific community.

- All of the data that I collected in the project will be made available upon request to the VCNP as well as to other researchers at no cost.

- In sum, the relocated trout—whether they are stocked Triploid Rainbows or stream born Browns/Rainbows—largely did not remain in the relocation areas.

**Recommendations** The study is terminated with no further recommendations relative to this research effort.

However, from a fisheries management perspective, the results suggest that it is unproductive for the VCNP resource managers to relocate trout from higher density areas to lower density areas.

Finally, the data collected by Bob Parmenter’s science teams are of very good quality and contain a great deal of information that can be drawn out with proper analysis. I urge other researchers to use this rich data resource to address questions of interest about trout behavior.

**Lessons learned.** The following summarizes lessons that I learned from the project.

1. Relocated trout migrate long distances whether their relocation is due to their removal from a hatchery to the stream or whether they are relocated on the same stream.
2. Monitoring and recording trout migrations is an extremely difficult process that involves much labor to tag and relocate the trout as well as recover them. The number of
recoveries is small relative to the number tagged. Thus, the recovered sample sizes are very small, which limits the amount and type of parametric analysis that can be applied to them.

3. Electroshocking is an excellent method to extract trout from a very limited reach of stream and this technique played an instrumental role in this project. Electroshocking showed convincingly that tagged trout had migrated away from their relocation areas and had not migrated back to the areas where they were extracted.

4. When properly briefed, anglers provide an excellent resource for recovering tagged trout. Although the data they produce is not as detailed and precise as those produced by electroshocking, they cover vast regions of the stream and the information that they produce is useful to understand the distances and direction of migrations. Anglers recovered 10 of the 15 tagged trout that were recovered in the project.

5. The VCNP was generally cooperative in not only providing in-kind support and equipment when needed, but also supplying quality data used to support the analysis. The VCNP visitor center staff was extremely dependable in briefing the anglers about the project and the recovery process.

6. Observations of trout movements by experienced anglers have great value, as demonstrated in the Triploid movement analysis.

7. An unfunded project such as this one is impossible without volunteers, especially for various events, such as electroshocking, which is very labor intensive. Two trout organizations, NM Trout and Trout Unlimited, provided many energetic, intelligent and cooperative helpers throughout the project. Other volunteers were also involved. The project would not have been possible without their help.
Appendix 1. Maps

Extraction and Reintroduction Areas:
Electroshocking Recoveries:

Trout Recoveries at the Rio San Antonio Reintroduction Site at the Cabin

Angler Recoveries:

Trout Recoveries on the Rio San Antonio
Angler Recoveries

Trout Recoveries on the East Fork

"Lightning shack"

"EF Reintroduction"
Appendix 2. Discussion about sample size, means and statistical testing

For readers not familiar with the terms used in the statistical testing, it is worth explaining in common language what the terms mean and the practicality of how they are used in the analysis.

Variance refers to the spread in values in a sample. For example, consider the range of growth rates for the trout recovered on the RSA (see table above). Tagged trout #130 showed the lowest growth rate, 0.0185 mm/day and trout #126 showed the highest, 0.1308 mm/day, over seven times greater. A smaller spread is found in the EF sample.

The arithmetic mean will find the approximate average value for a sample. The means for the two sample from RSA and the EF samples, as discussed above and shown in the associated tables, appear to be very different. Viewing these means (0.0438 vs. 0.0766), one might leap to the conclusion that the growth rate for trout in the RSA is clearly higher than for those in the EF.

But a rational analyst might be skeptical, thinking that it was simply luck that the RSA recoveries included two very large growth rate samples while the EF included no large ones. The rational analyst might question what might happen to those means if by chance the EF sample included a trout with the largest growth rate value of 0.1308 mm/day and the RSA sample by chance included one with the smallest growth rate value of 0.0165.

Supposing that such a swap of values happened—and it is clearly in the realm of possibility that it could—two new hypothetical distributions are created. The table at right presents this hypothetical example. The hypothetical mean growth rates are now computed as 0.0724 mm/day for the EF and 0.0602 mm/day for the RSA, the opposite of what we saw in the real distributions and begs the opposite conclusion.

This reversal of mean values occurred because the samples are so small that even a single large or small growth rate value can skew the mean of the sample significantly in one direction or the other. It is easy to imagine that if the recovery sample sizes were very large, say 50 from both streams, the rational analyst would be more confident in drawing conclusions about the difference in mean growth rates in the two streams.

Fundamentally, more data produce a more accurate picture of reality and a few extreme values in such a large sample have less influence on the overall average. Knowing this, a rational analyst is careful about drawing conclusion about growth rates on the streams based on small samples because these few data might not really represent the true conditions of trout growth rates in the stream.

The T test is a quantitative method to compare the difference between the two samples considering both the mean values and the variance, and to compute the probability of whether a difference is real. It helps a rational analyst draw rational conclusions.

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27 The standard deviation is equal to the square root of the variance.